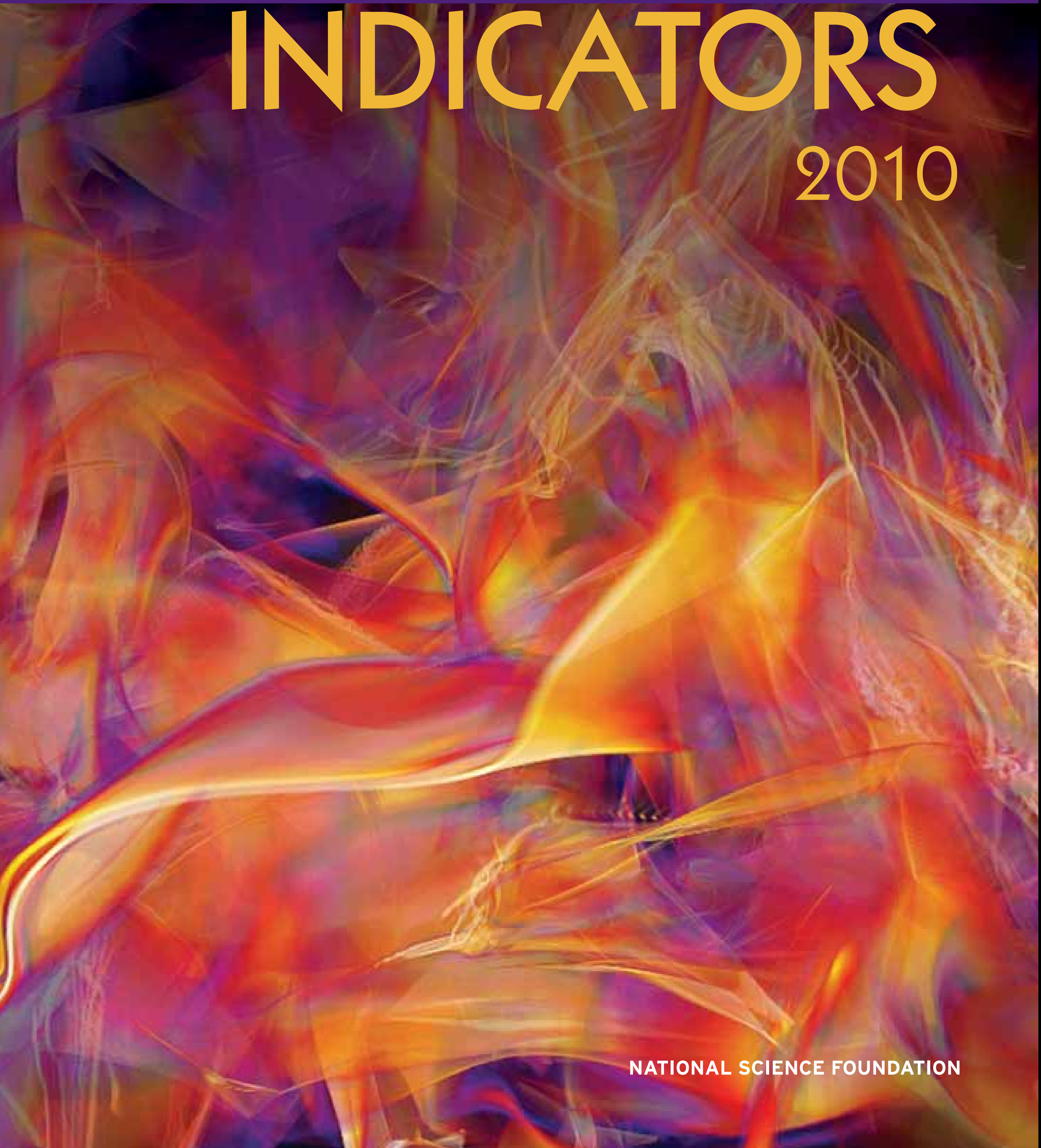
National Science Board

SCIENCE AND ENGINEERING INDICATORS

2010



NATIONAL SCIENCE FOUNDATION

National Science Board

STEVEN C. BEERING
Chair, President Emeritus, Purdue University

PATRICIA D. GALLOWAY
Vice Chair, Chief Executive Officer, Pegasus Global Holdings, Inc., Cle Elum, Washington

MARK R. ABBOTT
Dean and Professor, College of Oceanic and Atmospheric Sciences, Oregon State University

DAN E. ARVIZU
Director and Chief Executive, National Renewable Energy Laboratory, Golden, Colorado

BARRY C. BARISH
Board Consultant, Director, Global Design Effort for International Linear Collider, Linde Professor of Physics, Emeritus, California Institute of Technology

CAMILLA P. BENBOW
Patricia and Rodes Hart Dean of Education and Human Development, Peabody College of Education and Human Development, Vanderbilt University

RAY M. BOWEN
President Emeritus, Texas A&M University

JOHN T. BRUER
President, The James S. McDonnell Foundation, St. Louis

G. WAYNE CLOUGH
Secretary, Smithsonian Institution, Washington, DC

FRANCE A. CÓRDOVA
President, Purdue University

KELVIN K. DROEGEMEIER
Associate Vice President for Research, Regents' Professor of Meteorology and Weathernews Chair Emeritus, University of Oklahoma

JOSÉ-MARIE GRIFFITHS
Deputy Director (Biomedical Informatics), TraCS Institute, and Professor, School of Information and Library Science, University of North Carolina at Chapel Hill

ESIN GULARI
Dean of Engineering and Science, Clemson University

ELIZABETH HOFFMAN
Board Consultant, Executive Vice President and Provost, Iowa State University

LOUIS J. LANZEROTTI
Distinguished Research Professor of Physics, Center for Solar-Terrestrial Research, Department of Physics, New Jersey Institute of Technology

ALAN I. LESHNER
Chief Executive Officer, Executive Publisher, *Science*, American Association for the Advancement of Science, Washington, DC

G. P. "BUD" PETERSON
President, Georgia Institute of Technology

DOUGLAS D. RANDALL
Professor and Thomas Jefferson Fellow, University of Missouri

ARTHUR K. REILLY
Senior Director, Strategic Technology Policy, Cisco Systems, Inc., Ocean, New Jersey

DIANE L. SOUVAINE
Professor and Chair, Department of Computer Science, Tufts University

JON C. STRAUSS
Interim Dean, Edward E. Whitacre Jr. College of Engineering, Texas Tech University

KATHRYN D. SULLIVAN
Director, Battelle Center for Mathematics and Science Education Policy, John Glenn School of Public Affairs, Ohio State University

THOMAS N. TAYLOR
Roy A. Roberts Distinguished Professor, Department of Ecology and Evolutionary Biology, Curator of Paleobotany in the Natural History Museum and Biodiversity Research Center, The University of Kansas

RICHARD F. THOMPSON
Keck Professor of Psychology and Biological Sciences, University of Southern California

ARDEN L. BEMENT, JR.
Member ex officio, Director, National Science Foundation

CRAIG R. ROBINSON
Acting Executive Officer, National Science Board, and Director, National Science Board Office

National Science Board Committee on Science and Engineering Indicators

Louis J. Lanzerotti, *Chair*
Camilla P. Benbow
John T. Bruer
G. Wayne Clough
France A. Córdova

José-Marie Griffiths
G. P. "Bud" Peterson
Arthur K. Reilly
Jon C. Strauss
Richard F. Thompson

Rolf F. Lehming
Robert Bell
Executive Secretaries

Jean M. Pomeroy
NSB Staff Liaison

SCIENCE AND ENGINEERING INDICATORS 2010

National Science Board

Cover Image

The cover design for *Science and Engineering Indicators 2010* is based on a computer-simulated visualization of Mach 1 homogeneous turbulence. The white regions in the image show where the earlier passage of strong shock fronts heated the gas in this turbulent flow. Blue regions have the weakest vorticity, and as the vorticity increases in strength, the color goes through red to yellow and finally to white. The dynamic visualization was created at the Laboratory for Computational Science & Engineering (LCSE), a facility within the University of Minnesota's Digital Technology Center where innovative hardware and system software solutions to problems in computational science and engineering can be tested and applied. Work in the LCSE has been supported by a series of National Science Foundation equipment grants (the most recent is CNS 07-08822). (*Credit: Paul Woodward, Laboratory for Computational Science and Engineering, University of Minnesota.*)

Recommended Citation

National Science Board. 2010. *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation (NSB 10-01).

National Science Board

January 15, 2010

MEMORANDUM FROM THE CHAIRMAN OF THE NATIONAL SCIENCE BOARD

TO: The President and Congress of the United States

SUBJECT: *Science and Engineering Indicators 2010*

As Chairman of the National Science Board, it is my honor to transmit on behalf of the Board the nineteenth in the series of biennial science indicators reports, *Science and Engineering Indicators 2010*. The Board submits this report as required by 42 U.S.C. § 1863 (j) (1).

The Science Indicators series was designed to provide a broad base of quantitative information about U.S. science, engineering, and technology for use by policymakers, researchers, and the general public. *Science and Engineering Indicators 2010* contains analyses of key aspects of the scope, quality, and vitality of the Nation's science and engineering enterprise in the context of global science and technology.

The report presents information on science, mathematics, and engineering education at all levels; the scientific and engineering workforce; U.S. and international research and development performance; U.S. competitiveness in high technology; and public attitudes and understanding of science and engineering. A chapter on state-level science and engineering presents state comparisons on selected indicators. An Overview chapter distills selected key themes emerging from the report.

The Board hopes that both the Administration and Congress find the new quantitative information and analysis in the report useful and timely for informed thinking and planning on national priorities, policies, and programs in science and technology.

Steven C. Beering

Steven C. Beering
Chairman
National Science Board

National Science Foundation
4201 Wilson Boulevard • Arlington, Virginia 22230 • (703) 292-7000 • http://www.nsf.gov/nsb • email: NSBoffice@nsf.gov

Acknowledgments

The National Science Board (NSB) extends its appreciation to the staff of the National Science Foundation and to the many others, too numerous to list individually, who contributed to the preparation of this report. Primary responsibility for the production of the volume was assigned to Rolf F. Lehming, Director of the Science and Engineering Indicators Program of the Division of Science Resources Statistics (SRS) in the Directorate for Social, Behavioral and Economic Sciences: Lynda T. Carlson, Division Director; Mary J. Frase, Deputy Division Director; Myron P. Gutmann, Assistant Director; Judith S. Sunley, Deputy Assistant Director; and David W. Lightfoot, former Assistant Director.

The authors of the manuscript were:

Overview. Rolf F. Lehming, SRS

Chapter 1. Martha Naomi Alt, Xianglei Chen, Leslie Hall, MPR Associates; Lawrence Burton, SRS

Chapter 2. Joan S. Burrelli, SRS

Chapter 3. Nirmala Kannankutty, Steven Proudfoot, Mark C. Regets, SRS

Chapter 4. Mark Boroush, Francisco A. Moris, Raymond M. Wolfe, SRS

Chapter 5. Ronda Britt, Joan S. Burrelli, Lawrence Burton, Leslie Christovich, SRS

Chapter 6. Derek Hill, SRS

Chapter 7. Jaquelina C. Falkenheim, SRS

Chapter 8. Paula C. Dunnigan, Taratec Corporation

The volume benefited from extensive contributions from SRS staff. The division's senior staff and survey managers assured availability of data under often stringent deadlines: Richard J. Bennof, Mark K. Fiegener, Susan T. Hill, John E. Jankowski, Kelly H. Kang, Nancy Leach, Julia Oliver, and Michael Yamaner. Jacqueline Durham assisted in acquiring data from outside sources. Stephen Cohen, Jock Black, John E. Jankowski, Jeri M. Mulrow, Emilda B. Rivers, and Fan Zhang provided advice with statistical or data presentation issues. Robert Bell and Rolf F. Lehming worked closely with authors to develop and to implement plans for several chapters in the volume.

John R. Gawalt directed the overall production of the volume. Rolfe W. Larson was responsible for editorial and printing services. Robin Pentola provided Web direction and support. Tanya Gore assisted with the final review of the appendix tables, and Rajinder Raut prepared files for review and provided a technical review of the Web site. Web design and programming were performed by De Vo, Bridget Tuthill, Jason Shaffer, Moe Than, Makiko Fisher, Micah Horvat, and Richard Ashley of Compuware Corporation. Overall editing of the report was performed by David B. Fialkoff, Janet M. McNaughton, and the staff of Lockheed Martin Business Process Solutions. The staff of OmniStudio provided composition and production services for the print and electronic materials. Many others provided much appreciated advice and assistance and are listed under Contributors and Reviewers. Overall management of the volume was provided by Rolf F. Lehming, Robert Bell, John R. Gawalt and Lynda T. Carlson.

The National Science Board Office provided vital coordination throughout the project. The National Science Board is especially grateful to Kyscha Slater for providing operations support, Jennifer Lynn Richards for assistance to the S&E Indicators Committee, and Jean M. Pomeroy for serving as Liaison to the Committee. Robert Bell and Rolf F. Lehming were the Executive Secretaries.

Steven C. Beering

Dr. Steven C. Beering
Chairman, National Science Board

Louis J. Lanzerotti

Dr. Louis J. Lanzerotti
Chairman, Committee on Science and Engineering Indicators

Contributors and Reviewers

The following persons contributed to the report by reviewing chapters or otherwise assisting in its preparation. Their help is greatly appreciated.

Craig Abbey, SUNY
James D. Adams, Rensselaer Polytechnic Institute
David Aldrich, Booz Allen Hamilton
Nick Allum, University of Essex
Bernice T. Anderson, National Science Foundation
Anthony Arundel, UNU-MERIT
Cheikhou Athie, Taratec Corporation
Robert D. Atkinson, Information Technology and Innovation Foundation
Laudeline Auriol, Organization for Economic Cooperation and Development
Eleanor Babco, Council of Graduate Schools
Roland Bardon, SRI International
Kristina Bartsch, Bureau of Labor Statistics
William Beckett, Higher Education Statistics Agency, Ltd., England
Nathan Bell, Council of Graduate Schools
John Benskin, SRI International
Richard E. Bissell, National Academy of Sciences
Maria Borga, Bureau of Economic Analysis
Prudy Brown, SRI International
Patrick Callan, National Center for Public Policy and Higher Education
Patricia B. Campbell, Campbell-Kibler Associates, Inc.
Jill Cape, Taratec Corporation
Ann B. Carlson, National Science Foundation
C. Michael Carolina, Oklahoma Center for the Advancement of Science and Technology
Nevin P. Carr, Jr., Office of Naval Research
Susan Choy, MPR Associates
George DeBoer, American Association for the Advancement of Science
Connie K. Della-Piana, National Science Foundation
Douglas E. Devereaux, National Institute of Standards and Technology
James J. Duderstadt, University of Michigan
Jules Duga, Battelle
Janice M. Earle, National Science Foundation
Ronald Ehrenberg, Cornell University
John H. Falk, Oregon State University
Kaye Husbands Fealing, University of Minnesota
Noah Feinstein, University of Wisconsin at Madison
Michael Finn, Oak Ridge Institute for Science and Education
Barbara Fraumeni, University of Southern Maine
Ron Freedman, The Impact Group, Toronto
Carolyn L. Funk, Virginia Commonwealth University
Patrick Gallagher, National Institute of Standards and Technology
Myk Garn, Southern Regional Education Board
Howard Garrison, Federation of American Societies for Experimental Biology
Fred Gault, UNU-MERIT
Donna K. Ginther, University of Kansas
Wolfgang Glänzel, University of Leuven, Belgium
Leonid Gokhberg, Higher School of Economics, Russia
Kerry Gruber, National Center for Education Statistics
Gary Guenther, Congressional Research Service
Jong-on Hahm, National Science Foundation
Bronwyn Hall, University of California at Berkeley
Keith Hall, Bureau of Labor Statistics
Kimberly Hamilton, The Patent Board
David Hart, George Mason University
Christopher Hayter, National Governors Association
Robin Henke, MPR Associates
Christopher Hill, George Mason University
Jim Hirabayashi, U.S. Patent and Trademark Office
James Hoehn, EPSCoR/IDeA Foundation
Ned Howenstine, Bureau of Economic Analysis
Robert Ibarra, University of New Mexico
Harold Javitz, SRI International
Jolene Jesse, National Science Foundation
Mark Jones, Higher Education Statistics Agency, Ltd., England
Scott Keeter, Pew Research Center
Stuart Kerachsky, National Center for Education Statistics
Cheryl Kerr, Bureau of Labor Statistics
Hoon Kim, Korea Foundation for the Advancement of Science & Creativity
Kei Koizumi, Office of Science and Technology Policy
Roslyn Korb, National Center for Education Statistics
Alan B. Kreuger, Department of the Treasury
Jon A. Krosnick, Stanford University
Paris Kucharski, The Patent Board
Jessica Lacasse, Statistics Canada
J. Steven Landefeld, Bureau of Economic Analysis
Julia Lane, National Science Foundation
Charles F. Larson, Innovation Research International
Cheryl Lloyd, ICF Macro
Susan Carol Losh, Florida State University
Carol Lynch, Council of Graduate Schools
Jacques Maquet, Fundacion BBVA
Ray Mataloni, Bureau of Economic Analysis
Jacqueline Meszaros, National Science Foundation
Mala Mistry, Census Bureau
Sabrina L. Montes, Department of Commerce
Sue Okubo, Bureau of Economic Analysis
Dominic Olivastro, The Patent Board
Rafael Pardo, Fundación BBVA
Jongwon Park, SRI International
Amy P. Patterson, National Institutes of Health

Juan Cruz Perusia, UNESCO Institute for Statistics
Melissa F. Pollak, National Science Foundation
Alan Porter, Georgia Institute of Technology
Prem Premakumar, IHS Global Insight
Senta Raizen, Center for Improving Science Education/WestEd
Lawrence M. Rausch, National Science Foundation
Andrew Reamer, Brookings Institution
E.J. Reedy, Kauffman Foundation
Caird E. Rexroad, Department of Agriculture
Carol Robbins, Bureau of Economic Analysis
J. David Roessner, SRI International
Philip L. Rones, Bureau of Labor Statistics
Dietram A. Scheufele, University of Wisconsin at Madison
William Schmidt, Michigan State University
Barbara Schneider, Michigan State University
Kazuko Shinohara, National Science Foundation, Tokyo Office
Henry Small, Thomson Reuters
Kenneth L. Smith, Office of Naval Research
Shirley F. Smith, Small Business Administration
Thomas Snyder, National Center for Education Statistics
Dixie Sommers, Bureau of Labor Statistics
George Stamas, Bureau of Labor Statistics
Paula Stephan, Georgia State University
Carol Stoel, National Science Foundation
Amy Sussman, National Science Foundation
Gregory Tassey, National Institute of Standards and Technology
Michael S. Teitelbaum, Alfred P. Sloan Foundation
Lori Thurgood, SRI International
Marie Thursby, Georgia Institute of Technology
William Tirre, National Center for Education Statistics
Serge Tran, University of California at Los Angeles
John Tsapogas, National Science Foundation
Andrew Tyndall, Tyndall Report
William Valdez, Department of Energy
Carol Van Hartesveldt, National Science Foundation
Nancy Vincent, Council of Graduate Schools
Kenneth P. Voytek, National Institute of Standards and Technology
Caroline Wagner, SRI International
June Weis, Southern Regional Education Board
Vincent Welch, National Opinion Research Center
Laura Williams, ICF Macro
Michael Wolf, Bureau of Labor Statistics
Terry S. Woodin, National Science Foundation
Sacha Wunsch-Vincent, Organisation for Economic Cooperation and Development
William Zeile, Bureau of Economic Analysis
Klarka Zeman, Statistics Canada
Robert Zemsky, University of Pennsylvania

Contents

Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
ACC	American Chemistry Council
ACS	American Community Survey
AFT	American Federation of Teachers
AID	Agency for International Development
ANBERD	Analytical Business Enterprise R&D
AP	Advanced Placement
APL	Applied Physics Laboratory
ARRA	American Recovery and Reinvestment Act
AUTM	Association of University Technology Managers
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BRDIS	Business R&D and Innovation Survey
CATI	Cooperative Agreements and Technology Indicators
CGS	Council of Graduate Schools
CIP	Classification of Instructional Programs
CIS	Community Innovation Survey
CNSTAT	Committee on National Statistics
CPS	Current Population Survey
CRADA	cooperative research and development agreement
DHS	Department of Homeland Security
DNA	deoxyribonucleic acid
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EC	European Community
ECLS-K	Early Childhood Longitudinal Study-Kindergarten
ECS	Education Commission of the States
ED	Department of Education
EICC	EPSCoR Interagency Coordinating Committee
EPA	Environmental Protection Agency
EPSCoR	Experimental Program to Stimulate Competitive Research
Esnet	DOE's Energy Sciences Network
ESP	extrasensory perception
EU	European Union
FDI	foreign direct investment
FDIUS	Survey of Foreign Direct Investment in the United States
FFRDC	federally funded research and development center
FY	Fiscal Year
GAO	Government Accountability Office
GBAORD	government budget appropriations or outlays for R&D
GDP	gross domestic product
GED	General Equivalency Diploma
GM	genetically modified
GSS	General Social Survey Survey of Graduate Students and Postdoctorates in Science and Engineering
GUF	general university fund
HBCU	historically black college or university
HHS	Department of Health and Human Services
HS	Harmonized Commodity Description and Coding System
HT	high technology
ICE	Immigration and Customs Enforcement
ICT	information and communications technologies
IDeA	Institutional Development Award
IDR	interdisciplinary research
IEA	International Energy Agency
IOF	involuntarily out of the field
IRC	Internal Revenue Code
IRI	Industrial Research Institute
IRS	Internal Revenue Service
ISTE	International Society for Technology in Education
ITEA	International Technology Education Association
KEI	Knowledge Economy Index
KI	knowledge intensive
KTI	knowledge- and technology-intensive
LEHD	Longitudinal Employer-Household Dynamics
LSC	Local Systemic Change Through Teacher Enhancement
LTT	Long-Term Trend
MEP	Manufacturing Extension Partnership
MER	market exchange rate
MNC	multinational company
MOFA	majority-owned foreign affiliate
NAEP	National Assessment of Educational Progress
NAGB	National Assessment Governing Board
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NASF	net assignable square feet
NCES	National Center for Education Statistics
NCLB	The No Child Left Behind Act of 2001

NCRPA	National Cooperative Research and Production Act
NGA	National Governors Association
NIH	National Institutes of Health
NIPA	national income and product accounts
NIST	National Institute for Standards and Technology
NLR	National Lambda Rail
NOAA	National Oceanic and Atmospheric Administration
NORC	National Opinion Research Center
NRC	National Research Council
NS&E	natural sciences and engineering
NSB	National Science Board
NSCG	National Survey of College Graduates
NSF	National Science Foundation
NSRCG	National Survey of Recent College Graduates
OECD	Organisation for Economic Co-operation and Development
OES	Occupational Employment Statistics
OSTP	Office of Science and Technology Policy
OWH	other Western Hemisphere
PhRMA	Pharmaceutical Research and Manufacturers of America
PISA	Program for International Student Assessment
PPP	purchasing power parity
PSM	Professional Science Master's
PUMS	Public Use Microdata Sample
R&D	research and development
RA	research assistantship
RDD	random direct dialing
RDT	research, development, and testing
S&E	science and engineering
S&T	science and technology
SAR	special administrative region
SASS	Schools and Staffing Survey
SBIR	Small Business Innovation Research
SCI	Science Citation Index
SDR	Survey of Doctorate Recipients
SESTAT	Scientists and Engineers Statistical Data System
SOI	Statistics of Income
SREB	Southern Regional Education Board
SSCI	Social Sciences Citation Index
STEM	science, technology, engineering, and mathematics
STTR	Small Business Technology Transfer
TA	teaching assistant
TFA	Teach for America
TIMSS	Trends in International Mathematics and Sciences Study
TIP	Technology Innovation Program
U&C	universities and colleges
UFO	unidentified flying object
UK	United Kingdom
USDA	Department of Agriculture
USDIA	Survey of U.S. Direct Investment Abroad
USGS	U.S. Geological Survey
USPTO	U.S. Patent and Trademark Office
USSR	Union of Soviet Socialist Republics
VA	Department of Veterans Affairs
VCU	Virginia Commonwealth University
WebCASPAR	Integrated Science and Engineering Resources Data System
YSD	years since highest degree

About Science and Engineering Indicators

Science and Engineering Indicators (SEI)) is first and foremost a volume of record comprising the major high-quality quantitative data on the U.S. and international science and engineering enterprise. SEI is factual and policy neutral. It does not offer policy options, and it does not make policy recommendations. SEI employs a variety of presentation styles—tables, figures, narrative text, bulleted text, Web-based links, highlights, introductions, conclusions, reference lists—to make the data accessible to readers with different information needs and different information-processing preferences.

The data are “indicators.” Indicators are quantitative representations that might reasonably be thought to provide summary information bearing on the scope, quality, and vitality of the science and engineering enterprise. The indicators reported in SEI are intended to contribute to an understanding of the current environment and to inform the development of future policies. SEI does not model the dynamics of the science and engineering enterprise, and it avoids strong claims about the significance of the indicators it reports. SEI is used by readers who hold a variety of views about which indicators are most significant for different purposes.

SEI is prepared by the National Science Foundation’s Division of Science Resources Statistics (SRS) under the guidance of the National Science Board (Board). It is subject to extensive review by outside experts, interested federal agencies, Board members, and NSF internal reviewers for accuracy, coverage, and balance.

SEI includes more information about measurement than many readers unaccustomed to analyzing social and economic data may find easy to absorb. This information is included because readers need a good understanding of what the reported measures mean and how the data were collected in order to use the data appropriately. SEI’s data analyses, however, are relatively accessible. The data can be examined in various ways, and SEI generally emphasizes neutral, factual description and avoids unconventional or controversial analysis. As a result, SEI almost exclusively uses simple statistical tools that should be familiar and accessible to a college bound high school graduate. Readers comfortable with numbers and percentages and equipped with a general conceptual understanding of terms such as “statistical significance” and “margin of error” will readily understand the statistical material in SEI. A statistical appendix aids readers’ interpretation of the material presented.

SEI’s Different Parts

SEI includes seven chapters that follow a generally consistent pattern; an eighth chapter, on state indicators, presented in a unique format; and an overview that precedes these eight chapters. The chapter titles are

- Elementary and Secondary Education
- Higher Education in Science and Engineering
- Science and Engineering Labor Force
- Research and Development: National Trends and International Linkages
- Academic Research and Development
- Industry, Technology, and the Global Marketplace
- Science and Technology: Public Attitudes and Understanding
- State Indicators

An appendix volume, available online at http://www.nsf.gov/statistics/indicators/, contains detailed data tables keyed to each of the eight chapters. SEI includes a list of abbreviations/acronyms and an index.

A National Science Board policy statement companion piece, authored by the Board, draws upon the data in SEI and offers recommendations on issues of concern for national science and engineering research or education policy, in keeping with the Board’s statutory responsibility to bring attention to such issues. In addition, the Board publishes the *Digest of Key Science and Engineering Indicators*, a condensed version of SEI comprising a small selection of important indicators. The digest serves two purposes: (1) to draw attention to important trends and data points from across the chapters of SEI and (2) to introduce readers to the data resources available in the main volume of SEI *2010* and associated products.

The Seven Core Chapters

Each chapter consists of contents and lists of sidebars, text tables, and figures; highlights; introduction (chapter overview and chapter organization); a narrative synthesis of data and related contextual information; conclusion; notes; glossary; and references.

Highlights. The highlights provide an outline of major dimensions of a chapter topic. Each highlight starts with a statement that summarizes a key point made in the chapter. Bulleted points supporting the key point follow.

Introduction. The chapter overview provides a brief explanation of the importance of the topic. It situates the topic in the context of major concepts, terms, and developments relevant to the data reported. The introduction includes a brief narrative account of the logical flow of topics within the chapter.

Narrative. The chapter narrative is a descriptive synthesis that brings together significant findings. It is also a balanced presentation of contextual information that is useful for interpreting the findings. As a descriptive synthesis, the narrative aims (1) to enable the reader to assimilate a large amount of information by putting it in an order that facilitates comprehension and retention and (2) to order the material so that major points readily come to the reader's attention. As a balanced presentation, the narrative aims to include appropriate caveats and context information such that (3) a nonexpert reader will understand what uses of the data may or may not be appropriate, and (4) an expert reader will be satisfied that the presentation reflects a good understanding of the policy and fact context in which the data are interpreted by users with a range of science policy views.

Figures. Figures provide visually compelling representations of major findings discussed in the text. Figures also enable readers to test narrative interpretations offered in the text by examining the data themselves.

Text Tables. Text tables help to illustrate and to support points made in the text.

Sidebars. Sidebars discuss interesting recent developments in the field, more speculative information than is presented in the regular chapter text, or other special topics. Sidebars can also present definitions or highlight crosscutting themes.

Appendix Tables. Appendix tables, available online (http://www.nsf.gov/statistics/indicators/), provide the most complete presentation of quantitative data, without contextual information or interpretive aids. According to past surveys of SEI users, even experienced expert readers find it helpful to consult the chapter text in conjunction with the appendix tables.

Conclusion. The conclusion summarizes important findings. It offers a perspective on important trends but stops short of definitive pronouncements about either likely futures or policy implications. Conclusions tend to avoid factual syntheses that suggest distinctive or controversial viewpoints.

Glossary. The glossary defines terms used in the chapter.

References. SEI includes references to data sources cited in the text, stressing national or internationally comparable data. SEI does not attempt to review the analytic literature on a topic or summarize the social science or policy perspectives that might be brought to bear on it. References to that literature are included where they help to explain the basis for statements in the text.

The State Indicators Chapter

This chapter consists of data that can be used by people involved in state-level policy making, including journalists and interested citizens, to assess trends in S&T-related activities in their states. Indicators are drawn from a range of variables, most of which are part of the subject matter of the seven core chapters. The text explains the meaning of each indicator and provides important caveats about how to interpret it. Approximately three to five bullets highlight significant findings. Data for the indicators are graphically displayed in United States maps that color code states into quartiles and in state-by-state tables. A small number of appendix tables for this chapter can be found online.

No interpretive narrative synthesizes overall patterns and trends. SEI includes state-level indicators to call attention to state performance in S&T and to foster consideration of state-level activities in this area.

The Overview

The overview is a selective synthesis that brings together patterns and trends that unite data in several of the substantive chapters. The overview helps readers to synthesize the findings in SEI as a whole and draws connections among separately prepared chapters that deal with related topics. It is intended to serve readers with varying levels of expertise. Because the overview relies heavily on figures, it is well adapted for use in developing presentations, and presentation graphics for the figures in the overview are available on the Web. Like the core chapters, the overview strives for a descriptive synthesis and a balanced tone, and it does not take or suggest policy positions.

Presentation

SEI is released in printed and electronic formats. The printed volume provides the full content except for the appendix tables. The complete content of SEI is posted online at http://www.nsf.gov/statistics/indicators/ in html format and PDF, with text tables, appendix tables, and source data for each figure available in spreadsheet (MS Excel) format. In addition, selected figures are also available in presentation-style format as MS PowerPoint and JPEG files.

The printed version of SEI includes a CD-ROM in PDF format and a packaged set of information cards. The CD-ROM contains the complete content of SEI and, as with the online version, appendix tables in spreadsheet format. The full set of presentation slides is also included. The pocket-sized information cards highlight key patterns and trends. Each card presents a selection of figures with captions stating the major point that the figure is meant to illustrate.

Overview

List of Figures

Introduction

This overview of the National Science Board's *Science and Engineering Indicators 2010* brings together some major developments in international and U.S. science and technology (S&T). It is not intended to be comprehensive; the reader will find more extensive data in the body of each chapter. Major findings on particular topics appear in the Highlights sections that precede chapters 1–7.

The indicators included in *Science and Engineering Indicators 2010* derive from a variety of national, international, public, and private sources and may not be strictly comparable in a statistical sense. As noted in the text, some data are weak, and the metrics and models relating them to each other and to economic and social outcomes invite further development. Thus, the emphasis is on broad trends; individual data points and findings should be interpreted with care.

The overview focuses on the trend in the United States and many other parts of the world toward the development of more knowledge-intensive economies, in which research, its commercial exploitation, and other intellectual work play a growing role. Industry and government play key roles in these changes.

The overview examines how these S&T patterns and trends affect the position of the United States, using broadly comparable data wherever possible for the United States, the European Union (EU), Japan, China, and selected other Asian economies (the Asia-9: India, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Thailand, Taiwan, and Vietnam).

The overview sketches an analytical framework for, and a broad outline of, the main S&T themes, which it then examines through the lens of various indicators such as global R&D expenditures and human resources, including researchers. It describes research outputs and their use in the form of article citations and patents. It then turns to the growth and structural shifts in international high-technology markets, trade, and relative trade positions.

The data available as of this writing do not, for the most part, cover the ongoing changes that shook the global economy beginning in 2008. The data therefore cannot accurately portray their consequences for the world's S&T enterprise. Thus, the trends discussed here may already be changing in unexpected ways. Nevertheless, major patterns and trends that have developed over the past decade or more affect, and are shaped by, the range of S&T endeavors, from basic research to production and trade of high-technology goods and knowledge-intensive services. They are the starting points from which to mark any future changes.

A Bird's Eye View of the World's Changing S&T Picture

Since the 1990s, a global wave of market liberalization has produced an interconnected world economy that has brought unprecedented levels of activity and growth, along with structural changes whose consequences are not yet fully understood. Governments in many parts of the developing world have come to view science and technology (S&T) as integral to economic growth and development, and they have set out to build more knowledge-intensive economies in which research, its commercial exploitation, and intellectual work would play a growing role.

To that end, they have taken steps to open their markets to trade and foreign investment, develop or recast their S&T infrastructures, stimulate industrial R&D, expand their higher education systems, and build indigenous R&D capabilities. This has brought a great expansion of the world's S&T activities and their shift toward developing Asia, where most of the rapid growth has occurred. Governments there have implemented a host of policies to boost S&T capabilities as a means to ensuring their economies' competitive edge.

In most broad aspects of S&T activities, the United States continues to maintain a position of leadership but has experienced a gradual erosion of its position in many specific areas. Two contributing developments are the rapid increase in a broad range of Asian S&T capabilities outside of Japan and the fruition of EU efforts to boost its relative competitiveness in R&D, innovation, and high technology.

Asia's rapid ascent as a major world S&T center—beyond Japan—is driven by developments in China and several other Asian economies (Asia-9).[1] All are seeking to boost access to and the quality of higher education and to develop world-class research and S&T infrastructures. The Asia-9 form a loosely structured supplier zone for China's high-technology manufacturing export industries that increasingly appears to include Japan. Japan, long a preeminent world S&T nation, is holding its own in research and some high-value S&T activities but is losing ground to the Asia-9 in overall high technology manufacturing and trade. India's high gross domestic product (GDP) growth contrasts with a fledgling overall S&T performance.

The EU largely holds its own in the face of these worldwide S&T shifts. Its innovation-focused policy initiatives have been supported by the creation of a shared currency and the elimination of internal trade and migration barriers. Much of the EU's high-technology trade is with other EU members. EU research performance is strong and marked by pronounced EU-supported, intra-EU collaboration. The EU is also focused on boosting the quality and international standing of its universities.

Other countries share this heightened focus on S&T as a means of economic growth. Brazil and South Africa show high S&T growth rates, but from low bases. Among the more developed nations, Russia's S&T establishment continues to struggle in both relative and absolute terms, whereas Israel, Canada, and Switzerland are examples of mature, high-performing S&T establishments.

Multinational companies (MNCs) operating in this changing environment are seeking access to developing markets, whose governments provide incentives. Modern communications and management tools support the development of globally oriented corporations that draw on far-flung, specialized global supplier networks. In turn, host governments are attaching conditions to market access and operations that, along with technology spillovers, produce new and greater indigenous S&T capabilities. Western- and Japan-based MNCs are increasingly joined in world S&T markets by newcomers headquartered in developing nations.

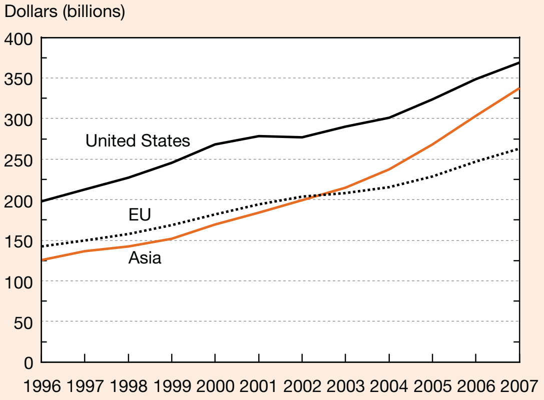
Global Expansion of Research and Development Expenditures

In a telling development, the world's R&D expenditures have been on an 11-year doubling path, growing faster than total global economic output.[2] This indicator of commitment to innovation went from an estimated $525 billion in 1996 to approximately $1.1 trillion in 2007 (figure O-1). The specific data point for each year shown in figure O-1 is an imprecise estimate, but the steady and large upward trend illustrates the rapidly growing global focus on innovation.[3]

The United States remained by far the single largest R&D-performing country. Its R&D expenditure of $369 billion in 2007 exceeded the Asian region's total of $338 billion and the EU's (EU-27) $263 billion[4] (figure O-2). The U.S. 2007 total broadly matched the combined R&D expenditures of the next four largest countries: Japan, China, Germany, and France.

If R&D expenditures are long-term investments in innovation, how much of a nation's economic activity should be devoted to them? A U.S. goal in the 1950s was to achieve an R&D investment of 1% of GDP by 1957. More recently, many governments set their sights at 3% of GDP in pursuit of developing knowledge-based economies; the EU formally embraced the 3% goal as its long-term planning target.[5]

Figure O-2
R&D expenditures for United States, EU, and Asia: 1996–2007



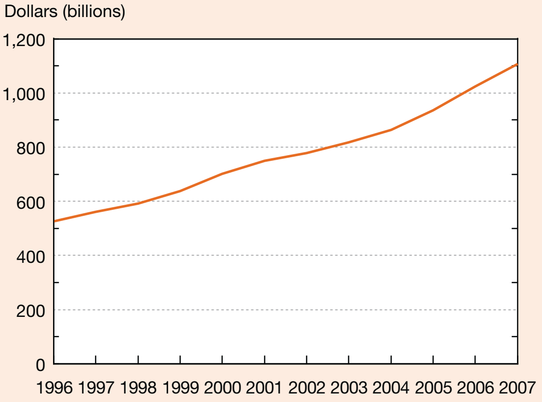
EU = European Union

NOTE: Asia includes China, India, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand. EU includes all 27 member states.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years); United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics, http://stats.uis.unesco.org/unesco/tableviewer/document.aspx?ReportId=143&1F_Language=eng; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure O-1
Estimated R&D expenditures worldwide: 1996–2007



SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years); United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics, http://stats.uis.unesco.org/unesco/tableviewer/document.aspx?ReportId=143&1F_Language=eng; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

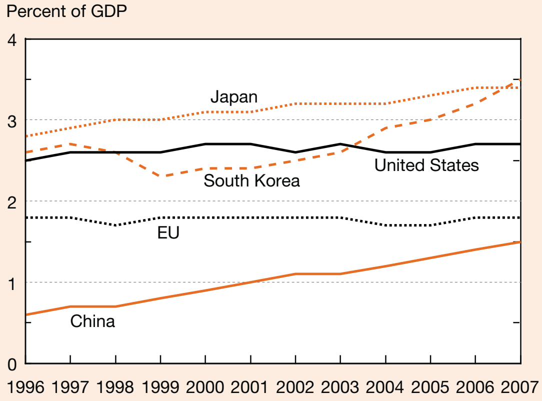
Nearly everywhere, however, decisions affecting the bulk of R&D expenditures are made by industry, thus removing achievement of such a target from direct government control. In the United States, industry funds about 67% of all R&D. For the EU, it is 55%, but with considerable range (e.g., nearly 70% for Germany and 45% for the United Kingdom). In China, Singapore, and Taiwan, industry funding ranges from 60% upward. Nevertheless, government planners monitor the R&D/GDP ratio as an indicator of innovative capacity, even as few countries reach the 3% mark.

Over the past decade, many Asian developing economies have exhibited increased R&D/GDP ratios; conversely, those in the United States and the EU have broadly held steady. Japan's R&D expenditures amounted to 3.4% of GDP in 2007; South Korea's increased steeply after the 1990s and reached 3.5% in 2007.

China's R&D/GDP ratio more than doubled, from 0.6% in 1996 to 1.5% in 2007, a period during which China's GDP grew at 12% annually—an enormous, sustained increase. The gap in China's R&D/GDP ratio relative to those of developed economies suggests that China's R&D volume can continue to grow rapidly (figure O-3).

Decade-long R&D growth rates of mature S&T countries differ dramatically from those of developing economies. Growth of R&D expenditures in the United States, the EU,

Figure O-3
R&D expenditures as share of economic output of selected countries: 1996–2007



EU = European Union; GDP = gross domestic product

NOTE: EU includes all 27 member states.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years).

Science and Engineering Indicators 2010

and Japan averaged about 5%–6% annually, not adjusted for inflation. Asian growth ranged from about 9% to 10% for India, South Korea, and Taiwan to more than 20% for China. Asian R&D growth reflects rising private spending by domestic and foreign firms, as well as increased public R&D spending designed to support strategic policies that aim to raise economic competitiveness through the development of knowledge-based economies (figure O-4).

The relatively greater R&D growth rates in Asia (excluding Japan) resulted in decreases in the percentages of world R&D expenditures for the mature S&T establishments—United States, the EU, and Japan—that were substantial, especially in view of the short period and large expenditures involved. The North America region's (United States, Canada, and Mexico) share of estimated world R&D activity decreased from 40% to 35%; the EU's share declined from 31% to 28%. The Asia/Pacific region's share increased from 24% to 31% even with Japan's comparatively low growth, and the share of the rest of the world increased from 5% to 6%—still a modest level but a very large relative gain that indicates the broadly shared belief in the importance of R&D for economic development (figure O-5).

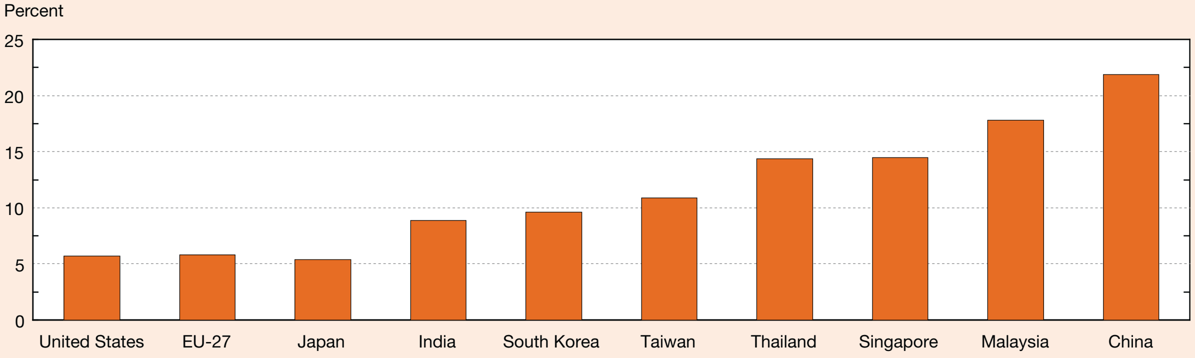
Overseas R&D by Multinational Companies

The shift toward greater R&D expenditures in Asia is also reflected in R&D flows between MNCs and their overseas affiliates in which they hold majority ownership (figure O-6).

Overseas R&D expenditures by U.S.-based MNCs ($28.5 billion in 2006) shifted toward emerging Asian markets whose combined share, excluding Japan, increased from 5% to 14% from 1995 to 2006. This change was driven by U.S. affiliates in China, South Korea, and Singapore. In 1995, about 90% of all overseas R&D by U.S.-headquartered MNCs took place in developed European economies, in Canada, and in Japan; by 2006, the combined percentage of these economies had declined to 80%.

In the United States, affiliates of foreign-headquartered MNCs spent $34.3 billion on R&D in 2006. Their R&D

Figure O-4
Average annual growth of R&D expenditures for United States, EU-27, and selected Asia-8 economies: 1996–2007

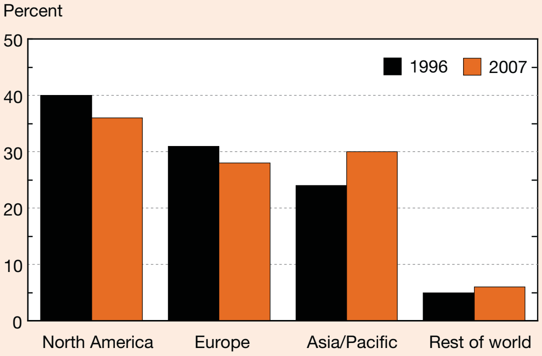


EU = European Union

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years); United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics, http://stats.uis.unesco.org/unesco/tableviewer/document.aspx?ReportId=143&1F_Language=eng; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure O-5
Location of estimated worldwide R&D expenditures: 1996 and 2007



NOTE: Estimated total worldwide R&D expenditures were $525 billion in 1996 and $1.1 trillion in 2007.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years); United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics, http://stats.uis.unesco.org/unesco/TableViewer/document.aspx?ReportId=143&IF_Language=eng; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

expenditures represented about 14% of total U.S. business R&D performance, up from less than 10% in the 1980s.

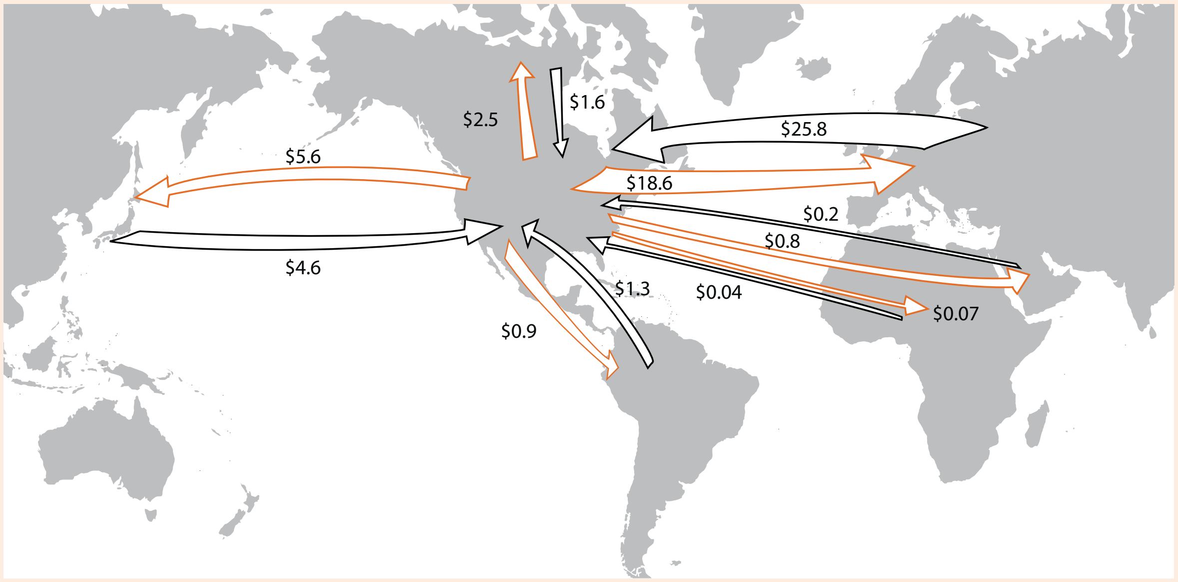
Global Higher Education and Workforce Trends

No comprehensive measures of the global S&E labor force exist, but fragmentary data indicate rapid growth in the number of individuals who pursue advanced education, especially in developing nations. In recent decades, the increasing number of new S&E degrees, including degrees in natural sciences and engineering, awarded in developing countries has diminished the advantage that mature countries had held in advanced education.[6]

Worldwide, the number of persons with a tertiary education continues to grow.[7] Estimates for 1980 and 2000, the latest available year, show an increase of about 120 million individuals, from 73 million to 194 million (figure O-7). The completion of tertiary education expanded most rapidly in developing Asian economies, where the combined shares of China, India, South Korea, the Philippines, and Thailand increased from 14% to 25% of the world's total. The number of individuals with advanced education in these Asian countries in 2000, 49 million, nearly matched the 2000 U.S. total; in 1980, these countries had accounted for less than half.

Figure O-6
R&D performed by U.S. affiliates of foreign companies in United States, by investing region, and performed by foreign affiliates of U.S. multinational companies, by host region: 2006

(Billions of current U.S. dollars)



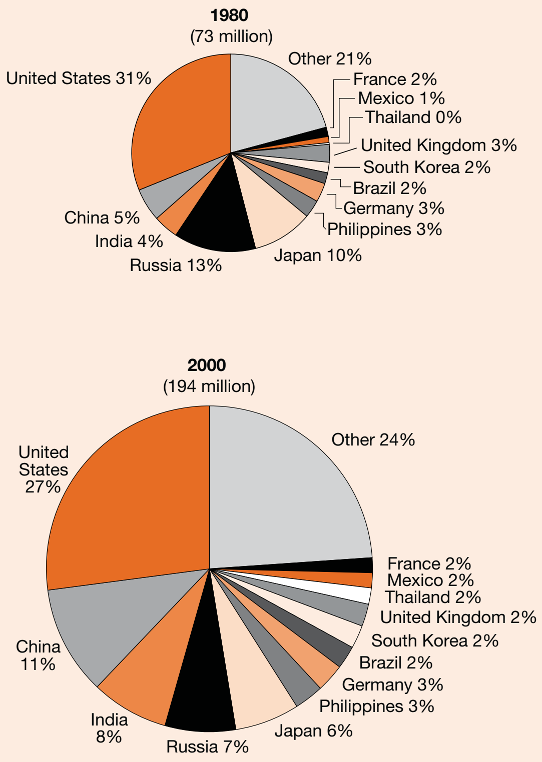
NOTE: Preliminary estimates.

SOURCES: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series); and Survey of U.S. Direct Investment Abroad (annual series). See appendix tables 4-32 and 4-34.

Science and Engineering Indicators 2010

Figure O-7

Tertiary-educated population 15 years old or older, by country/economy: 1980 and 2000



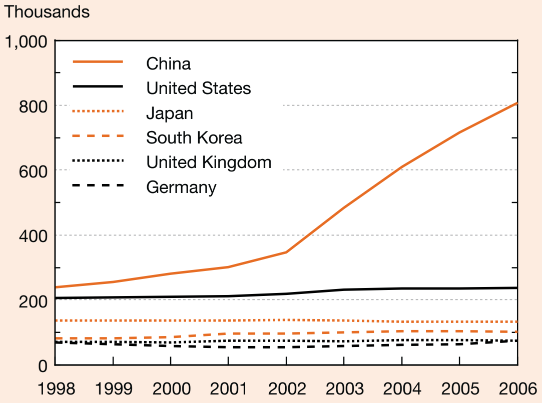
NOTE: Detail may not add to total because of rounding.

SOURCE: Adapted from Barro RJ and Lee J, International data on educational attainment: Updates and implications. Center for International Development Working Paper No. 042 (2000). http://cid.harvard.edu/cidwp/042.htm, accessed 9 September 2009.

Science and Engineering Indicators 2010

Figure O-8

First university degrees in natural sciences and engineering, selected countries: 1998–2006



NOTE: Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics.

SOURCES: China—National Bureau of Statistics of China, China Statistical Yearbook, annual series (Beijing), various years; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea and Germany—Organisation for Economic Co-operation and Development, Online Education Database, http://www.oecd.org/education/database/; United Kingdom—Higher Education Statistics Agency; and United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

Trends in fragmentary international degree data suggest that Asian growth has continued and perhaps accelerated.

Governments in many Western countries and in Japan are concerned about lagging student interest in studying natural sciences or engineering (NS&E), fields they believe convey technical skills and knowledge that are essential for knowledge-intensive economies. In the developing world, the number of first university NS&E degrees, broadly comparable to a U.S. baccalaureate, is rising, led by large increases in China, from about 239,000 in 1998 to 807,000 in 2006. New NS&E degrees earned by Japanese and South Korean students combined in 2006 (about 235,000) approximated the number earned by U.S. students in that year, even though the U.S. population was considerably larger (300 million vs. 175 million) (figure O-8).

The expansion of NS&E degrees extends beyond first university degrees to degrees certifying completed advanced study. Since the early 1990s, the number of NS&E doctorates awarded in Japan and India has increased by more than 70%—to approximately 7,100 and 7,500, respectively. The number awarded in South Korea nearly tripled over the same period, reaching approximately 3,500. China's domestic NS&E doctorate awards have increased more than tenfold over the period, to about 21,000 in 2006, nearing the number of NS&E doctorates awarded in the United States (figure O-9).

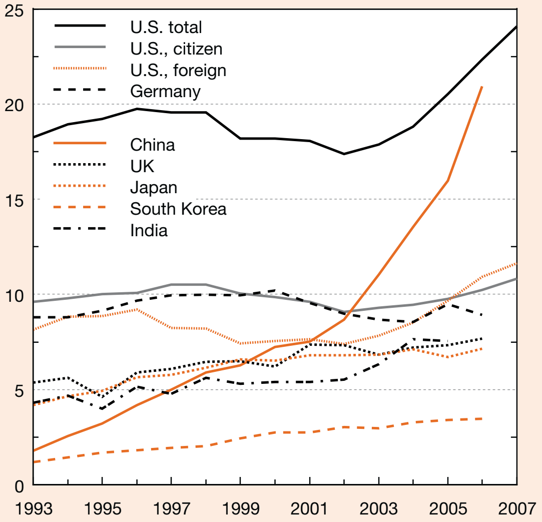
Most of the post-2002 increase in U.S. NS&E doctorate production reflects degrees awarded to temporary and permanent visa holders, who in 2007 earned about 11,600 of 22,500 U.S. NS&E doctorates.[8] Foreign nationals have earned more than half of U.S. NS&E doctorates since 2006. Half of these students are from East Asia, mostly from China (31%), India (14%), and South Korea (7%).

For engineering, the numbers are more concentrated. Since 1999, the share of U.S. engineering doctorates earned by temporary and permanent visa holders has risen from 51% to 68% in 2007. Nearly three-quarters of foreign national recipients of engineering doctorates were from East Asia or India.

Many of these individuals, especially those on temporary visas, will leave the United States after earning their doctorates, but if past trends continue, a large proportion will stay. Sixty percent of temporary visa holders who had earned a

Figure O-9

Doctoral degrees in natural sciences and engineering, selected countries: 1993–2007



UK = United Kingdom

NOTE: Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics.

SOURCES: China—National Bureau of Statistics of China, China Statistical Yearbook, annual series (Beijing), various years; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development (OECD), Online Education Database, http://www.oecd.org/education/ database/; United Kingdom—Higher Education Statistics Agency; Germany—Federal Statistical Agency, Prüfungen an Hochschulen, and OECD, Online Education Database, http://www.oecd.org/education/database/; and United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

U.S. S&E doctorate in 1997 were gainfully employed in the United States in 2007—the highest 10-year stay rate ever observed.[9]

Expanding Global Researcher Pool

Estimates of the number of the world's researchers provide broad support for the trends and shifts suggested by the R&D and degree data discussed previously.

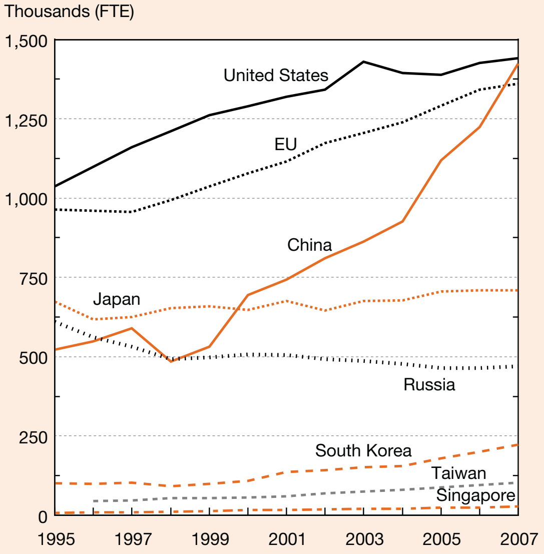
The estimated number of researchers grew from nearly 4 million in 1995 to about 5.7 million in 2007.[10] The United States and the 27 EU members each accounted for about 1.4 million researchers—a combined 49% of the total but below the 51% share they had held a decade earlier. China's researchers more than doubled in number, from just over half a million to more than 1.4 million, boosting its world share from 13% to 25% over the period (figure O-10).

Trends in researcher growth rates vary greatly by country/region. The United States and the EU had moderate annual growth of about 3% between 1995 and 2006. Japan's rate was below 1%. Growth in the Asian region outside Japan ranged from 7% to 11%. China, the biggest country, averaged nearly 9% growth, including a brief but sharp break in 1998–99 that reflected the rapid conversion of state-owned to privately owned enterprises as a result of the central government's policy change. Russia's researcher growth rate, which is now flat, declined over the period (figure O-11).

The contribution of multinational corporations to researcher growth in the overseas markets in which they operate is unknown. Data on overseas R&D employment of U.S.-based MNCs and their majority-owned affiliates are available only every 5 years. The latest data available show that their overseas R&D employment increased from 102,000 in 1994 to 138,000 in 2004. Over the same period, U.S. R&D employment of these MNCs increased from 625,000 to about 716,000. As a result, the overseas share of R&D employment increased from 14% to 16% (figure O-12). These data do not include researchers employed by overseas firms in which MNCs hold less than majority

Figure O-10

Researchers in selected regions/countries/ economies: 1995–2007



EU = European Union; FTE = full-time equivalent

NOTES: Researchers are full-time equivalents. Time span is 1995–2007 or closest available year. U.S. data for 2007 estimated based on 2004–06 growth rate.

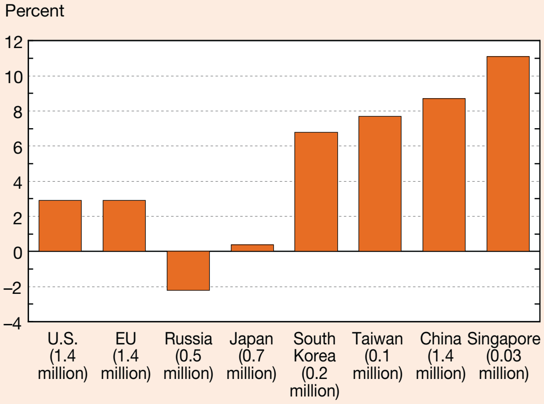
SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years).

Science and Engineering Indicators 2010

ownership or by firms that perform research under contract to MNCs.

Employment of researchers by foreign-based MNCs in other countries is unavailable, except for those working in the United States. Growth in U.S. employment of researchers working for U.S. affiliates of foreign-based MNCs has been broadly in line with overall U.S. researcher trends.

Figure O-11
Average annual growth in number of researchers in selected regions/countries/economies: 1995–2007



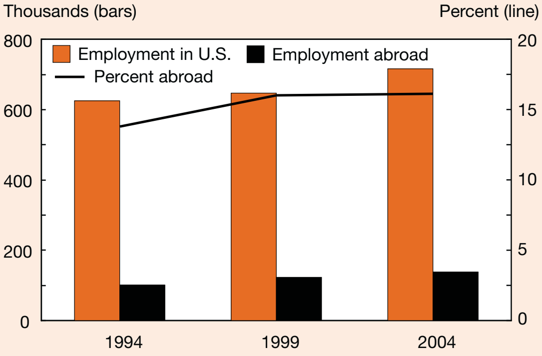
EU = European Union

NOTES: Researchers are full-time equivalents. Time span is 1996–2007 or closest available year. Number of researchers in 2007 or most recent year in parentheses. U.S. data for 2007 estimated based on 2004–06 growth rate. EU includes all 27 member states.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2009/1 and previous years); and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure O-12
R&D employment of U.S.-based multinational corporations: 1994, 1999, and 2004



NOTE: Employment abroad limited to majority-owned affiliates.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad (2004 and previous years), http://www.bea.gov/International/index.htm.

Science and Engineering Indicators 2010

Research Outputs: Journal Articles and Patents

Research produces new knowledge, products, or processes. Research publications reflect contributions to knowledge, patents indicate useful inventions, and citations on patent applications to the scientific and technical literature indicate the linkage between research and practical application.

The number of research articles published in a set of international, peer-reviewed journals has grown from about 460,000 in 1988 to an estimated 760,000 in 2008.[11] The geographical distribution of the authors provides yet another indication of the size of a country's or region's research enterprise and its ability to produce research results that can pass peer review.

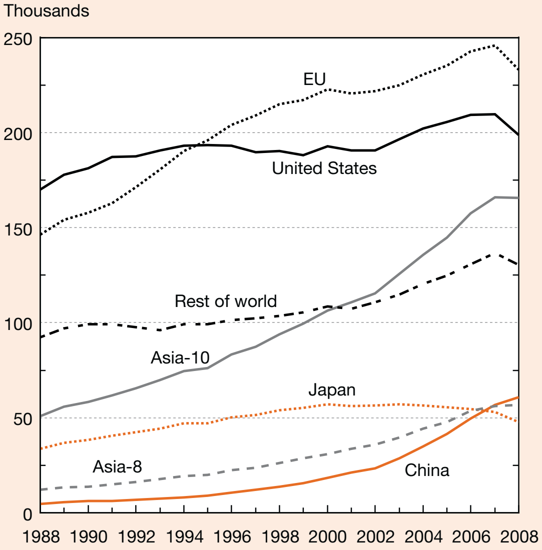
Researchers in the EU and the United States have long dominated world article production, but their combined world share of published articles decreased steadily from 69% in 1995 to 59% in 2008 as Asia's output increased. In little more than a decade, Asia's world article share expanded from 14% to 23%. The increase principally reflected China's output volume, which expanded by about 14% annually over the period. In 2008, China produced about 8% of world article output, up from 1% in 1988. By 2007, China's publication volume exceeded Japan's, moving it into 2nd place behind the United States—a distant 2nd place, but up from 14th place in 1995. In contrast, India's output of scientific and technical articles stagnated through the late 1990s before beginning to increase, and India's ranking hardly moved, changing from 12th place in 1995 to 11th place in 2008 (figure O-13).

The distribution of a country's research publications across different fields broadly reflects its research priorities. In 2007, more than half of the articles published by U.S. researchers reported on work in the biomedical and other life sciences, whereas scientists in Asia and some major European countries published a preponderance of articles in the physical sciences[12] and engineering (figure O-14). Priority shifts not evident in figure O-14 include China's growing focus on chemistry R&D (related articles increased as a share of China's S&E articles from 13% in 1988 to 24% in 2008) and declining share of other physical sciences articles (from 39% to 28%) as well as South Korea's shift toward greater output in biological and medical sciences (from a combined 17% to 38%). These changes in research portfolios reflect government policy choices: China is building up its chemicals industry; South Korea is trying to develop a reputation in health sciences.

Worldwide, the number of engineering research articles increased substantially faster over the past 20 years than total S&E article production, particularly in Asia, where the growth rate (7.8%) in engineering article output exceeded that of total S&E article output (6.1%). Growth in the United States and Japan averaged less than 2%; in the EU, about 4.4%. China's engineering article output grew by close to 16% annually, and the Asia-8 economies expanded their combined output by 10% a year.

Figure O-13

S&E journal articles produced by selected regions/countries: 1988–2008



EU = European Union

NOTES: See glossary for countries included in Asia-8 and Asia-10. EU includes all 27 member states. Articles classified by year of publication and assigned to region/country on basis of authors' institutional address(es). For articles with collaborating institutions from multiple countries/ economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. Counts for 2008 are incomplete.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

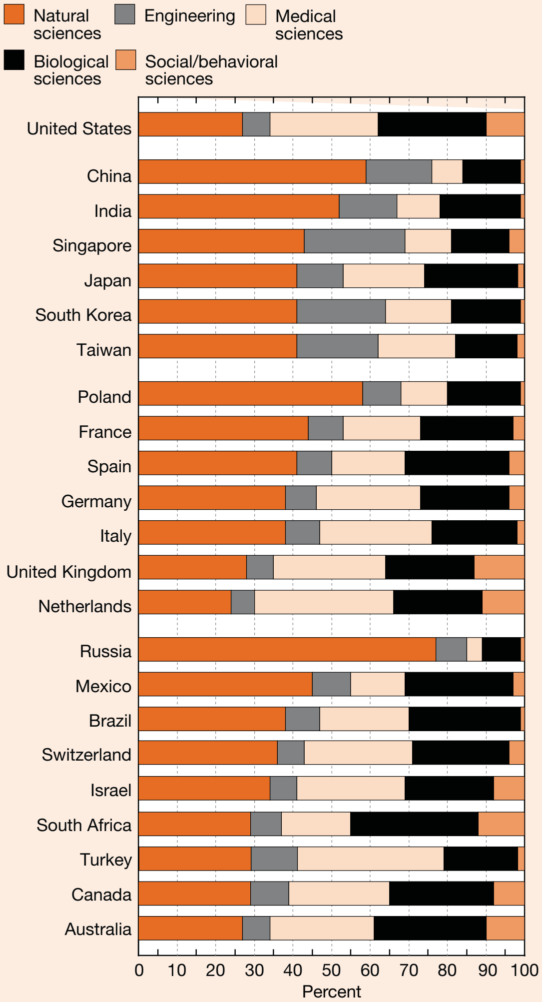
Science and Engineering Indicators 2010

Consequently, the production of engineering research articles has shifted away from established S&T nations. In 1988, the U.S. share of engineering articles was 36%; by 2008, it was 20%. Japan's share declined from 12% to 7% during the same period. Only the EU managed to maintain its share at 28%. Asia's share, excluding Japan, increased from 7% to 30%, with China producing nearly half (14%) of these articles by 2008 (figure O-15).

This strong and rapidly growing preponderance of engineering articles produced in developing Asian economies (figure O-16) is consistent with the region's emphasis on developing high-technology manufacturing capabilities. The Asia-10 region produced more engineering articles than the United States starting in 1999 and overtook the EU in 2003. In 2005, China overtook Japan in engineering article output and moved from ninth place in 1988 to second place. India's relative strength in engineering allowed it to move from seventh place to fifth place in the past 10 years.

Figure O-14

Field shares of research articles for selected countries/economies: 2007



NOTE: Natural sciences include astronomy, chemistry, physics, geosciences, mathematics, and computer sciences.

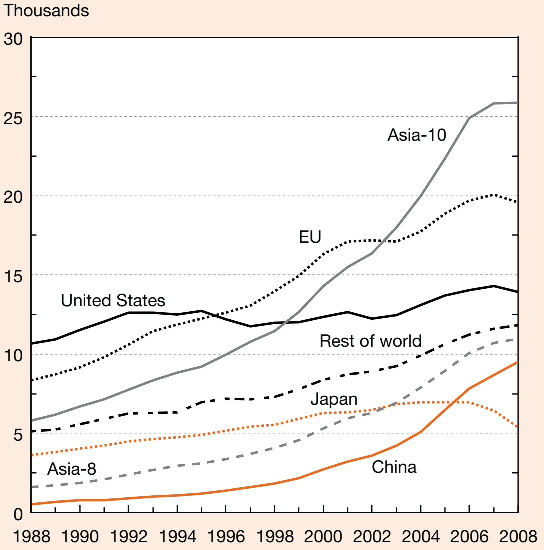
SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Expanding International Research Collaborations

Collaborative research is becoming the norm, as indicated by the increasing coauthorship of journal articles. Articles with authors in two or more countries have increased in number faster than any other segment of the S&E literature, indicating growing collaboration across national boundaries. In 1988, only 8% of the world's S&E articles

Figure O-15
Engineering journal articles produced by selected regions/countries: 1998–2008



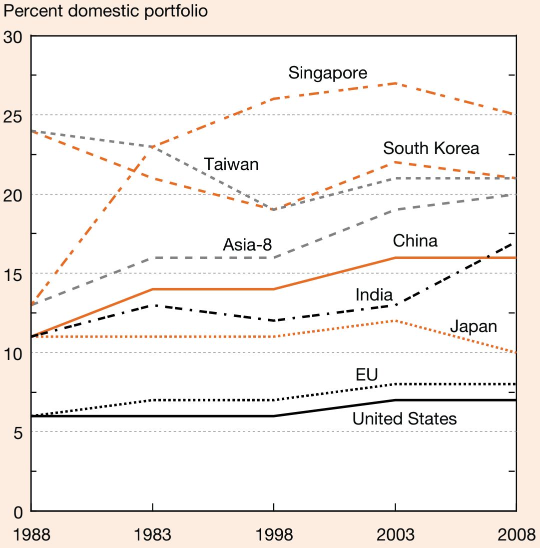
EU = European Union

NOTES: See glossary for countries included in Asia-8 and Asia-10. Articles classified by year of publication and assigned to region/country on basis of authors' institutional address(es). For articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. Articles counts are 2-year moving average. Counts for 2008 are incomplete.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure O-16
Engineering article share of total S&E article output for selected regions/countries/economies: 1988–2008



EU = European Union

NOTES: See glossary for countries included in Asia-8. EU includes all 27 member states. Articles classified by year of publication and assigned to region/country on basis of authors' institutional address(es). For articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit based on proportion of its participating institutions. Counts for 2008 are incomplete.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

had international coauthors; by 2007, this share had grown to 22%.

The United States rate of international collaboration is similar to that of Japan and China but lower than that of the EU, where explicit EU policies coupled with incentives stimulate international, and specifically intra-EU, collaboration (figure O-17). As a result of the large volume of total U.S. article output, however, U.S.-based authors appeared on 43% of the world's internationally coauthored articles in 2008.

An index of international collaboration corrects for the effects of unequal size of countries' research establishments.[13] It summarizes regional and country coauthorship patterns, with values above "1" indicating higher-than-expected, and values below 1 indicating lower-than-expected, collaborations.

U.S. international collaborations measured by this bilateral index were widespread, were generally lower than expected, and remained mostly steady over the past decade (1998–2008). EU collaborations were equally widespread, were generally lower than expected for its large members, and increased measurably over the period, quite likely in response to explicit EU policies. Unlike the index values for established scientific nations, Asia's index values were substantially higher than expected.

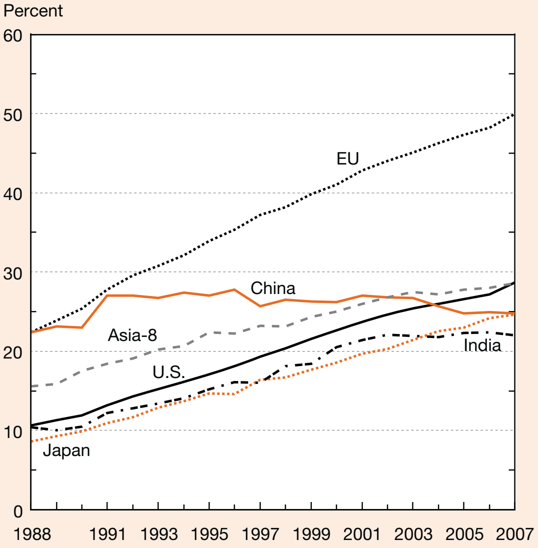
In 2008, U.S. research collaborations were especially strong with Canada and Mexico in North America (1.18 and 1.03), with Israel (1.25), and with South Korea and Taiwan in Asia (1.23). U.S. collaborations with China, Japan, and India were above the U.S. average.

EU policies to increase intra-European research integration appear to be having their desired effect, as intra-EU collaboration index values increased substantially over the period, most of them above unity.

Intraregional collaborations are prevalent in Asia, where they have developed even without the integrating framework provided by the EU. Over the 10-year period, high levels of collaboration were evident between China and Japan, South Korea, Singapore, and Taiwan, whereas the rate of collaboration between China and India diminished noticeably. India, in turn, collaborated more with Japan, South Korea, Singapore, and Taiwan. The underlying index values

Figure O-17

International coauthorship of S&E articles, by region/country: 1988–2007



EU = European Union

NOTES: See glossary for countries included in Asia-8. EU includes all 27 member states. Articles classified by year that they entered the database and assigned to region/country on basis of authors' institutional address(es). Each collaborating country or sector credited one count.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

suggest the genesis of an intra-Asian zone of scientific collaboration that has a counterpart in knowledge- and technology-intensive economic activities.

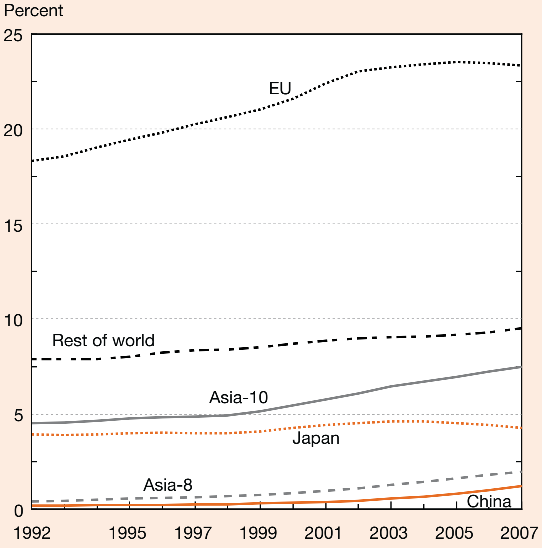
New Research Patterns Reflected in World's Citations Base

Citations to the work of others in the literature are a broad indicator of the usefulness of this work in ongoing research.[14] Citations to nondomestic articles can indicate the existence of useful work being done elsewhere.

Citations in U.S. articles (henceforth, U.S. citations) to the domestic literature dropped steadily since 1992 from 69% to 60% in 2007, attesting to the growth of relevant work elsewhere. Figure O-18 shows the regional breakdown of nondomestic citations relative to total U.S. citations.

Figure O-18

Citations in U.S. S&E articles to non-U.S. publications: 1992–2007



EU = European Union

NOTES: See glossary for countries included in Asia-8 and Asia-10. EU includes all 27 member states. Articles classified by year that they entered the database and assigned to region/country on basis of authors' institutional address(es). For articles with collaborating institutions from multiple countries/ economies, each country/ economy receives fractional credit on basis of proportion of its participating institutions.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

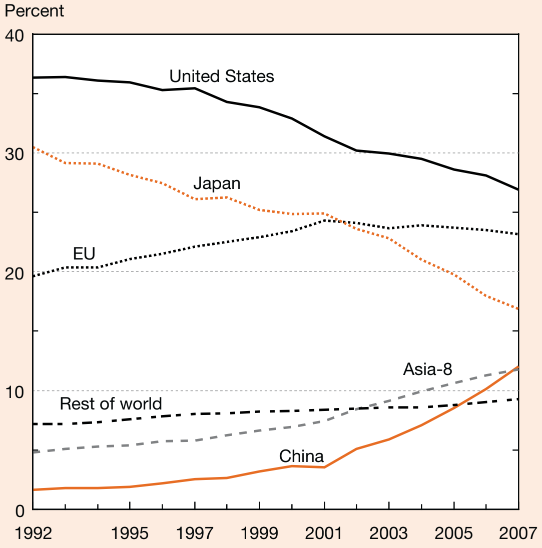
Most U.S. citations to the nondomestic literature referenced EU publications. In 2007, 23% of total U.S. citations were to EU work, up from about 18% in 1992 but flat in recent years. Over the same period, the Japanese share gradually declined. Slowly rising citation shares to work done in the Asia-8 group remained at a low level, partly because of the overall low level of their publications output, but probably also because of language, cultural barriers, and research quality.

EU citation patterns have undergone similar changes, with citations to the U.S. literature dropping from 36% to 28% over the 1992–2007 period. Total citations to Asian articles increased modestly from 5% to 8%, whereas citations to the rest of the world increased from 13% to 18%.

Major changes are evident in the Asia-10 group, whose internal citations increased from 37% to 41% of the Asia-10 total over the 1992–2007 period. Within this group, Japan's share dropped steeply from 31% to 17%, whereas China's share increased from 2% to 12% and the Asia-8's share increased from 5% to 12%. The EU share slowly increased, whereas the U.S. share declined from 36% to 27% (figure O-19).

The sheer number of citations by Chinese authors is rising steeply, but in a relative sense, Chinese authors are increasingly citing domestic articles and those by researchers in the Asia-8 group but less frequently the work of U.S. scientists. Thus, although the number of citations to U.S. articles increased from about 6,000 in 1992 to approximately

Figure O-19
Citations in Asia-10 S&E articles, by cited region/ country: 1992–2007



EU = European Union

NOTES: See glossary for countries included in Asia-8 and Asia-10. EU includes all 27 member states. Articles classified by year that they entered the database and assigned to region/country on basis of authors' institutional address(es). For articles with collaborating institutions from multiple countries/ economies, each country/economy receives fractional credit on basis of proportion of its participating institutions.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

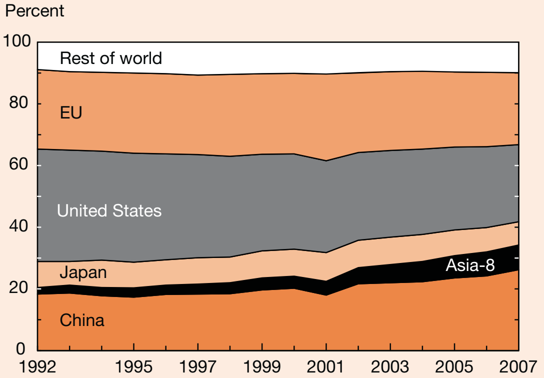
82,000 in 2007, the U.S. share contracted from 36% to 25%. Japan's share of citations in the Chinese literature has basically remained unchanged since the early 1990s; the same holds for the EU (figure O-20).

Even as global production and citation patterns have shifted, the relative quality distribution of worldwide articles, as measured by citations, has changed little. In 2007, the United States had consistently higher proportions of its articles in the most highly cited categories than the EU or the Asia-10 (figure O-21). This broad pattern held for the entire 1998–2007 period and for all major S&E fields.

Inventive Activity Shown by Patents

Patents are an indicator of inventive activity. By issuing patents that allow the patent owner to demand payment for their use, governments protect inventions that are new, not obvious, and useful. The U.S. Patent and Trademark Office (USPTO) grants patents to inventors from all over the world, and because of the sheer volume of U.S. patents and the im-

Figure O-20
Citations in China S&E articles, by cited region/ country: 1992–2007



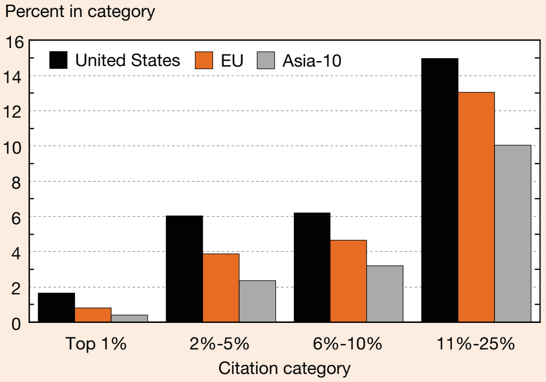
EU = European Union

NOTES: See glossary for countries included in Asia-8 and Asia-10. EU includes all 27 member states. Articles classified by year that they entered the database and assigned to region/country on basis of authors' institutional address(es). For articles with collaborating institutions from multiple countries/economies, each country/ economy receives fractional credit on basis of proportion of its participating institutions.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure O-21
Share of region's/country's papers among world's most cited S&E articles: 2007



EU = European Union

NOTES: See glossary for countries included in Asia-10. EU includes all 27 member states.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

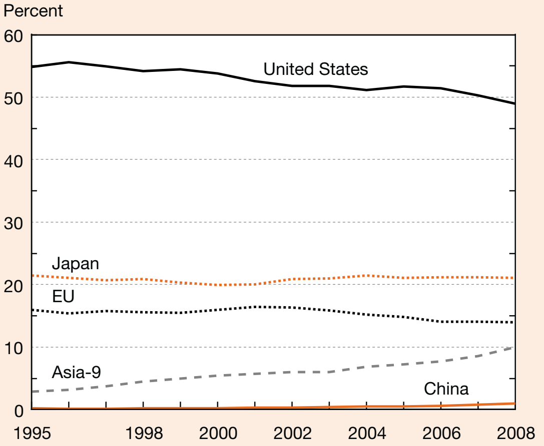
portance of the U.S. market, they are a useful indicator of trends in the geographic location of inventive activity.

About half (49%) of the patents granted by the USPTO went to U.S.-based inventors in 2008, down from 55% in 1995 and somewhat below the U.S. share of applications.[15] Japan's share has been a steady 20%–22% over the period, above its share of applications; the EU members received 14%–16%. The Asia-9's share increased from 3% to 10% over the period, mostly on the strength of South Korea and Taiwan. China's share remained in the 1% range in all major technology areas. Indigenous inventive activity, a focus of government policy, appears elusive, at least as indicated by patents filed in a major Western market (figure O-22).

Patents on inventions for which protection is sought in the United States, the EU, and Japan require substantial resources for obtaining and maintaining them. This suggests that their owners consider them to be valuable. These patents are herein treated as an indicator of the distribution of high-value patenting around the world.

Just over 30% of high-value patents had U.S. inventors in 2006, down somewhat from 34% in 1997.[16] The EU's share declined somewhat more, to 29% in 2006, followed closely by Japan. The Asia-9's increasing share largely reflects patents with Korean inventors. As with U.S. patents, Chinese inventors appeared on only 1% of these high-value patents (figure O-23).

Figure O-22
Share of U.S. patent grants for selected regions/ countries: 1995–2008



EU = European Union

NOTES: See glossary for countries included in Asia-9. China includes Hong Kong. EU includes all 27 member states.

SOURCE: U.S. Patent and Trademark Office, Number of Utility Patent Applications Filed in the United States, by Country of Origin, Calendar Years 1965 to Present, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Fast-Rising Global Output of Knowledge- and Technology-Intensive Firms

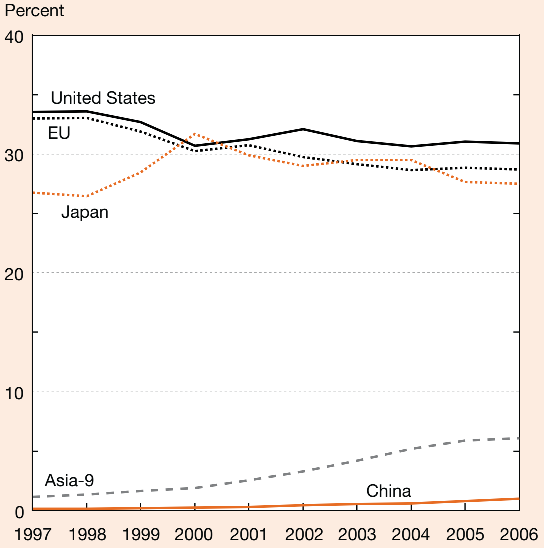
Governments in many parts of the world are acting on the conviction that knowledge- and technology-intensive economies create well-paying jobs, contribute high-value output, and ensure economic competitiveness. In response to changing opportunities, knowledge-intensive (KI) services industries and high-technology (HT) manufacturing industries have grown more rapidly than other segments of economic activity[17] (figure O-24).

In 2007, these knowledge- and technology-intensive (KTI) industries combined contributed just under $16 trillion to global economic output—about 30% of world GDP (figure O-25).

Initially these industries were the province of developed nations, but they have grown rapidly in developing markets. The global value-added volume for the largest aggregate—commercial knowledge-intensive services—increased from $4.5 trillion in 1995 to $9.5 trillion in 2007 (figure O-26).

The United States, with $3.3 trillion in 2007, produced the largest value-added output of these industries, which include business services, financial services, and communications.

Figure O-23
Share of high-value patents, for selected regions/ countries: 1997–2006



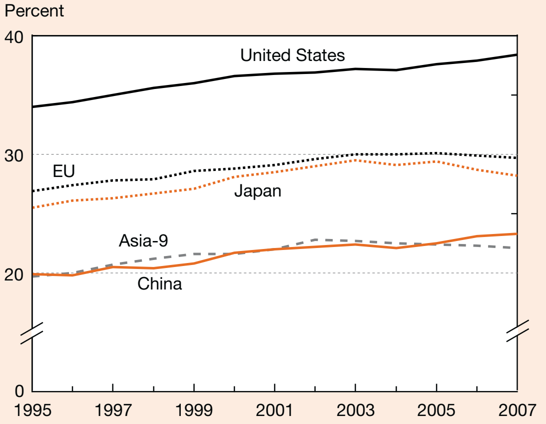
EU = European Union

NOTES: High-value patents are registered in three markets: the United States, the EU, and Japan. See glossary for countries included in Asia-9. China includes Hong Kong. EU includes all 27 member states.

SOURCE: Organisation for Economic Co-operation and Development (OECD), OECD.StatExtracts, patent statistics, http://stats.oecd.org/index.aspx; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure O-24
Value added of knowledge-intensive and high-technology industries as share of region's/country's GDP: 1995–2007



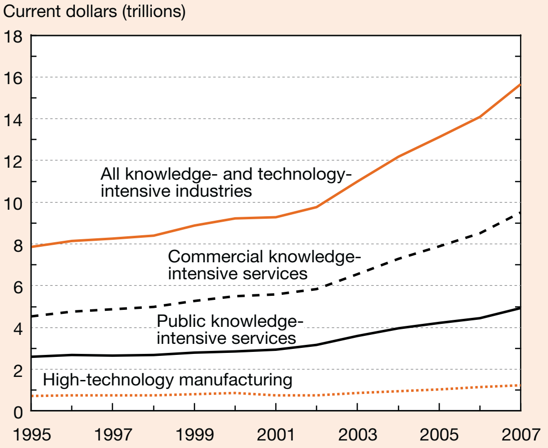
EU = European Union; GDP = gross domestic product

NOTE: Knowledge intensive services and high technology manufacturing industries as defined by Organisation for Economic Co-operation and Development. See glossary for countries included in Asia-9. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations.

Science and Engineering Indicators 2010

Figure O-25
Global value added of knowledge- and technology-intensive industries: 1995–2007

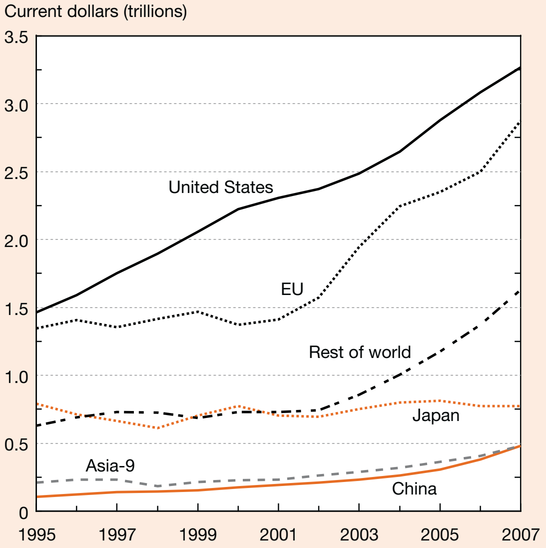


NOTES: Industries defined by Organisation for Economic Co-operation and Development. See glossary for definitions of knowledge-intensive services and high-technology manufacturing.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations.

Science and Engineering Indicators 2010

Figure O-26
Value added of commercial knowledge-intensive services, by selected region/country: 1995–2007



EU = European Union

NOTES: Industries defined by Organisation for Economic Co-operation and Development. See glossary for definitions of knowledge-intensive services and Asia-9. China includes Hong Kong. EU includes all 27 member states.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations.

Science and Engineering Indicators 2010

The United States was followed by the EU with $2.9 trillion. World shares in these industries fluctuated for the United States and the EU, but by 2007 had settled near their 1995 levels. Increased production by China and the Asia-9 expanded their value-added output of commercial KI services, but at about half a trillion dollars each, their world market shares remained just below 5%. Flat output growth in Japan caused its market share to decline by more than half, to 8%.

The same pattern is evident in the individual KI service sectors: fluctuations in the U.S. and EU shares, steep declines for Japan's shares, and modest to rapid growth from low bases for China and the Asia-9, leading to modest increases in their world shares.

Relative to these KI trends, high-technology manufacturing shows a much stronger world position for the developing Asian economies and much steeper decline for Japan. The Asia-9 output was about 10% of the value-added world total over the 1995–2007 period, while China's share increased from 3% to 14%. Japan's share dropped from 27% to 11%. The U.S. and EU shares both showed modest upward movement.

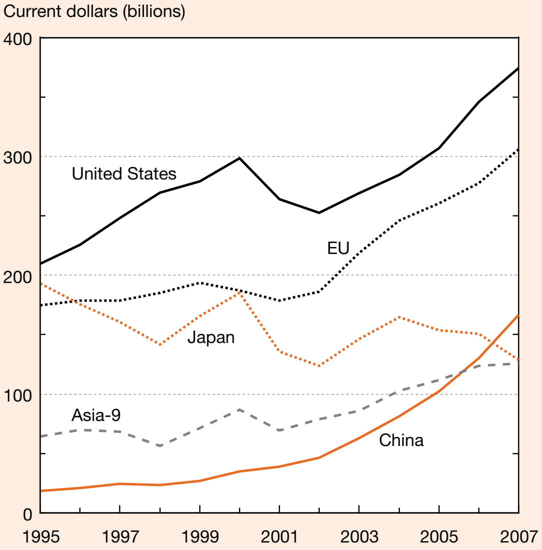
The five HT industries are, in decreasing order of the $1.2 trillion 2007 global value-added total: communications and semiconductors ($445 billion), pharmaceuticals ($319 billion), scientific instruments ($189 billion), aerospace ($153 billion), and computers and office machinery ($114 billion). The aggregate distribution by country/economy is shown in figure O-27.

The United States ranked first with 31% of the total, followed by the EU's 25% share. The United States was the world leader in communications and semiconductors (29%), pharmaceuticals (32%), and aerospace (52%), and ranked behind the EU in scientific instruments (19% vs. 44%).

However, in computers, the United States (25%), the EU (15%), and Japan (5%) all ranked well behind China (39%). This category saw a particularly rapid shift in relative world value-added positions (figure O-28).

These data obscure a larger dynamic, discussed briefly below: the development of a high-technology assembly zone in the Asia region, arrayed largely around China. It is likely that part of China's rapid growth of value-added in computer manufacturing reflects the large-scale movement of Taiwanese manufacturing facilities to, and subsequent export of computer products from, China. Nevertheless, these data highlight the growing concentration of the world's computer and office machinery manufacturing in Asia.

Figure O-27
Value added of high-technology manufacturing industries, by selected region/country: 1995–2007



EU = European Union

NOTES: Industries defined by Organisation for Economic Co-operation and Development. See glossary for definitions of high-technology manufacturing and Asia-9. China includes Hong Kong. EU includes all 27 member states.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations.

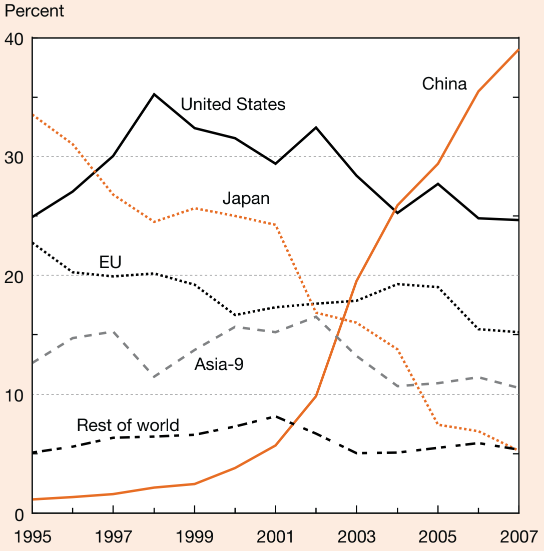
Science and Engineering Indicators 2010

Booming Global High-Technology Exports Rearranging World Trade Patterns

The total export volume of high-technology products increased faster than gross production and pushed exports close to 60% of production in 2007, up from 37% in 1995 (figure O-29). This increase reflects the broadened international base of high-technology manufacturing, the expansion of multinational firms' overseas production, and a shift in the nature of production to increasingly specialized and geographically dispersed suppliers. The global economic slowdown is mirrored in the greater decline of exports than production and the downturn in the 2008 export share.

The global expansion of high-technology trade has made China the largest single high-technology exporter and has changed the relative positions of the developed and developing countries. China's share of world high-technology exports increased from 6% in 1995 to 20% in 2008, while the Asia-9 maintained a 26%–29% share (figure O-30). Japan's export share eroded from 18% to 8%, the U.S. share dropped from 21% to 14%, and the EU maintained a 16%–18% share.[18]

Figure O-28
Global value added market shares of computer and office machinery manufacturing, by region/country: 1995–2007



EU = European Union

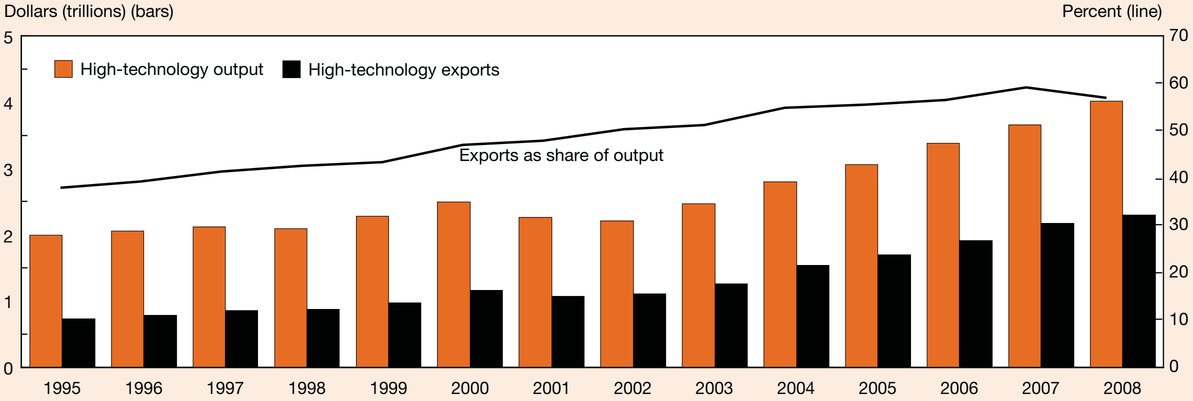
NOTES: Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations.

Science and Engineering Indicators 2010

The drop in the U.S. share was driven by below-average U.S. export growth in computers and information and communications (ICT) products, contrasting with China's nearly twelvefold expansion (figures O-30 and O-31). Since 1995, China and the Asia-9 have moved from a combined 42% of ICT product exports to 64% of the world's total, and almost 70% of computers alone.

Figure O-29
Global high-technology exports as share of production: 1995–2008

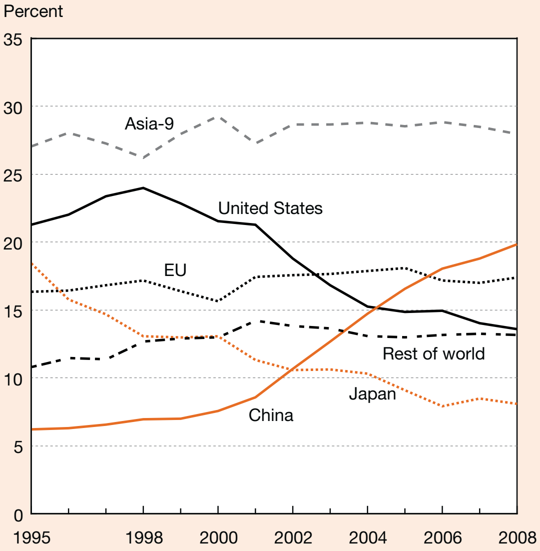


NOTE: Excludes intra-European Union trade.

SOURCE: IHS Global Insight, World Industry Service and World Trade Service databases, special tabulations.

Science and Engineering Indicators 2010

Figure O-30
Share of global high-technology exports, by region/country: 1995–2008



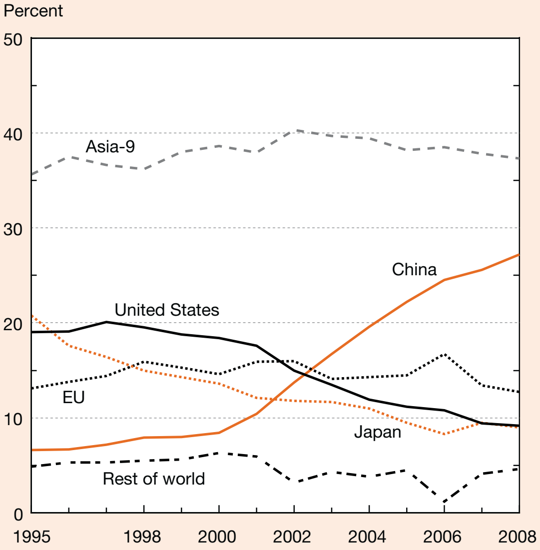
EU = European Union

NOTES: Excludes intra-EU trade. See glossary for countries included in Asia-9. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCES: IHS Global Insight, World Trade Service database, special tabulations.

Science and Engineering Indicators 2010

Figure O-31
Global export shares in information and communications technology products, by region/country: 1995–2008



EU = European Union

NOTE: Includes computers and communications and semiconductors. See glossary for countries included in Asia-9. China includes Hong Kong. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations.

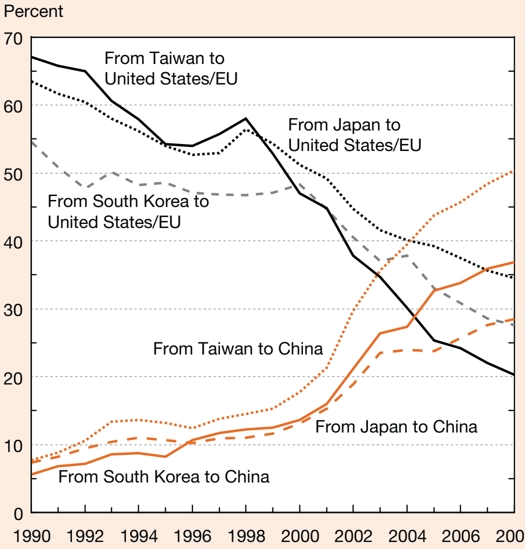
Science and Engineering Indicators 2010

An Asian high-technology supplier zone appears to be developing that is largely arrayed around China. The shift in output of high-technology goods toward developing Asian economies has been accompanied by the growth of intraregional supplier relationships that provide intermediate goods, many for further assembly and eventual export. Chinese high-technology exports to the United States increased from $28 billion in 2000 to $112 billion 8 years later, when the U.S. recession dampened the pace of increase. Chinese exports to the EU increased at a slightly faster pace over the period (figures O-32 and O-33).

Big Shifts in World Trade Positions in High-Technology Products

In the high-technology goods trade, the United States had small trade surpluses during the mid- to late 1990s; these turned into a widening deficit after 1998 that has fluctuated at about $80 billion since 2005[19] (figure O-34). The U.S. trade deficit in ICT goods—communications and semiconductors and computers—is larger than that. It reached a record $126 billion in 2007 before contracting marginally to $119 billion in 2008, reflecting recession-induced lowered imports.

Figure O-32
Selected Asian countries'/economies' share of high-technology exports to United States/EU and China: 1990–2008



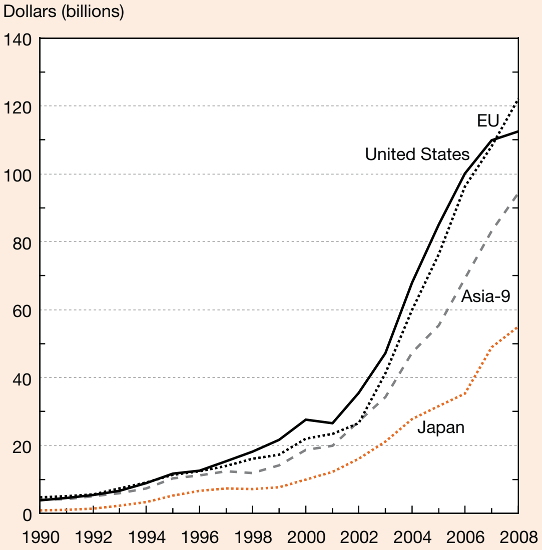
EU = European Union

NOTES: China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations.

Science and Engineering Indicators 2010

Figure O-33
China's high-technology exports to selected regions/countries: 1990–2008



EU = European Union

NOTES: See glossary for countries included in Asia-9. EU includes all 27 member states.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations.

Science and Engineering Indicators 2010

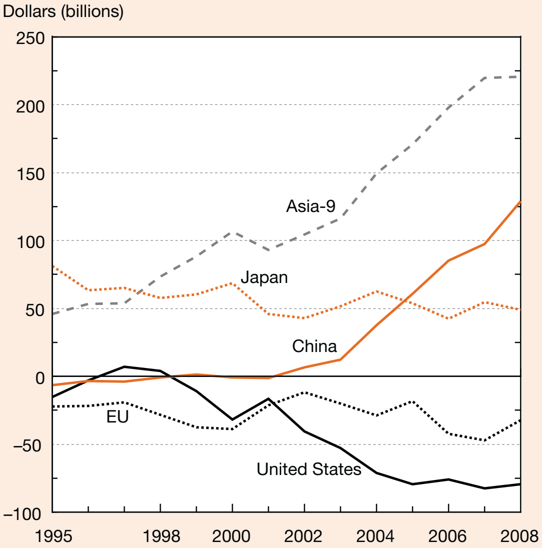
ICT goods have been the major driver behind the overall U.S. high-technology trade deficit. The broad shift in the location of production of these goods to Asia coincided with growing U.S. demand, which in turn stimulated growing imports. Pharmaceuticals contributed a further $21 billion to the 2008 deficit. Aerospace and scientific instruments were in surplus, at $50 billion and $9 billion, respectively.

The EU had a relatively stable 1995–2008 trade deficit for all high-technology classes combined, smaller than that of the United States. However, its ICT deficit was almost identical to that of the U.S., reflecting the same dynamic of rising domestic demand and relocated production. The EU's aerospace, pharmaceuticals, and scientific instruments trade balances were in surplus.

China and the Asia-9 had substantial 2008 high-technology trade surpluses of $129 billion and $221 billion, respectively. Both showed strong increases after 2002. Japan had a surplus that fluctuated at about $50 billion for most of the period, despite its loss of market share in the production of high-technology industries.

Figure O-34

Trade balance in high-technology goods for selected regions/countries: 1995–2008



EU = European Union

NOTES: See glossary for countries included in Asia-9. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations.

Science and Engineering Indicators 2010

Continued Surpluses From U.S. Trade in Knowledge-Intensive Services and Intangible Assets

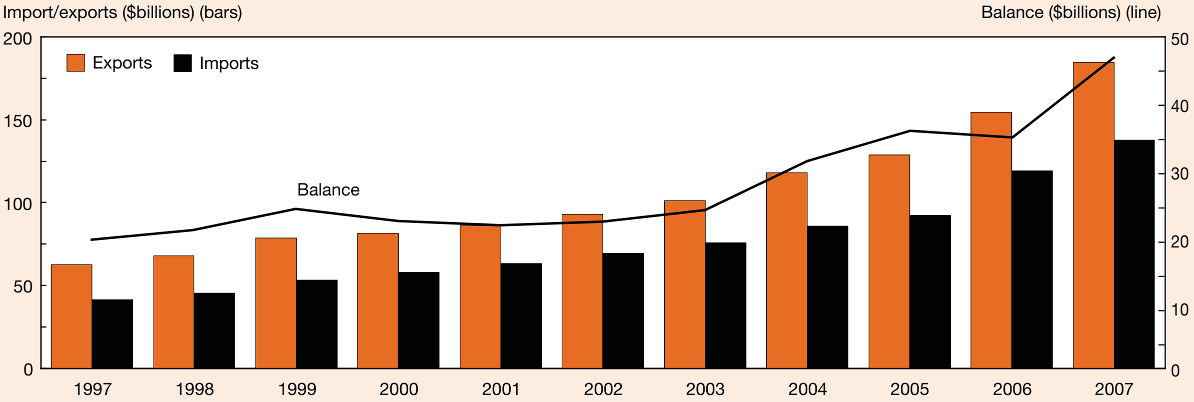
Unlike U.S. trade in high-technology products, U.S. trade in commercial knowledge-intensive services—business, financial, and communications services—has produced a consistent and growing surplus (figure O-35). The trade balance widened from $21 billion in 1997 to nearly $50 billion in 2007, as exports grew faster than imports. Likewise, U.S. trade in intangible assets—payments for the use of others' property rights in the production of goods, trademarks, use of computer software, books, records, franchise fees, and the like—exhibited a similar trend of growing surpluses, which reached nearly $60 billion in 2007.

Conclusion

Science and technology are no longer the province of developed nations; they have, in a sense, become "democratized." Governments of many countries have firmly built S&T aspects into their development policies as they vie to make their economies more knowledge- and technology-intensive and, thereby, ensure their competitiveness in a globalizing world. These policies include long-term investments in higher education to develop human talent, infrastructure development, support for research and development, attraction of foreign direct investment and technologically advanced multinational firms, and the eventual development of indigenous high-technology capabilities.

Figure O-35

U.S. imports, exports, and trade balance in commercial knowledge-intensive services: 1997–2007



SOURCE: IHS Global Insight, World Trade Service database, special tabulations.

Science and Engineering Indicators 2010

The resulting developments open the way for widespread international collaboration.[20] The broad trend in this direction is clearly reflected in the rapid growth of international coauthorships of research articles in the world's leading journals.

The developments also carry with them competitive elements. The quest for international talent, once largely limited to major Western nations, is now pursued by many, and "brain drain" has evolved into cross-national flows of highly trained specialists. In S&T, nations are eager to establish specialty niches and develop indigenous world-class capacity.

The globalization of the world economy has brought unprecedented levels of growth to many countries, demonstrating that benefits can accrue to all. But the structural changes that are part and parcel of rapid growth bring with them painful dislocations, amplified by the uncertainties and potential changes fostered by the world-wide recession. How these are resolved will inevitably affect the health and development of nations' S&T systems and their place in the world.

Notes

1. The Asia-9 includes India, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Thailand, Taiwan, and Vietnam.

2. The World Bank estimates global gross national income to have increased about 80% over the period (current PPP dollars).

3. These estimates rely on data from the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific, and Cultural Organization Institute for Statistics; they are not precise measures. Reported data are converted to dollar totals using purchasing power parities (PPPs), the local costs of a market basket of goods and services; the accuracy of this standard economic conversion may degrade in the case of developing economies. In addition, estimation of some missing data and variable reporting mean that there is uncertainty about any specific point estimate. The reader's focus is directed to the overall trend, which reflects an internally consistent estimate over time.

4. The latest updated 2007 U.S. R&D estimate is $398 billion; see http://www.nsf.gov/statistics/nsf08318/tables/tab1.xls. The overview uses the most recent OECD number to allow more direct comparison with other countries' values.

5. European Commission, Barcelona European Council, *Presidency Conclusions* (Barcelona, Spain, March 2002).

6. See Joan Burrelli and Alan Rapoport, *Reasons for International Changes in the Ratio of Natural Science and Engineering Degrees to the College-Age Population,* SRS 09-308 (Arlington, VA: National Science Foundation, January 2009).

7. Tertiary education by international convention is broadly comparable to at least a U.S. technical school or associate's degree.

8. Both figures exclude those with unknown citizenship (1,600 in 2007) and those with degrees in medical/other life sciences. Engineering figures exclude about 630 with unknown citizenship.

9. Michael Finn, Stay rates of foreign doctorate recipients from U.S. universities, (Oak Ridge, TN: Oak Ridge Institute for Science and Education, forthcoming).

10. Both estimates are based on data from a limited number of countries reporting their data, on a full-time equivalent basis, to the OECD.

11. The database used is Thomson Scientific, Science and Social Science Citation Indexes; IpIQ, Inc.; and NSF tabulations.

12. The physical sciences are physics; chemistry; earth, atmospheric, and ocean sciences; and astronomy.

13. The index numerator is the percent of country A's international collaborations with country B; the denominator is B's percentage of the world's international collaborations. See appendix table 5-41.

14. Citation indicators are subject to a number of distortions: self-citation, citation of failed theories, hypotheses, and approaches; citation of domestic vs. foreign articles; language and cultural barriers; etc. However, when aggregated over many articles, citation indicators carry information about the relative use of articles in subsequent work.

15. In these data, USPTO patents are assigned to the location of the first-named inventor.

16. The geographic distribution is based on location of inventor. Multiple-inventor patents are credited fractionally to geographic location.

17. These industry groups are defined by the OECD and form the basis for databases of economic activity that over a large number of the world's economies. Knowledge-intensive services industries include the commercially tradable business, financial, and communications services, and education and health services, which are considered more nearly location-bound and closer to government functions. High-technology manufacturing industries include aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communication equipment; and medical, precision, and optical instruments.

18. Internal EU trade was subtracted from both the world and EU totals, because the unified EU market structure makes trade among its member states akin to trade among U.S. states.

19. U.S. trade in advanced technology products shows a similar deficit path. These products, defined by the U.S. Bureau of the Census, include computer software, advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information/communications technology, life sciences, nuclear technology, optoelectronics, and weapons. However, data categorized in this fashion are unavailable for most other countries and differ from other trade data discussed earlier that are based on OECD definitions.

20. See National Science Board, *International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and Our Nation's Innovation Enterprise,* NSB-08-4 (Arlington, VA: National Science Foundation, 2008).

Glossary

Asia-8: Includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

Asia-9: Includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam

Asia-10: Includes China, Japan, India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

European Union: The 27 member states of the European Union since 2007 include Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

High-technology manufacturing: Includes air- and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communication equipment; and medical, precision, and optical instruments.

Knowledge-intensive services: Includes commercial business, financial, and communication services and largely publicly supported education and health services. Commercial knowledge-intensive services exclude education and health.

Chapter 1

Elementary and Secondary Mathematics and Science Education

List of Sidebars

List of Tables

List of Figures

Highlights

Student Learning in Mathematics and Science

Initial disparities in mathematics skills found in the Early Childhood Longitudinal Study, Kindergarten Class of 1999 (ECLS–K), tended to grow as these students progressed through grade 8.

- Kindergarten test scores, along with many demographic characteristics, were strong predictors of students' skills in 2007, after 9 years of schooling. Gaps generally grew through about grade 3 and thereafter remained stable, with some narrowing marginally.
- Science understanding was tested in grades 3, 5, and 8; gaps between more and less advantaged groups stayed about the same over these grades.

Scores on the National Assessment of Educational Progress (NAEP) mathematics test increased among younger students through 2008, continuing a steadily rising pattern since 1990.

- From 1990 to 2007, fourth graders gained 27 points and eighth graders gained 19 points (on a scale of 0–500 for both grades).
- These increases in performance were shared by boys and girls; white, black, and Hispanic students; and students from lower- and higher-income families.
- The score gaps in 1990 among racial/ethnic groups remained in 2007, but one gap shrank: black fourth graders gained enough points to narrow the gap with whites. Between 2000 and 2007, score differences decreased for six groups: between black and white students in both grades, Hispanic and white students in both grades, and low-income and higher-income students in both grades.
- The two younger age groups (9- and 13-year-olds) participating in NAEP Long-Term Trend tests in 2008 had higher average mathematics scores than their 1973 peers had, but performance among 17-year-olds was flat.
- Relatively large score increases among 9-year-olds occurred during the 1980s and early 2000s, while 13-year-olds had steadier (but less steep) gains over the 35 years. In each age group, black students narrowed the gaps with whites first observed in 1973.

On one recent international assessment, the Trends in International Mathematics and Science Study (TIMSS:2007), the scores of U.S. fourth and eighth graders were higher than in 1995 in mathematics but not in science.

- TIMSS exams closely follow the curriculums commonly taught in participating countries. U.S. students' 2007 average mathematics score was higher than their 1995 average score. The U.S. standing among selected comparison countries also rose slightly, placing the United States near the median of selected nations in both grades.
- Scores at the 90th percentile provide information about high-achieving students (those who scored higher than 90% of all test takers). In both fourth and eighth grades, the U.S. 90th percentile scores in mathematics were also near the median of selected countries on this measure.
- Science results were mixed: the average 2007 science scores of U.S. fourth and eighth graders had not changed measurably from the 1995 average scores. However, the U.S. position among selected countries declined in fourth grade (two more nations outscored the United States and four fewer had lower scores in 2007) and increased slightly in eighth grade (where two fewer scored above and two more scored below the United States).

On another international test, the Program for International Student Assessment (PISA:2006), U.S. 15-year-olds scored below most selected nations in 2006, and the U.S. standing among selected nations dropped below its 2000 rank in both mathematics and science. The U.S. PISA results in both subjects contrasted sharply with the U.S. TIMSS results, particularly in mathematics.

- PISA aims to test students' ability to apply what they have learned (e.g., explain answers in mathematical or scientific terms, use logical reasoning, synthesize information). Among 19 nations with data available for both years, the United States scored below 7 nations in mathematics in 2000 and below 15 nations in 2006.
- In 2006, the average mathematics score of U.S. students was lower than scores in 18 comparison nations (out of 24), and higher than those in 4 other countries—3 of them developing economies. The U.S. 90th percentile score in mathematics was similarly low relative to scores in other nations.
- Between 2000 and 2006, the number of countries scoring higher than the United States on the PISA science assessment rose from 6 to 12.

Teachers of Mathematics and Science

Most fifth and eighth grade students in public schools were taught mathematics and science by teachers with basic credentials such as a bachelor's degree and teaching certificate (but not necessarily in mathematics and science). Most students were also taught by teachers with more than 3 years of teaching experience.

- Virtually all fifth and eighth grade students in public schools were taught mathematics and science by teachers who had attained at least a bachelor's degree, and about half of them were taught these two subjects by teachers with a master's or higher degree. More than

80% of students had teachers with a regular or advanced teaching certificate.

- Forty percent of fifth grade students in 2004 were taught mathematics and science by teachers with either a degree or certificate in their teaching field (i.e., in-field teachers). In contrast, 54% of fifth graders had teachers of mathematics and science with general education preparation. When these students reached eighth grade in 2007, 80% of them were taught mathematics and science by in-field teachers, and the percentage of students taught mathematics and science by teachers with general education preparation fell to 9%–10%.
- Eighty-two percent or more of fifth and eighth grade students in public schools had teachers with more than 3 years of teaching experience.

Access to better-qualified teachers of mathematics and science was not equally distributed among students.

- In 2004, black and Hispanic fifth grade students were less likely than white students to be taught mathematics by teachers with a master's or advanced degree (39% and 42% vs. 51%, respectively), a regular or advanced teaching certificate (86% and 85% vs. 92%), and more than 3 years of experience teaching grade 5 (48% and 58% vs. 68%).
- Also among fifth graders, a third of those in the lowest achievement quartile in grade 3 were taught mathematics by a teacher with a degree or certificate in math. In contrast, 42% of fifth graders in the top achievement quartile in grade 3 had such teachers.
- In 2007, eighth grade students whose mothers had not earned a high school diploma were less likely than those whose mothers had a bachelor's or higher degree to be taught science by teachers who had a master's or advanced degree (46% vs. 57%), a regular or advanced teaching certificate (79% vs. 87%), a degree or certificate in science (84% vs. 93%), and more than 3 years of experience teaching science (69% vs. 83%).
- Eighth grade students from families with low incomes were less likely than those from higher-income families to be taught science by teachers with a regular or advanced teaching certificate (79% vs. 86%), a degree or certificate in science (84% vs. 89%), and more than 3 years of experience in teaching science (69% vs. 79%).
- About 92% of eighth graders with high achievement in fifth grade were taught mathematics by a teacher with a degree or certificate in mathematics, compared with 77% of those with low fifth grade achievement.

Teacher participation in professional development in mathematics and science at the elementary level was not as common as that at the middle and high school levels.

- While teacher participation in professional development during a school year was almost universal at public middle and high schools, in 2004, 47% of public school fifth grade students were taught science by teachers who reported no staff development in science, and 27% of students were taught mathematics by teachers who reported no staff development in mathematics.
- On average, teacher participants spent about 14 hours on staff development in mathematics and science during the entire school year.
- Roughly 40% of fifth grade students had teacher participants rating this activity as very useful.

Over the past decade, teachers' pay increased little after adjusting for inflation. Teacher salaries continue to lag behind salaries in comparable professions, and the gaps have widened in recent years.

- In 2006–07, the average salary for all K–12 teachers was about $51,000. After adjusting for inflation, teacher salaries grew by 2.8% between 1996-97 and 2006-07.
- In 2006, full-time public school teachers earned 86% as much in weekly wages as did those in six occupations requiring comparable education and job skills: accountants, reporters, registered nurses, computer programmers, members of the clergy, and personnel officers. Between 1996 and 2006, the gap in weekly wages between full-time teachers and those in these comparable occupations widened from $7 to $153 (in constant dollars).

Most public school mathematics and science teachers had favorable perceptions of their working conditions. However, these positive perceptions were less widely held among teachers of disadvantaged and low-achieving students.

- A majority of public school teachers who taught mathematics and science to fifth and eighth grade students expressed positive views of their principal's leadership, their school's mission and spirit, the efforts of teachers to learn new ideas, the relationships among colleagues, and parental support. Relatively few of them reported student learning and behavioral problems.
- These positive perceptions, however, were less widely held among teachers of black and Hispanic students, low-achieving students, and students from low-income and less-educated families.

Instructional Technology in Education

Access to the Internet in U.S. schools is nearly universal.

- In 2005, 94% of classrooms in U.S. public schools had computers with Internet access, and the ratio of students to instructional computers was 4:1.

Most states have implemented standards for students' understanding of computer technology and teachers' use of technology for instruction.

- All 50 states currently include computer technology in their curriculum standards as a subject in which students should receive instruction, and 46 include technology in their teaching standards.

An increasing number of students have access to and are enrolling in distance education opportunities, particularly online courses.

- Twenty-five states sponsored virtual schools as of 2007, and 57% of secondary schools nationwide provided some online learning opportunities to their students in 2005. Most state-led programs are at the high school level.
- During the 2004–05 school year, there were 506,950 student enrollments in online courses nationwide, up from 317,070 students in 2002–03, but little is known about course taking or achievement in science and math in particular.

Transition to Higher Education

Most Organisation for Economic Co-operation and Development (OECD) countries outperform the United States in terms of secondary school completion.

- In 2006, the United States ranked 17th among 23 OECD countries with data available on the rate of student secondary school completion.

On-time high school graduation rates have remained steady in the United States, and large gaps between racial/ethnic groups persist.

- The nationwide on-time graduation rate was 73% in 2006, and the on-time graduation rate for white students was approximately 20 percentage points higher than the rate for black and Hispanic students.

Student test taking in Advanced Placement (AP) mathematics and science subjects has increased rapidly since 1990.

- The number of test takers increased in virtually all AP mathematics and science subjects in 2008. In some subjects, the number of test takers increased fivefold or more, although participants remain a small proportion of the high school population. Fifteen percent of the class of 2008 earned a score of 3 or higher on at least one AP test during high school.
- The number of students passing an AP exam is also increasing. Almost 250,000 students passed a mathematics AP exam in 2008, compared with just over 50,000 in 1990, and more than 200,000 passed a science AP exam in 2008, compared with fewer than 50,000 in 1990.

Among high school graduates in 2004, earning credits for advanced science and mathematics courses was linked to higher rates of postsecondary enrollment at 4-year colleges and lower rates of postsecondary remediation, confirming the results of earlier studies.

- Among students with two or more advanced mathematics or science credits, 88% and 90%, respectively, enrolled in a 4-year college within 2 years of high school graduation, compared with only 22% and 12% of students with no advanced credits.
- More than 40% of students whose highest mathematics course was less advanced than algebra II reported taking remedial mathematics at the postsecondary level, compared with 17% of students who had taken calculus.

Introduction

This chapter describes both inputs and outcomes related to K–12 mathematics and science education in the United States. The first section focuses on student achievement, including student achievement growth over time and achievement gaps among groups of students. The second section focuses on a key determinant of student learning: teachers' qualifications and working conditions. It examines fifth and eighth grade teachers' education, licensure, and working conditions. New data permit analysis of how the characteristics of students and their teachers are related, providing greater context for understanding students' achievement. This section also presents data on teacher salaries and recent research comparing teacher salaries with the salaries of other workers.

The third section describes student access to instructional technology, including data on student access to the Internet and eighth graders' use of computers in mathematics and science classes. The section also reports on student participation in distance education, a subject new to this volume.

The fourth and final section describes students' transitions from secondary to postsecondary education—the subject of chapter 2 in this volume. The section begins with an update on high school graduation rates and a comparison of U.S. high school graduation rates with those in other countries. It next presents data on student participation in Advanced Placement (AP) examinations and addresses information on high school graduates' immediate enrollment in postsecondary education. New to this section are data on the relationship between students' high school coursetaking and achievement in mathematics and science and enrollment and remediation in postsecondary education.

Table 1-1 presents an overview of the topics discussed in this chapter and the indicators used to illuminate and flesh out the concepts. Whenever a difference or change over time is cited in this chapter, it is statistically significant at the 0.05 probability level.[1]

Student Learning in Mathematics and Science

One of the central goals of educators and legislators is increasing overall student achievement, with a special focus on increasing learning by low performers. Concern also centers on advancing U.S. performance in relation to that of other countries, especially in mathematics, science, and technical fields. The most commonly used tools for measuring changes in achievement are standardized assessments. (The terms *achievement* and *performance* are used interchangeably in this section when discussing scores on these tests.)

This section is divided into two parts. The first examines trends in mathematics and science achievement among public and private school students in the United States, using two kinds of national data. Longitudinal data follow the same group of students over several years, allowing observers to track how individual students learn over time. In some

Table 1-1
Indicators of elementary and secondary school mathematics and science education

Topic	Indicator
Student learning in mathematics and science	• Elementary/middle school achievement in mathematics and science (longitudinal data) • Fourth and eighth graders' mathematics achievement (cross-sectional data) • International comparisons of fourth and eighth graders' mathematics and science achievement (cross-sectional data) • International comparisons of 15-year-olds' mathematics achievement (cross-sectional data)
Teachers of mathematics and science	• Degrees, certification, and experience of fifth and eighth grade teachers of mathematics and science • Professional development • Teacher salaries • Teachers' working conditions
Availability and use of instructional technology	• Access to computers and the Internet • Computer and Internet use in eighth grade • Distance education
Student transitions to higher education	• High school graduation rates • Advanced Placement (AP) mathematics and science coursetaking and test performance • International comparisons of secondary school graduation rates • High school courses and postsecondary success • Immediate college enrollment • International comparisons of college enrollment rates

Science and Engineering Indicators 2010

cases, longitudinal test data may also be linked to teaching practices and other factors thought to influence achievement. New test data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K), collected in 2007, allow study of performance changes among a kindergarten cohort through eighth grade and of changes over time in initial achievement gaps among groups of students.

Cross-sectional data, in contrast to longitudinal data, provide information on particular groups' performance measured at different points in time. The National Assessment of Educational Progress (NAEP) data presented in the first section, for example, examine performance of fourth and eighth graders who were sampled in various years between 1990 and 2007. These data indicate whether and how achievement is changing over time for comparable groups of students.

The second part of this section compares student achievement in the United States with that in other countries. The latest Trends in International Mathematics and Science Study (TIMSS:2007) allows comparisons of U.S. fourth and eighth graders with their counterparts in other countries. The Program for International Student Assessment (PISA:2006) provides test score data for 15-year-olds in the same subjects. These international assessments are both cross-sectional studies.

Students' Performance on National Assessments

Mathematics and Science Performance as Students Progress Through Elementary and Middle Grades

ECLS-K has followed a group of students who first entered kindergarten in fall 1998 over 9 school years. (The mathematics and science education of students who are homeschooled is not addressed in this chapter; see sidebar "Homeschooling in the United States.") The study concluded in spring 2007, when most students were in eighth grade.[2] The sample used in this analysis included roughly 8,000 students. ECLS-K is unusual among major national and international data collections not only in its focus on the earlier years of schooling but also because it allows researchers to examine students' performance in light of variables likely to influence learning. Cognitive tests measured students' mathematics knowledge in kindergarten and grades 1, 3, 5, and 8 and tracked their science understanding in grades 3, 5, and 8. The study also collected demographic and family information from a parent and surveyed teachers and schools for information about school environments, teacher qualifications, and classroom practices.

Gains in Mathematics Test Scores and Gap Changes. Students begin kindergarten with differing levels of mathematics skills, and researchers have suggested several factors that may be related to these initial gaps. A body of research has focused in particular on initial gaps between white and black children. The early home environment, including how well parents prepare children for school (e.g., time spent reading to them) plays a role (Magnuson, Rosenbaum, and Waldfogel 2008; Jencks and Phillips 1998). Other reasons posited include income and education differences among parents (Magnuson, Rosenbaum, and Waldfogel 2008; Campbell et al. 2008), school segregation (Vigdor and Ludwig 2008), access to effective and well-trained teachers (Corcoran and Evans 2008), ability to listen and concentrate, and children's fine motor skills, which need to reach a certain level of development for young children to learn to write and draw (Grissmer and Eiseman 2008).

Students' mathematics achievement was measured on a single scale ranging from 0 to 174 throughout the study, allowing the tracking of achievement growth and comparisons between groups as children progressed through elementary and middle grades. The 1998–99 kindergarten cohort started school with an average mathematics score of 26 and gained 113 points by the spring of eighth grade, to 139 (table 1-2).

For most characteristics, gaps widened during the early years of school (when the overall score changes were greater) and then stabilized or even narrowed slightly starting at grade 3 or 5, when the rate of overall growth also declined. Students' relative achievement when starting school had an influence on growth and eventual grade 8 scores, shown by the trajectories of those scoring in the lowest, middle two, and highest quartiles in kindergarten (figure 1-1). These varying growth patterns were in turn related to demographic characteristics. For example, the gap between kindergartners

Homeschooling in the United States

In spring 2007, an estimated 1.5 million students ages 5–17 were homeschooled in the United States, accounting for about 3% of the K−12 student population at that time (Bielick 2008). Trends from 1999 to 2007 show a 74% increase in the number of homeschooled students over this 8-year period. Homeschooled students in these estimates are defined as those who are schooled at home for at least part of their education and whose enrollment in public or private school does not exceed 25 hours per week.

The decentralized nature of the homeschooled population limits researchers' ability to collect nationally representative data on these students' achievement and other outcomes. A growing number of families choose to homeschool their children, and many states are drafting and implementing regulations for homeschooling (Belfield 2004; Lines 2003; Lips and Feinberg 2008). Thus far, however, no national data allow researchers to examine homeschooled students' involvement with mathematics and science courses or to compare their achievement with that of students who attend public or private schools (Lips and Feinberg 2008).

Table 1-2

Average mathematics scores of students followed from kindergarten through grade 8, by student characteristics: Fall 1998–spring 2007

Student characteristic	Fall 1998, kindergarten	Spring 2000, grade 1	Spring 2002, grade 3	Spring 2004, grade 5	Spring 2007, grade 8
All students	26	62	99	123	139
Kindergarten mathematics score					
Lowest quartile	17	46	78	101	120
Middle two quartiles	25	61	98	123	140
Highest quartile	38	79	123	144	157
Race/ethnicity					
White	29	66	106	129	145
Black	22	52	84	105	123
Hispanic	22	56	92	118	135
Asian	30	65	105	133	148
Mother's education in 1998					
Less than high school	20	51	82	106	123
High school diploma	24	58	93	116	133
Some college	26	63	101	125	142
Bachelor's or higher degree	32	72	114	138	154

NOTES: Mathematics assessment scale ranged from 0 to 174 across all grades. For simplicity, students in Early Childhood Longitudinal Study followups referred to by modal and expected grade, e.g., first graders in spring 2000 assessment. Total row includes other race/ethnicity, not shown separately.

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K), fall 1998 and spring 2000, 2002, 2004, and 2007; and National Science Foundation, Division of Science Resources Statistics. See appendix table 1-1.

Science and Engineering Indicators 2010

whose mothers had no high school diploma versus a bachelor's or advanced degree was 12 points (20 versus 32) (figure 1-1; table 1-2). This initial gap in kindergarten grew to 32 points in third grade and then remained at about that level. In grade 8, children whose mothers had not finished high school reached a score of 123, roughly equivalent to the score in grade 5 of those whose mothers had some college.

In another example, white children scored 29 on the test given in the fall of their kindergarten year and Asians scored 30, compared with 22 for both black and Hispanic children. The gaps between white and black students and Hispanic and Asian students reached a certain point and then stabilized after grade 3.

Gaps based on a few characteristics narrowed a little in later grades: English proficiency in kindergarten, primary language spoken at home, and the white–Hispanic gap. See appendix table 1-2 for score gains by various grade ranges.

Proficiency in Different Skill Areas. The ECLS-K test data also indicate whether students were proficient in nine mathematics skill areas. (The skills are arranged in a hierarchy such that proficiency in a given area presumes proficiency in the areas below it. See sidebar "Mathematics Skills Areas Assessed" for definitions.) By eighth grade, nearly all students were proficient in ordinality and sequence, addition and subtraction, and multiplication and division (appendix table 1-3). Large majorities of eighth graders were also proficient in place value and rate and measurement (89% and 66%, respectively), which they had studied for several years. Only 37% of eighth graders overall were proficient in working with fractions, however, a skill area that the National Mathematics Advisory Panel (2008) argues is essential for understanding even a first algebra course. Many states and districts are debating (and some now require) that all eighth graders take algebra (Loveless 2008).

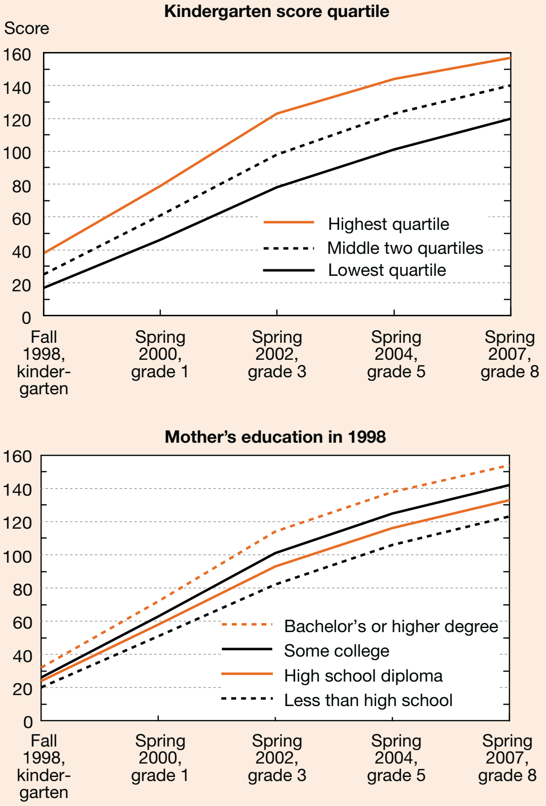
Substantial differences among groups appeared in the three highest skill areas—rate and measurement, fractions, and area and volume—and differences grew as the difficulty level increased. For example, 63% of students whose mothers had a bachelor's degree were proficient in fractions, compared with 16% of students whose mothers had not completed high school (figure 1-2). The same pattern was found for proficiency in rate and measurement and area and volume.

Differences by initial math skills in kindergarten were also considerable for the *highest* skill area in which students had reached proficiency by eighth grade (table 1-3; appendix table 1-4). Kindergarten low achievers were far more likely than others to demonstrate no more than low-level skills. For example, 21% of low achievers' highest skill was multiplication and division, versus 0% for high achievers. Also, 39% percent of low achievers did not progress beyond proficiency with place value, compared with 7% of high achievers.

Some early low achievers in kindergarten did reach proficiency in high skill areas, however: 24% achieved proficiency with rate and measurement, 7% with fractions, and 2% with area and volume, the highest skill area assessed. Thus, although most initial low-scoring students progressed relatively slowly, some managed to overcome obstacles they had at school entry.

High mathematics scores in kindergarten were also strong predictors of proficiency with higher-level mathematical concepts in eighth grade. By grade 8, 37% of those who

Figure 1-1
Mathematics achievement scores of kindergartners followed through grade 8, by kindergarten mathematics score quartile and mother's education: Fall 1998–spring 2007


Kindergarten score quartile

Mother's education in 1998

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99, fall 1998, and spring 2000, 2002, 2004, and 2007; and National Science Foundation, Division of Science Resources Statistics. See appendix table 1-1.

Science and Engineering Indicators 2010

Mathematics Skills Areas Assessed

ECLS-K measures student proficiency at nine specific mathematics skill levels. These skill levels, which were identified based on frameworks from other national assessments and advice from a panel of education experts, represent a progression of mathematics skills and knowledge. Levels 6, 7, and 8 were first assessed in third grade, and level 9 was first assessed in fifth grade. By the fifth grade, levels 1 through 4 were not assessed. Each level is labeled by the most sophisticated skill in the set (Princiotta, Flanagan, and Germino Hausken 2006; West, Denton, and Reaney L 2000):

- *Level 1, Number and shape:* Recognize single-digit numbers and shapes.
- *Level 2, Relative size:* Count beyond 10, recognize the sequence in basic patterns, and compare the relative size and dimensional relationship of objects.
- *Level 3, Ordinality and sequence:* Recognize two-digit numbers, identify the next number in a sequence, identify the ordinal position of an object, and solve simple word problems.
- *Level 4, Add and subtract:* Solve simple addition and subtraction items and identify relationships of numbers in sequence.
- *Level 5, Multiply and divide:* Perform basic multiplication and division and recognize more complex number patterns.
- *Level 6, Place value:* Demonstrate understanding of place value in integers to the hundreds place.
- *Level 7, Rate and measurement:* Use knowledge of measurement and rate to solve word problems.
- *Level 8, Fractions:* Solve problems using fractions.
- *Level 9, Area and volume:* Solve problems using area and volume.

scored in the highest quartile in kindergarten had achieved proficiency in all of the skill areas shown in table 1-3, and another 33% had progressed to proficiency with fractions, the second highest skill level measured.

Gains in Science Test Scores and Gap Changes. ECLS-K science assessments were given in grades 3, 5, and 8 and, as with mathematics, were measured on a single scale, in this case from 0 to 111. The average science score in grade 3 was 51 points, increasing to 83 by grade 8. In general, growth patterns were similar to those found with mathematics over these higher grades: few changes in gap size, and those changes that did occur were minimal (appendix table 1-5). Exceptions included some racial/ethnic differences. White students had the highest science scores in third and fifth grades, at 56 and 70, respectively, but by eighth grade Asians had closed that gap, with both groups scoring 88–89. English language learners (assessed in kindergarten) demonstrated another exception: they were 20 points behind English-proficient students on the third grade science assessment but only 15 points behind in eighth grade.

Trends in Mathematics and Science Performance in Grades 4 and 8 Through 2007

NAEP includes two assessment programs. The *national* (or *main*) NAEP assesses national samples of 4th and 8th grade students at regular intervals and 12th grade students occasionally. These assessments are updated periodically to reflect contemporary standards of what students should know and be able to do in various subjects, including science and mathematics. Student achievement measured by NAEP is documented in an ongoing series of reports, The Nation's

Report Card, that first began in 1969. A second testing program, the NAEP *Long-Term Trend* (LTT), is based on nationally representative samples of 9-, 13-, and 17-year-olds. The mathematics content framework for NAEP LTT has remained the same since it was first given in 1973, permitting analyses of trends over more than three decades.

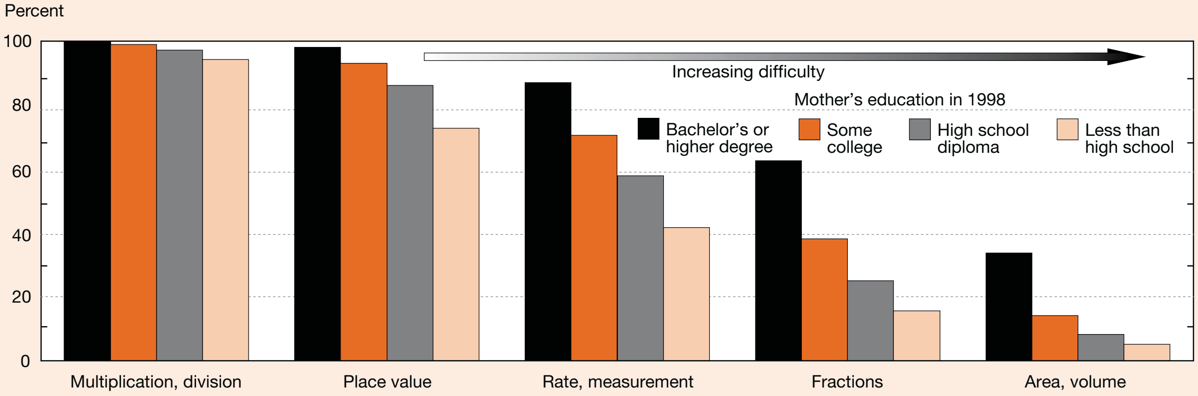
This section briefly summarizes NAEP science trends—reported in detail in *Science and Engineering Indicators 2008* (NSB 2008) and then focuses on the new mathematics score data for fourth and eighth graders in 2007 and on trends in these scores from 1990 to 2007. New data are neither available for 12th grade mathematics nor for science in any grade.[3] The NAEP LTT scores in mathematics are also updated through 2008, for three age groups.

NAEP rates students' performance in two ways: average scale scores and the percentage reaching various achievement levels. Scale scores place students along a continuous scale based on their overall performance on the assessment. A single mathematics scale of 0 to 500 points covers both grades 4 and 8. See sidebar "Development and Content of NAEP Mathematics Assessments" for further information on the assessments' content and design. The NAEP website has a searchable database of released NAEP test items (http://nces.ed.gov/nationsreportcard/itmrls).

Science Performance. No new NAEP science data are available for any grade; a science assessment was conducted in early 2009 and data will be available in early 2010, too late for inclusion in this volume. As reported in *Science and Engineering Indicators 2008* (NSB 2008), average NAEP science scores increased for 4th graders, held steady for 8th graders, and declined for 12th graders between

Figure 1-2

Eighth graders proficient in various mathematics skill areas, by mother's education: Spring 2007



NOTE: Skill areas are hierarchical and structured so proficiency in given area assumes proficiency in all lower areas.

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99, spring 2007; and National Science Foundation, Division of Science Resources Statistics. See appendix table 1-3.

Science and Engineering Indicators 2010

Table 1-3

Highest mathematics skill area in which fall 1998 kindergarteners demonstrated proficiency in grade 8, by student characteristics: Spring 2007

(Percent distribution)

Student characteristic	Ordinality, sequence	Addition, subtraction	Multiplication, division	Place value	Rate, measurement	Fractions	Area, volume
All students	1	2	8	24	30	20	15
Kindergarten mathematics score							
Lowest quartile	2	5	21	39	24	7	2
Middle two quartiles	0	1	6	26	37	21	10
Highest quartile	0	0	0	7	23	33	37

NOTES: Percentages may not add to 100% because of rounding. Two lowest skill areas omitted.

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998-99 (ECLS-K), fall 1998 and spring 2007; and National Science Foundation, Division of Science Resources Statistics. See appendix table 1-4.

Science and Engineering Indicators 2010

Development and Content of NAEP Mathematics Assessments

The National Assessment of Educational Progress (NAEP) assessments use frameworks developed by educators, policymakers, assessment and curriculum experts, and skilled practitioners (e.g., mathematicians) in a consensus-oriented process. Frameworks define what students should know at a given grade level and provide a blueprint for the assessment (Lee, Grigg, and Dion 2007). Once developed, the frameworks are reviewed and approved by the National Assessment Governing Board (NAGB). NAGB then defines three performance levels for each grade. The *basic* level indicates partial mastery of material appropriate for the grade level, *proficient* indicates solid academic performance, and *advanced* indicates superior performance. (Students in the basic category have scores at or above the minimum score for basic but lower than the minimum for proficient.) For more detailed definitions of the NAEP proficiency levels, see *Science and Engineering Indicators 2006*, pp. 1-13 and 1-14 (NSB 2006).

Although experts have approved the NAEP tests as measuring achievement with sufficient accuracy (for example, see Daro et al. 2007), some have disagreed about whether the NAEP proficiency levels are appropriately defined. The National Mathematics Advisory Panel concluded in its 2008 study, “On the basis of international performance data, there are indications that the NAEP cut scores for the two highest performance categories [the *proficient* and *advanced* levels] are set too high” (NMP 2008). An earlier study commissioned by the National Academy of Sciences concluded that the process used to set these levels was “fundamentally flawed” (Pellegrino, Jones, and Mitchell 1999). NAGB acknowledges the controversy surrounding the proficiency levels (Bourque and Byrd 2000) and warns data users to interpret findings related to these levels with caution (NCES 2006b). Some of the disagreement may stem from different understandings of the word *proficient*, as well as differing expectations about what students should be able to do at particular grade levels. (Mandated statewide achievement tests reflect a range of these expectations; see sidebar “NAEP Contrasted With State Achievement Tests” for more information.)

NAEP Contrasted With State Achievement Tests

Provisions in the No Child Left Behind (NCLB) Act require states to test students annually in mathematics, science, and English in grades 3–8 and once in high school. These test results, in particular the percentage of students reaching the *proficient* level, must be reported to the U.S. Department of Education, and schools must show adequate gains every year toward the goal of 100% of students reaching *proficient*. However, states are free to create their own tests and set the minimum score for *proficient* wherever they want. The incentives of these accountability systems may push policymakers to use easy tests, set the minimum *proficient* score low, or both (Cronin et al. 2007; Peterson and Hess 2008; Loveless 2006). The requirement for steady improvement encourages making the tests easier to pass over time, thus boosting apparent achievement. State standards vary widely in difficulty, content coverage, and the minimum scores set for reaching *proficient*. This variation has prevented making valid comparisons of student achievement across states using state test scores.

To address this problem, a recent study converted the *proficient* cutoff scores that states set for their own fourth and eighth grade mathematics tests to the 2005 National Assessment of Educational Progress (NAEP) scale (NCES 2007b). For example, for a state that rated 75% of its students proficient on the state’s test, researchers assigned that state’s “NAEP-equivalent score” as the NAEP score at the 75th percentile on NAEP’s test for the same subject and grade level. After converting score data from all available states to this NAEP metric, the study found that, in most states, students who reached the *proficient* level on state tests had reached NAEP’s *basic* level, and many states’ average scores were *below basic*. In addition, the range of states’ proficiency standards was 55 NAEP score points at grade 4 and 81 at grade 8. To put those ranges in context, they are roughly two to three times the difference between black and white students’ scores on recent NAEP mathematics assessments.

To document progress in achievement for NCLB, a federal regulation issued in late 2008 (Title I—Improving the Academic Achievement of the Disadvantaged, Final Rule (73 Fed. Reg. 64435 [2008]) adds another requirement: states must report their students’ NAEP test scores along with state test results for the same grade and subject. These data will provide information for observers interested in state-by-state comparisons as well as the overall range of achievement across states.

1996 and 2005 (NCES 2006a). Rising scores among lower-performing and average fourth graders were the primary drivers of the increase. The proportion of students reaching the *proficient* level for their grade in science held steady at grades 4 and 8, and declined a bit at grade 12. Proficiency rates were lower among 12th graders than among students in the lower grades.

Mathematics Performance of Fourth and Eighth Graders. The upward achievement trends that occurred through 2005 on the NAEP fourth and eighth grade mathematics tests continued with the 2007 tests. Between 1990 and 2007, the average mathematics score for fourth graders rose from 213 to 240, and for eighth graders from 263 to 281 (appendix table 1-6).

At both grade levels, students' scores increased in each of the five content areas tested (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions) (Lee, Grigg, and Dion 2007). Performance also improved across the achievement distribution in both grades, with scores at five selected percentiles of the score distribution (10th, 25th, 50th, 75th, and 90th) all increasing consistently over these years (figure 1-3; appendix table 1-6). The scores of low-achieving fourth graders rose faster than the scores of others, reducing the gaps with high achievers (Lee, Grigg, and Dion 2007).

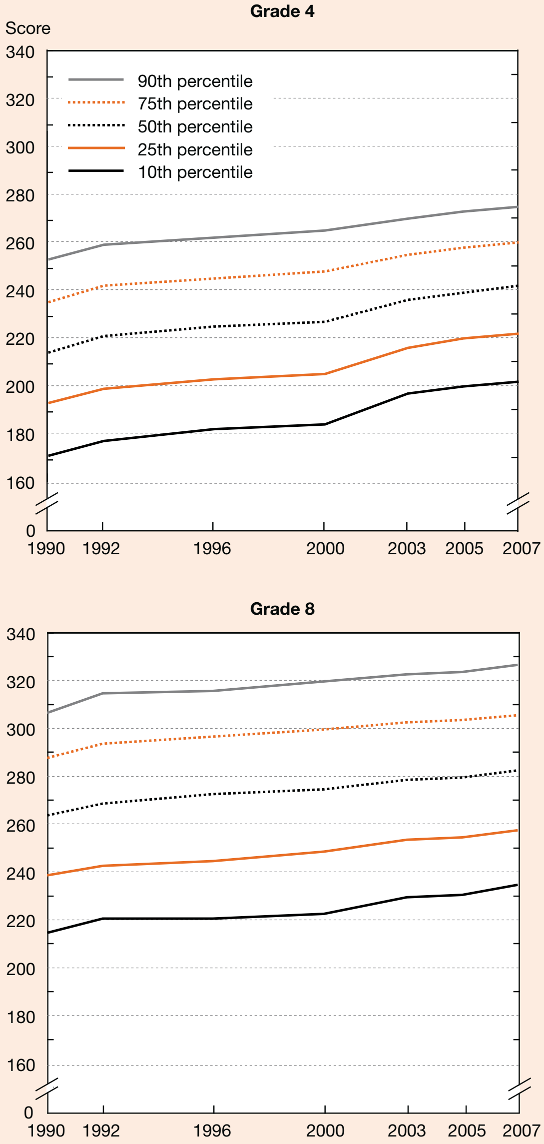
Achievement trends for nearly all demographic groups reflected the same upward movement (table 1-4). In grades 4 and 8, both boys and girls increased their scores between 1990 and 2007. Students in both grades increased their scores between 2000 and 2007, regardless of whether they were eligible for the subsidized lunch program, an indicator of poverty.

The scores of fourth graders in each racial/ethnic group with 1990–2007 data available rose consistently over those 17 years. Black fourth graders had the largest score increase, at 34 points (figure 1-4; appendix table 1-6). Similarly, white, black, and Hispanic eighth graders scored consistently higher in mathematics. Asians/Pacific Islanders' performance remained level after 2005, and American Indians/Alaska Natives showed no change between 2000 (the first year with data available) and 2007.

NAEP 2009 results, released as this volume was going to press, show that the upward trend in fourth grade mathematics scores has halted, that mathematics scores of eighth graders have continued to improve, and that score gaps among racial/ethnic groups are unchanged (NCES 2009a).

Gaps in Mathematics Performance. In most years, boys had marginally higher mathematics scores than girls, and these gaps remained about equal over the 17-year period (appendix table 1-6) (Lee, Grigg, and Dion 2007). Among fourth graders, boys performed better than girls in four of the five mathematics content areas in 2007; girls scored higher only in geometry/spatial sense. Among eighth graders, boys

Figure 1-3
NAEP mathematics scores of students in grades 4 and 8 at various percentiles: 1990–2007



NAEP = National Assessment of Educational Progress

NOTES: Scores on a 0–500 scale across grades 4 and 8. Accommodations for disabilities or limited English proficiency permitted only in the 1996 and later assessments.

SOURCE: Lee J, Grigg WS, Dion GS, The Nation's Report Card: Mathematics 2007, NCES 2007-494 (2007). See appendix table 1-6.

Science and Engineering Indicators 2010

scored higher in three of five content areas—number properties and operations, measurement, and algebra—while girls scored higher in one area—data analysis and probability. In geometry/spatial sense, boys and girls did not differ in performance.

Most gaps among racial/ethnic groups that existed in 1990 remained in 2007, but some have narrowed, especially in recent years. The average score gap between white and black fourth graders decreased from 32 to 26 scale points between 1990 and 2007. Among eighth graders, the gap increased from 1990 to 2000 but then decreased from 2000 to 2007. Similarly, the gaps between white and Hispanic students in both grades narrowed from 2000 to 2007.

Score gaps related to family income, as indicated by student eligibility for subsidized lunches, also shrank between 1996 (the first year available) and 2007, as well as between 2000 and 2007 for fourth graders. For eighth graders, the gap between low-income and other students was about the same in 1996 and 2007, with some fluctuations in between. It showed a decrease from 2000 to 2007.

Achievement is also measured in a different way from the scale scores discussed above: the percentages of students scoring at or above the *basic* and *proficient* levels and reaching the *advanced* proficiency level set by the NAEP governing board. Students also improved steadily from 1990 to 2007 on this measure (figure 1-5; appendix table 1-7), with one exception: fourth graders in 2007 showed no change from 2005 in the percentage reaching the *advanced* level (Lee, Grigg, and Dion 2007).

Long-Term Trends in Mathematics Performance. The NAEP Long-Term Trend assessment program has tested students ages 9, 13, and 17 in mathematics for more than three decades. LTT assessments differ from the main NAEP assessment, whose frameworks and tests are revised over time to follow changes in common curriculum at targeted grade levels, in that the LTT assessment for each grade level has tested the same knowledge and skills over time.[4]

Since this testing program began, 9- and 13-year-olds raised their scores, while 17-year-olds' scores were essentially flat, with no difference between the first test score (304) in 1973 and the most recent (306) in 2008 (appendix table 1-8) (Rampey, Dion, and Donahue 2009). Among 9-year-olds, the average score increased 24 points, to 243 in 2008; among 13-year-olds, scores increased 15 points, to 281. The periods of achievement growth differed as well,

Table 1-4

Changes in NAEP mathematics scores of students in grades 4 and 8, by student characteristics and other measures: 1990–2007 and 2000–07

	Grade 4		Grade 8	
Student characteristic	1990–2007	2000–07	1990–2007	2000–07
All students	↑	↑	↑	↑
Sex				
Male	↑	↑	↑	↑
Female	↑	↑	↑	↑
Race/ethnicity				
White	↑	↑	↑	↑
Black	↑	↑	↑	↑
Hispanic	↑	↑	↑	↑
Asian/Pacific Islander[a]	↑	NA	↑	↑
American Indian/Alaska Native[a]	NA	↑	NA	≈
Free/reduced-price lunch[b]				
Eligible	↑	↑	↑	↑
Not eligible	↑	↑	↑	↑
Changes in score gaps				
Gender gap	≈	≈	≈	≈
White-black gap	↓	↓	≈	↓
White-Hispanic gap	≈	↓	≈	↓
Low-income family vs. other family gap[b]	↓	↓	≈	↓

↑ = increase; ≈ = no change; ↓ = decrease; NA = not available

NAEP = National Assessment of Educational Progress

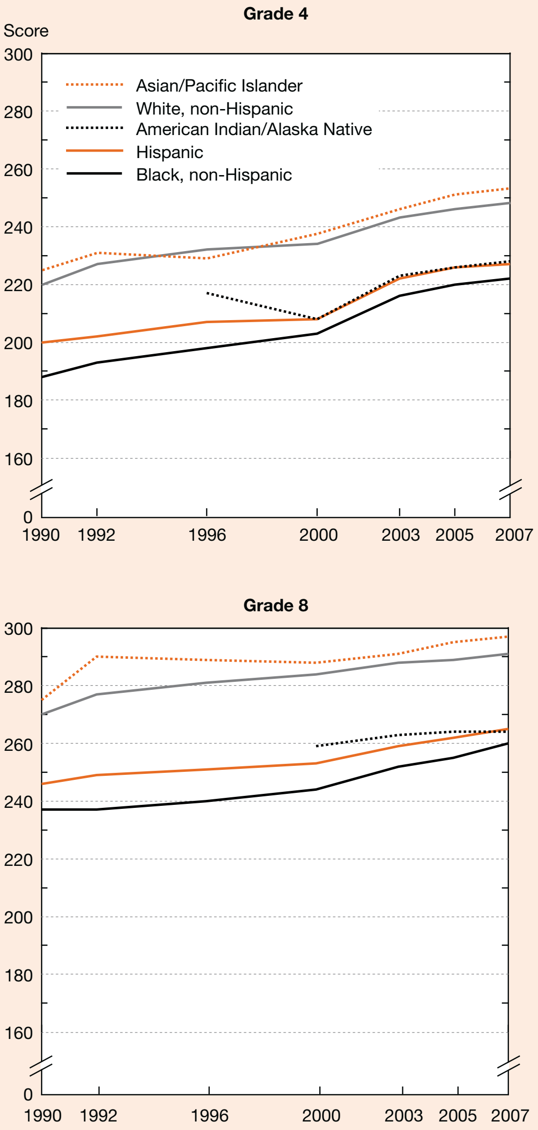
[a] Data for grade 4 Asians/Pacific Islanders in 2000 omitted because of concerns about estimates' accuracy. Insufficient sample size in 1990 American Indians/Alaska Natives (in both grades) precluded calculation of reliable estimates.

[b] Information on student eligibility for subsidized lunch program, a measure of family poverty, first collected in 1996; comparisons in 1990–2007 columns cover 1996 to 2007.

SOURCES: Lee J, Grigg W, Dion G, The Nation's Report Card: Mathematics 2007, NCES 2007-494 (2007); and NAEP 1990, 1996, 2000, and 2007 mathematics assessments. See appendix table 1-6.

Science and Engineering Indicators 2010

Figure 1-4
Average NAEP mathematics score of students in grades 4 and 8, by race/ethnicity: 1990–2007



NAEP = National Assessment of Educational Progress

NOTES: Scores on a 0–500 scale across grades 4 and 8. Accommodations for disabilities or limited English proficiency permitted only in the 1996 and later assessments. Average scores for Asians in 2000 (grade 4) and 1996 (grade 8) extrapolated.

SOURCE: Lee J, Grigg WS, Dion GS, The Nation's Report Card: Mathematics 2007, NCES 2007-494 (2007). See appendix table 1-6.

Science and Engineering Indicators 2010

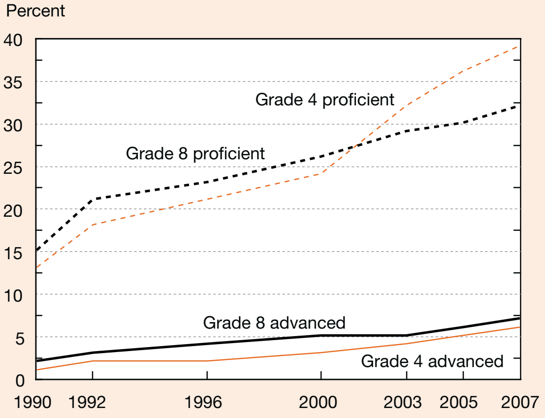
with 9-year-olds making larger gains during the 1980s and after 1999, and 13-year-olds increasing steadily since 1990.

In each age group, black students gained more points than white students over the earlier part of the period, narrowing the gaps with whites. The gap between blacks and whites for 9-year-olds narrowed from 35 points in 1973 to 26 in 2008. For 13-year-olds, the gap decreased substantially, from 46 to 28 points. For both of the younger age groups, this narrowing occurred mainly through 1986; after that, both racial groups increased their scores at roughly similar rates. Among 17-year-olds, the 1973 gap between blacks and whites of 40 points decreased to 26 points in 2008, with the smallest gap appearing in 1990.

Hispanic students at all three ages gained more points over time than did whites on the mathematics assessments, particularly 13- and 17-year-olds. The score gaps with their white peers thus appeared to decrease, but none of those changes was significant, in part due to relatively small Hispanic sample sizes in some years.

Parents' educational attainment, a measure of socioeconomic status, was collected from 13- and 17-year-olds. At all levels of parental education, 13-year-olds' achievement increased over the 35 years, while 17-year-olds' performance improved only among students whose parents had not finished high school.

Figure 1-5
Students meeting various NAEP proficiency levels in mathematics, grades 4 and 8: 1990–2007



NOTE: Proficient includes advanced.

SOURCE: Lee J, Grigg WS, Dion GS, The Nation's Report Card: Mathematics 2007, NCES 2007-494 (2007).

Science and Engineering Indicators 2010

Students' Performance on International Assessments of Mathematics and Science

Two recent assessments place U.S. student achievement in mathematics and science in an international context: the Trends in International Mathematics and Science Study and the Program for International Student Assessment. TIMSS and PISA differ in several fundamental ways; see sidebar "Differences Between TIMSS and PISA Assessments." Reports on TIMSS and PISA test results typically compare U.S. performance with that of all participating countries or with that of all members of the Group of Eight (G-8) or Organisation for Economic Co-operation and Development (OECD) (Gonzales et al. 2008; Miller et al. 2009; Gonzales et al. 2004; Baldi et al. 2007). The differences in the characteristics of countries that participate in these two studies, however, confound comparisons between the United States' relative standing on the two assessments.

This section compares U.S. performance to that of a subset of nations that either have advanced economies that compete globally in fields related to science, technology, engineering, and mathematics (STEM) or have developing economies with rapidly growing capabilities in these areas. Most of the selected countries were included because of their current capabilities in science and technology. A few Asian countries that are seeking to develop such capacity were also included to highlight student performance in these highly dynamic countries. (This geographic focus is maintained where possible in the international sections of other chapters.) Not all of the 28 selected nations participated in each assessment, so the number available for comparison with the United States differs by test. Scores for all participating nations are shown in appendix tables.

Results from the two assessments are contradictory: U.S. average scores on TIMSS tend to place the United States around the middle of the group of selected nations, and in mathematics, the United States improved over time. In contrast, U.S. scores on PISA were generally near the bottom of the group, and the U.S. standing relative to other nations declined in both mathematics and science. Some of these performance differences may be explained by the differences in the tests and which countries participate (see sidebars "Differences Between TIMSS and PISA Assessments" and "Sample Items From TIMSS and PISA Assessments").

Differences Between TIMSS and PISA Assessments

Several primary differences in the design and purpose of these two assessments likely contribute to the differing U.S. results: age of students tested, test content, and participating nations.

First, the Trends in International Mathematics and Science Study (TIMSS) tests the mathematics and science achievement of students in grades 4 and 8, regardless of their age. The Program for International Student Assessment (PISA) assesses the performance of secondary school students by sampling 15-year-olds, who are nearing the age when compulsory schooling ends in many countries. The divergent international results shown here are consistent with differences by age in the main National Assessment of Educational Progress (NAEP) results: U.S. 12th graders have generally shown flat or even declining achievement over time, whereas younger students, particularly 4th graders, have demonstrated steadily rising scores (NSB 2008). Similar patterns from the NAEP Long-Term Trend assessment are described in "Long-Term Trends in Mathematics Performance."

A second difference between TIMSS and PISA is how closely they adhere to the mathematics and science curriculums used for instruction in various countries. TIMSS focuses on application of familiar skills and knowledge emphasized often in classrooms. (Content experts and teachers from various countries select elements of curriculums common to most participating nations.) The PISA tests, in contrast, emphasize students' abilities to apply skills and information learned in school (or from life experiences) to solve problems or make decisions they may face at work or other circumstances. PISA test questions tend to deemphasize factual recall and demand more complex reasoning and problem-solving skills than those in TIMSS (Neidorf et al. 2006; Loveless 2009), requiring students to apply logic, synthesize information, and communicate solutions clearly. Curriculums and teaching methods may vary in their emphasis on these skills. (See sidebar "Sample Items From TIMSS and PISA Assessments" for examples of science test questions included on the two assessments.)

A third main difference between the two assessments is the number of participating countries and their levels of economic development. Countries participating in TIMSS form a large and diverse group: some highly industrialized nations and many developing ones, the latter of which have been growing in number over time. In contrast, nearly all countries that participated in PISA were members of OECD and thus are economically advanced nations. The international comparisons here were limited to nations that are current or likely potential competitors with the United States in scientific and technical fields, however. This restriction increased the overlap between nations taking both tests and excluded nearly all developing nations from these analyses. Restricting to this group of selected nations prevents the increasing number of developing countries from artificially inflating the United States' standing relative to other nations over time, particularly in TIMSS.

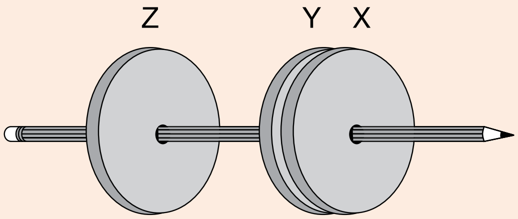
Sample Items from TIMSS and PISA Assessments

Sample Science Items from Trends in International Mathematics and Science Study (TIMSS) Tests (for Eighth Graders)

1) Food and oxygen are produced during photosynthesis in green plants. Chlorophyll is one thing that is needed for photosynthesis. Name two more factors that are needed for photosynthesis.

Correct answer: Sunlight and carbon dioxide.

Difficulty level: High international benchmark (550)



2a) The diagram shows what happens to three magnets when they are placed close together on a pencil. Magnets X and Y move until they touch each other, but magnets Y and Z remain separated. Explain why magnets X and Y touch each other.

Correct Answer: Because north and south poles were facing each other.

2b) Explain why magnets Y and Z remain separated.

Correct answer: Because they may have had south and south or north and north facing each other.

Difficulty level: Advanced international benchmark (625)

Additional sample questions: http://timss.bc.edu/TIMSS2007/items.html.

Sample Science Items from Program for International Student Assessment (PISA) Tests (for 15-Year-Olds)

1) Statues called Caryatids were built on the Acropolis in Athens more than 2,500 years ago. The statues are made of a type of rock called marble. Marble is composed of calcium carbonate. In 1980, the original statues were transferred inside the museum of the Acropolis and were replaced by replicas. The original statues were being eaten away by acid rain.

1a) Normal rain is slightly acidic because it has absorbed some carbon dioxide from the air. Acid rain is more acidic than normal rain because it has absorbed gases like sulfur oxides and nitrogen oxides as well. Where do these sulfur oxides and nitrogen oxides in the air come from?

Correct answer: For full credit, students needed to include one or more major sources: car exhausts, factory emissions, burning fossil fuels such as oil and coal, gases from volcanoes, or "burning of materials that contain sulphur and nitrogen." Answers that mention one actual source and one incorrect source (such as nuclear power plants) received only partial credit.

Difficulty level: 506

1b) The effect of acid rain on marble can be modeled by placing chips of marble in vinegar overnight. Vinegar and acid rain have about the same acidity level. When a marble chip is placed in vinegar, bubbles of gas form. The mass of the dry marble chip can be found before and after the experiment. A marble chip has a mass of 2.0 grams before being immersed in vinegar overnight. The chip is removed and dried the next day.

What will the mass of the dried marble chip be?

A. Less than 2.0 grams
B. Exactly 2.0 grams
C. Between 2.0 and 2.4 grams
D. More than 2.4 grams

Correct answer: A

Difficulty level: 460

1c) Students who did this experiment also placed marble chips in pure (distilled) water overnight. Explain why the students included this step in their experiment.

Correct Answer: For full credit, students needed to explain that the acid in vinegar dissolves some of the marble just like acid in acid rain does, and that distilled water does not dissolve marble because it's much less acidic (the water test is a control).

Difficulty level: 717 for full-credit answers, 513 for partial credit

Additional sample questions: http://www.pisa.oecd.org/dataoecd/13/33/38709385.pdf (for science) and http://www.oecd.org/dataoecd/14/10/38709418.pdf (for mathematics).

Sources: Gonzales et al. 2008; OECD 2007.

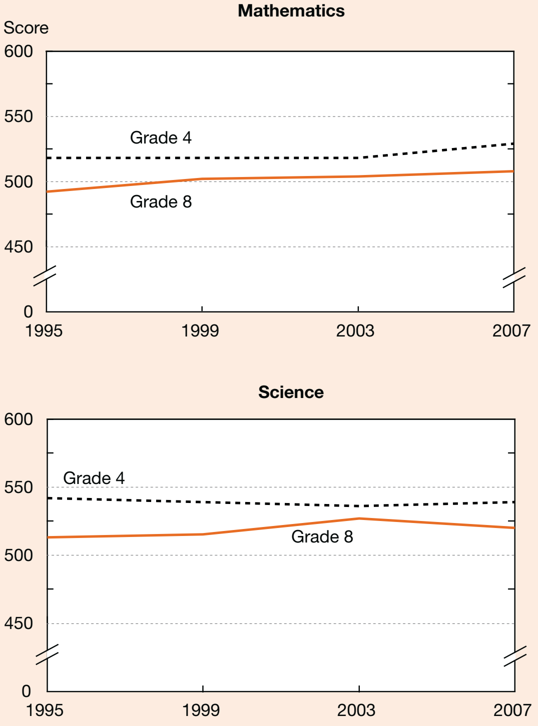
Mathematics Performance of U.S. Fourth and Eighth Graders on TIMSS

The fourth grade TIMSS mathematics exam covers three content areas: number, geometric shapes and measures, and data display. The eighth grade assessment addresses four content domains: number, algebra, geometry, and data and chance.

Performance Trends. Over the 12 years since the first TIMSS mathematics assessments in 1995, U.S. fourth and eighth graders raised their scores and international ranking (Gonzales et al. 2008). The fourth grade average of 529 in 2007 was 11 points higher than in 1995. For eighth graders, the U.S. average of 508 in 2007 reflected a 16-point rise over 1995's score (figure 1-6). In addition, while the U.S. eighth grade score in 1995 was 8 points below the international scale average of 500, in 2007 it was 8 points above, at 508.

Not only did U.S. fourth graders' mathematics scores increase, but the U.S. position relative to selected other nations also shifted upward from 1995 to 2007. Of the selected nations whose fourth graders participated in both the 1995 and 2007 TIMSS, four outscored the United States in 1995, compared with three in 2007 (figure 1-7).[5] U.S. eighth graders also gained ground over time, outperforming no foreign

Figure 1-6
U.S. average TIMSS scores, by grade: 1995, 1999, 2003, and 2007

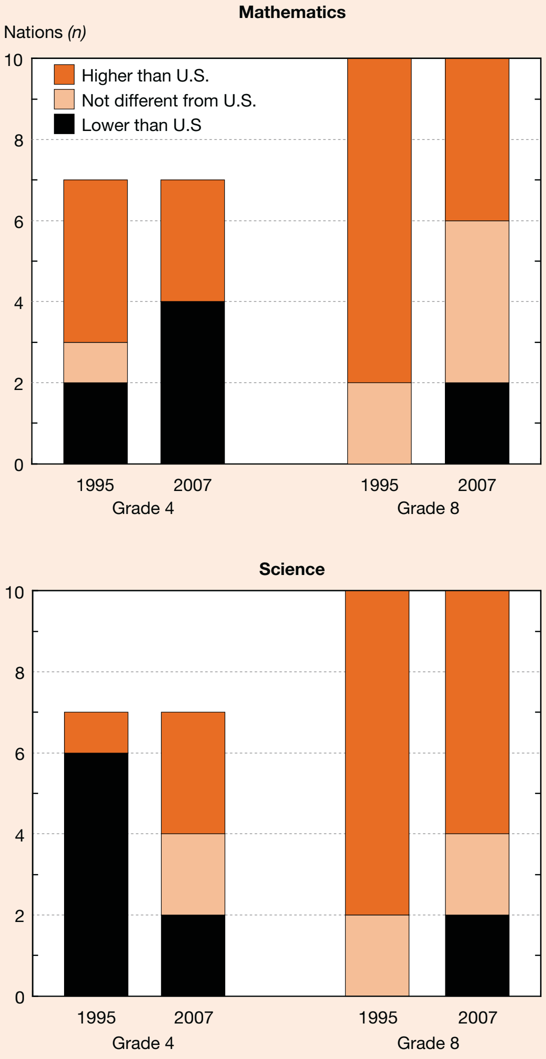


TIMSS = Trends in International Mathematics and Science Study

SOURCE: Gonzales P, Williams T, Jocelyn L, Roey S, Kastberg D, Brenwald S, Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context, NCES 2009-001 (2008).

Science and Engineering Indicators 2010

Figure 1-7
Changes in selected nations' performance on TIMSS assessments, relative to U.S. performance: 1995 and 2007



TIMSS = Trends in International Mathematics and Science Study

NOTES: All comparisons refer to number of selected nations scoring higher or lower than, or not statistically different from, the U.S. for same test (among those participating in both years). The selected countries for grade 4 include Czech Republic, England, Hong Kong SAR, Hungary, Japan, Norway, and Singapore. Selected countries for grade 8 include the grade 4 countries plus Korea, Russian Federation, and Sweden.

SOURCE: Gonzales P, Williams T, Jocelyn L, Roey S, Kastberg D, Brenwald S, Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context, NCES 2009-001 (2008).

Science and Engineering Indicators 2010

peers in 1995 but two in 2007. Students from eight of the selected nations outscored U.S. eighth graders in 1995, compared with four in 2007.

Performance on the 2007 TIMSS Mathematics Tests. The fourth grade tests focused on three content domains: number, geometric shapes and measures, and data display (about half the assessment emphasized the number domain, including introductory algebra). For eighth grade, the four content domains were number, algebra, geometry, and data and chance. The cognitive domains addressed in TIMSS are the same for both grades—knowing, applying, and reasoning.

U.S. fourth graders' average score on the 2007 TIMSS mathematics assessment (529) was just below the combined average for 14 selected nations (534) (table 1-5). (Results for all participating nations are available in appendix table 1-9.) When those 14 jurisdictions are compared with the United States, 6 scored higher, 6 scored lower, and 2 did not differ, placing the United States near the middle of the distribution. The top scorers—Hong Kong SAR, Singapore, Chinese Taipei, and Japan—each had average scores above 550.

The U.S. eighth grade average mathematics score of 508 was also below the combined average (514) for 16 selected nations and below 5 nations' individual averages (table 1-5). The United States scored higher than 7 nations, putting it just above the middle among these 16 nations. The average score of students in Chinese Taipei (the leader) was 90 points higher than U.S. eighth graders' average.

Although U.S. students as a whole did not lead the world in TIMSS mathematics, two U.S. states that participated individually (Massachusetts and Minnesota) provide examples of high performance (see sidebar "Two States' Performance on TIMSS: 2007"). Scores at the 90th percentile present another way to examine high-achieving students (those who scored higher than 90% of all test takers). In mathematics, the 90th percentile score for U.S. fourth graders was 625, lower than that of six other nations (table 1-6). U.S. fourth graders scored higher than six nations on this measure, and so were at the middle. Similarly, the 90th percentile score for U.S. eighth graders was 607, lower than the corresponding scores for six countries but higher than that of six others. For eighth graders, the 90th percentile score gap with top scorers Chinese Taipei and the Republic of Korea was more than 100 scale points.

Table 1-5

Average TIMSS mathematics scores of students in grades 4 and 8 in selected nations, relative to U.S. average: 2007

Nation	Grade 4	Nation	Grade 8
United States	529	United States	508
Score higher than U.S.		Score higher than U.S.	
Hong Kong SAR[a]	607	Chinese Taipei	598
Singapore	599	Republic of Korea	597
Chinese Taipei	576	Singapore	593
Japan	568	Hong Kong SAR[a]	572
Russian Federation	544	Japan	570
England	541		
		Score not statistically different from U.S.	
Score not statistically different from U.S.		Hungary	517
Germany	525	England	513
Denmark	523	Russian Federation	512
		Czech Republic	504
Score lower than U.S.			
Australia	516	Score lower than U.S.	
Hungary	510	Australia	496
Italy	507	Sweden	491
Sweden	503	Italy	480
Czech Republic	486	Malaysia	474
Norway	473	Norway	469
		Thailand	441
		Indonesia	397

TIMSS = Trends in International Mathematics and Science Study

[a] Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

NOTES: Scores on separate 0–1000 scales for each grade. Nations ordered by 2007 average score, within categories. A few nations did not meet TIMSS guidelines for sampling, participation rates, or related issues, and are omitted here. (They are included in appendix table 1-9, which lists all nations.) For details, see source report. Tests for significance take into account the standard error for the reported difference.

SOURCES: Gonzales P, Williams T, Jocelyn L, Roey S, Kastberg D, Brenwald S, Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context, NCES 2009–001 (2008), table 9; and International Association for the Evaluation of Educational Achievement data (2007). See appendix table 1-9.

Science and Engineering Indicators 2010

Two States' Performance on TIMSS: 2007

Massachusetts and Minnesota participated in a special benchmarking study included in the Trends in International Mathematics and Science Study (TIMSS) 2007, along with three Canadian provinces, the city of Dubai, and one region of Spain. Results for these entities were compared with those for all participating nations. These two states, particularly Massachusetts, are among the higher-scoring states on the National Assessment of Educational Progress (NAEP), and thus provide some insight into how some of the best students in the United States compare with their competitors in other nations.

In mathematics, Massachusetts fourth graders scored 572, far above the scale average of 500, and in third place after only two jurisdictions, Hong Kong and Singapore (Mullis et al. 2008). Massachusetts' average score was equivalent to scores in Chinese Taipei and Japan. Minnesota scored slightly lower (554), below only four Asian leaders and on par with Kazakhstan, England, and the Russian Federation. At grade 8, both U.S. states (at 547 and 532, respectively) scored below the five leading Asian nations but above all other participants, including European nations.

In fourth grade science, Massachusetts ranked second with its score of 571, after only Singapore (Martin et al. 2008). Minnesota also performed well (551), bested only by Massachusetts and Singapore and scoring on par with eight jurisdictions (including the United States overall) but above all the rest. Massachusetts eighth graders' science score (556) was similar to the four leading Asian economies' scores (Singapore, Chinese Taipei, Japan, and Republic of Korea) and higher than scores from all other participants. At grade 8, Minnesota (at 539) was outscored by the four top Asian countries but performed similarly to a group that included Hong Kong and several high-scoring European nations.

Table 1-6
TIMSS mathematics scores at the 90th percentile for students in grades 4 and 8, by selected nations: 2007

Nation	Grade 4	Nation	Grade 8
United States	625	United States	607
Score higher than U.S.		Score higher than U.S.	
Singapore	702	Chinese Taipei	721
Hong Kong SAR[a]	691	Republic of Korea	711
Chinese Taipei	663	Singapore	706
Japan	663	Hong Kong SAR[a]	681
Russian Federation	647	Japan	677
England	647	Hungary	624
Score not statistically different from U.S.		Score not statistically different from U.S.	
Australia	620	England	618
Hungary	620	Russian Federation	617
		Australia	600
Score lower than U.S.		Czech Republic	599
Denmark	611		
Germany	607	Score lower than U.S.	
Italy	601	Sweden	582
Sweden	586	Malaysia	578
Czech Republic	576	Italy	574
Norway	566	Thailand	562
		Norway	552
		Indonesia	509

TIMSS = Trends in International Mathematics and Science Study

[a] Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

NOTES: Scores on separate 0–1000 scales for each grade. Nations ordered by 2007 average score, within categories. A few nations did not meet TIMSS guidelines for sampling, participation rates, or related issues. (These nations are included in source report's table, which lists all nations.) For details, see source report. Tests for significance take into account the standard error for the reported difference. Score at the 90th percentile is score in each distribution that is greater than 90% of all scores.

SOURCES: Gonzales P, Williams T, Jocelyn L, Roey S, Kastberg D, Brenwald S, Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context, NCES 2009–001 (2008), table 9; and International Association for the Evaluation of Educational Achievement data (2007).

Science and Engineering Indicators 2010

Science Performance of U.S. Fourth and Eighth Graders: TIMSS

Performance Trends. In contrast to the mathematics trends, which showed improvement in both grades, the average scores of U.S. students on the TIMSS science assessment have remained flat since 1995. Fourth graders have lost ground internationally, whereas eighth graders slightly improved their position relative to other nations (Gonzales et al. 2008). At fourth grade, the United States outperformed six of seven selected nations in 1995 but only two of them in 2007. In addition, the single comparison nation that did better than the United States in 1995 (Japan) was joined by Singapore and Hong Kong in 2007.

The trend in U.S. standing of eighth graders was slightly upward: nations scoring higher than the United States on the science assessment dropped from eight in 1995 to six in 2007. In addition, the United States had not outperformed any of the 10 other nations in 1995 but outscored 2 of them in 2007 (Sweden and Norway).

Performance on the 2007 TIMSS Science Tests. The fourth grade science tests focused on three content areas: life, physical, and earth sciences; and on three main skills: knowing, applying, and reasoning. At eighth grade, content areas expanded to four: biology, chemistry, physics, and earth sciences. The cognitive domains underlying test development were the same for both grades: knowing, applying, and reasoning. The fourth grade tests emphasize knowing more than the eighth grade tests, while reasoning is a greater focus in eighth grade.

On the 2007 TIMSS science test for fourth graders, four of the comparison nations scored higher and six scored lower than the United States, putting the United States just above the middle of the group (table 1-7). (Results for all participating nations are presented in appendix table 1-10.) The four economies that outperformed the United States in fourth grade science also had the highest scores on most TIMSS tests: Singapore, Chinese Taipei, Hong Kong, and Japan. U.S. eighth graders' average science score of 520 was lower than that of eight nations, higher than that of six, and

Table 1-7

Average TIMSS science scores of students in grades 4 and 8 in selected nations, relative to U.S. average: 2007

Nation	Grade 4	Nation	Grade 8
United States	539	United States	520
Score higher than U.S.		Score higher than U.S.	
Singapore	587	Singapore	567
Chinese Taipei	557	Chinese Taipei	561
Hong Kong SAR[a]	554	Japan	554
Japan	548	Republic of Korea	553
		England	542
Score not statistically different from U.S.		Hungary	539
Russian Federation	546	Czech Republic	539
England	542	Russian Federation	530
Hungary	536		
Italy	535	Score not statistically different from U.S.	
		Hong Kong SAR[a]	530
Score lower than U.S.		Australia	515
Germany	528		
Australia	527	Score lower than U.S.	
Sweden	525	Sweden	511
Denmark	517	Italy	495
Czech Republic	515	Norway	487
Norway	477	Malaysia	471
		Thailand	471
		Indonesia	427

TIMSS = Trends in International Mathematics and Science Study

[a] Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

NOTES: Scores on separate 0–1000 scales for each grade. Nations ordered by 2007 average score, within categories. A few nations did not meet TIMSS guidelines for sampling, participation rates, or related issues. (They are included in appendix table 1-10, which lists all nations.) For details, see source report. Tests for significance take into account the standard error for the reported difference.

SOURCES: Gonzales P, Williams T, Jocelyn L, Roey S, Kastberg D, Brenwald S, Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context, NCES 2009–001 (2008), table 11; and International Association for the Evaluation of Educational Achievement data (2007). See appendix table 1-10.

Science and Engineering Indicators 2010

equivalent to the remaining two—in other words, slightly below the middle (table 1-7).

The U.S. 90th percentile score for fourth graders was 643, ranking lower than in 2 other nations and higher than in 8, or above the midpoint for these 15 nations (Gonzales et al. 2008). The difference between Singapore (whose fourth graders led all countries) and the United States at the 90th percentile was 58 points. In eighth grade, U.S. students at the 90th percentile in science scored roughly in the middle of the group—lower than in six other nations and higher than in five. See sidebar "Linking NAEP and TIMSS Results."

Mathematics Performance of U.S. 15-Year-Olds: PISA

Performance Trends. In contrast to the TIMSS results, U.S. 15-year-olds' performance consistently dropped on the PISA tests of mathematical and scientific literacy in relation to student performance in other nations. The U.S. mathematics average of 474 in 2006 is 19 points lower than in 2000, when the first PISA exams were given, but changes in the tests mean that the scores cannot be directly compared (OECD 2001; Baldi et al. 2007). While the United States scored below 7 nations in 2000, it scored below 15 nations in 2006 (of 19 nations with data available for both years).

Linking NAEP and TIMSS Results

To compare the performance of other countries' students with the achievement standards set for the National Assessment of Educational Progress (NAEP), a series of studies has used various statistical methods to project the results of one assessment into the scale of the other (Beaton and Gonzales 1993; Johnson and Siegendorf 1998; Johnson et al. 2005; Pashley and Phillips 1993). In the most recent of these studies (Phillips 2007), scores from the Trends in International Mathematics and Science Study (TIMSS) eighth grade mathematics and science assessments in 1999 and 2003 were translated into the 2000 NAEP eighth grade performance levels using data from a sample of students who participated in both the 1999 TIMSS and 2000 NAEP assessments.

NAEP results have long demonstrated that a minority of U.S. students reaches the *proficient* level of performance as defined in NAEP. The linked TIMSS data for both years were not only consistent with this finding in both mathematics and science, but showed that few countries' students met the standard for achievement set by NAEP's *proficient* criterion. In math, six countries had an average score that met this criterion in 1999, and five countries did so in 2003. In science, two countries' average scores fell within the *proficient* level in each year.

Performance on the 2006 PISA Mathematics Test. PISA assesses 15-year-old students in all OECD nations and a range of other nations every 3 years on literacy in mathematics, science, and reading. The mathematics test covers four content areas: space and shape, change and relationships, quantity, and uncertainty. A main mathematics skill tested is problem solving (explored in greatest depth in 2003, when math was PISA's main focus). Sjøberg (2007) and Goldstein (2004) discuss PISA's content, including challenges and critiques.

On the most recent PISA tests, the U.S. score was 474, below 18 of the selected nations' scores (table 1-8). Students in the United States demonstrated higher mathematical literacy than students in only four other countries (Italy, Thailand, Indonesia, and Brazil).

The U.S. score at the 90th percentile in mathematics was 593, lower than that in 18 other nations that participated in the PISA exam and higher than in another 3 nations (Thailand, Indonesia, and Brazil) (Baldi et al. 2007). None of the OECD member nations had a lower 90th percentile score than the United States.

Science Performance of U.S. 15-Year-Olds: PISA

Performance Trends. The U.S. rank among selected nations declined on the PISA scientific literacy test, as on the mathematics assessment. In 2000, the United States scored below 6 other selected nations (out of 19 participating in both years), but in 2006, that number doubled to 12 (figure 1-8).[6]

Performance on the 2006 PISA Science Test. To measure scientific literacy, PISA includes three skill areas: identifying and understanding scientific issues, explaining phenomena scientifically, and using scientific evidence. Students were tested on their grasp of essential scientific concepts and theories in four content areas: physical systems, living systems, earth and space systems, and technology systems. Test items probed whether students understood how scientists obtain evidence (scientific means of inquiry) and how scientists use data. The test scores range from 1 to 1,000, and the mean for the 2006 science test was set at 500. The score scale is divided into six distinct proficiency levels that measure competence in science concepts and reasoning; each proficiency level encompasses roughly 75 points (OECD 2007). To put score differences in context, the average gain from one grade to the next was 38 points, or roughly half a full proficiency level. (This one-grade gain was measured using data from nations with sufficient numbers of 15-year-olds in two consecutive grades.)

The science literacy performance of U.S. 15-year-olds in 2006 placed the United States below 15 of 24 other nations and above 4, far below the midpoint (table 1-8; all participating nations' results are available in appendix table 1-11). The U.S. score of 489 fell behind Finland's (the leading nation) by 74 points.

Table 1-8

Average PISA mathematics and science literacy scores of 15-year-old students in selected nations, relative to U.S. average: 2006

Nation	Mathematics	Nation	Science
United States[a]	474	United States[a]	489
Score higher than U.S.		Score higher than U.S.	
Chinese Taipei	549	Finland	563
Finland	548	Hong Kong SAR[b]	542
Hong Kong SAR[b]	547	Canada	534
Republic of Korea	547	Chinese Taipei	532
Netherlands	531	Japan	531
Switzerland	530	Australia	527
Canada	527	Netherlands	525
Japan	523	Republic of Korea	522
Australia	520	Germany	516
Denmark	513	United Kingdom	515
Czech Republic	510	Czech Republic	513
Germany	504	Switzerland	512
Sweden	502	Ireland	508
Ireland	501	Hungary	504
France	496	Sweden	503
United Kingdom	495		
Hungary	491	Score not statistically different from U.S.	
Norway	490	Denmark	496
		France	495
Score not statistically different from U.S.		Spain	488
Spain	480	Norway	487
Russian Federation	476	Russian Federation	479
Score lower than U.S.		Score lower than U.S.	
Italy	462	Italy	475
Thailand	417	Thailand	421
Indonesia	391	Indonesia	393
Brazil	370	Brazil	390

OECD = Organisation for Economic Co-operation and Development; PISA = Program for International Student Assessment

[a] Average score for United States may be misestimated by approximately 1 score point because of error in test booklet printing.

[b] Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

NOTES: Scores on 0–1000 scale. Nations ordered by 2006 average score, within categories.

SOURCES: Baldi S, Jin Y, Skemer M, Green PJ, Herget D, Highlights From PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context, National Center for Education Statistics (NCES), NCES 2008-016 (2007), tables 2 and 3; and 2006 data from OECD. See appendix table 1-11.

Science and Engineering Indicators 2010

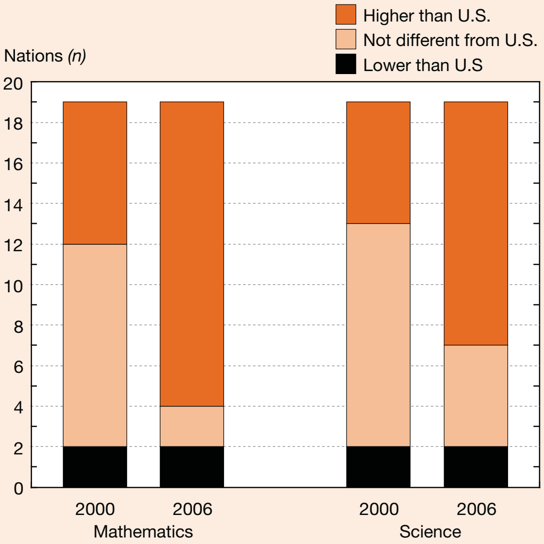
The U.S. 90th percentile score in scientific literacy was 628, below the corresponding score in 10 of the 24 nations with data, but above it in 9, putting U.S. top-scoring students just below the middle of the 90th percentile science score distribution for these selected nations. Thus, U.S. high achievers in science placed in a better position relative to other countries than did U.S. students on average.

Teachers of Mathematics and Science

Among the many factors that influence student learning, teacher quality is believed to be one of the most crucial. Studies have found that various aspects of teachers and teaching make a significant difference in student performance (Boyd et al. 2008; Clotfelter, Ladd, and Vigdor 2007; Croninger et al. 2003; Darling-Hammond et al. 2005; Goe 2008; Guarino et al. 2006; Hanushek et al. 2005; Harris and Sass 2007; Nye, Konstantopoulos, and Hedges 2004; Wayne and Youngs 2003; Xue and Meisels 2004). To ensure that all classrooms are led by teachers who are effective in promoting student learning, the federal No Child Left Behind Act (NCLB) of 2001 mandates that schools and districts hire only "highly qualified" teachers, defining "highly qualified" in terms of state certification (excluding emergency, provisional, or temporary licenses),[7] a minimum of a bachelor's degree, and demonstrated subject area competence.[8]

This section examines indicators of teacher preparedness, experience, professional development, salaries, and working conditions. The major data source used here is the Early Childhood Longitudinal Study, Kindergarten Class of

Figure 1-8
Changes in selected nations' performance on PISA assessments of 15-year-olds, relative to U.S. performance: 2000 and 2006



PISA = Program for International Student Assessment

NOTES: All comparisons refer to the number of selected nations scoring higher or lower than, or not statistically different from, the U.S. for the same test (among those participating in both years). The selected countries include Australia, Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Korea, Norway, Russian Federation, Spain, Sweden, Switzerland, and United Kingdom.

SOURCE: Baldi S, Jin Y, Skemer M, Green PJ, Herget D, Highlights From PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context, NCES 2008-016 (2007).

Science and Engineering Indicators 2010

1998–99.[9] This longitudinal study followed students from kindergarten through eighth grade and collected data from students' teachers and schools as well as from the students and their families. When the cohort was in grades 5 and 8 (in 2004 and 2007, respectively), ECLS-K collected data from their teachers in each of the core academic subjects (i.e., reading/language arts, mathematics, and science), allowing researchers to distinguish teachers who taught mathematics and science from all other teachers.[10] Because the teacher information in ECLS-K was linked to the sampled students, the data enable analysis of whether students from different backgrounds and with different levels of prior achievement had equal access to high-quality and experienced teachers in their fifth and eighth grade mathematics and science classrooms. When possible, comparable data from the 2008 edition of *Science and Engineering Indicators* are either cited or included as complementary information about teachers of mathematics and science at the middle school and high school levels.

Teacher Quality

Researchers have often relied on indicators such as test scores (e.g., Praxis; see Gitomer 2007), education credentials, professional certifications, and teaching experience as proxies for teacher quality (Darling-Hammond 2000; Wayne and Youngs 2003). These indicators are relatively easy to measure and can be readily used to screen prospective candidates. They also align with the requirements for highly qualified teachers specified in NCLB. The following analysis examines the quality of mathematics and science teachers by focusing on the educational attainment, certification status, subject area preparation, and years of teaching experience of those who taught mathematics and science in public schools to fifth graders in 2004 and eighth graders in 2007.

Teacher quality is not limited to the characteristics examined here, however; it may include other important elements that are difficult or costly to measure, such as teachers' abilities to motivate students, manage the classroom, maximize instruction time, and diagnose and overcome students' learning difficulties. Current research on "teacher quality" is designed to yield measurable characteristics of teachers that are associated with student learning (Angrist and Guryan 2008; Boyd et al. 2008; Hill, Rowan, and Ball 2005; Goe 2008). This work is beginning and is expected to yield measures of teacher quality more directly related to student achievement than are the indicators examined here.

Formal Preparation

Teachers acquire a significant amount of subject knowledge and teaching skills through formal education and certification. Thus, teachers' level of educational attainment and type of professional certification provide some indication of how well teachers are prepared for their work.[11] Data on teachers' highest degree and certification status (regardless of the field in which the degree/certification was held) indicate that virtually all of them had at least a bachelor's degree. Nearly half also had a master's or higher degree, and a majority held a regular or advanced teaching certificate (NSB 2008).

Similar patterns are observed when the analysis focuses on how many students are taught mathematics and science by teachers with various levels of educational attainment and types of certification. For example, almost all public school fifth grade students in 2004 and eighth grade students in 2007 were taught mathematics and science by teachers who had attained a bachelor's or higher degree (regardless of the field in which the degree was earned), and about half of them were taught these two subjects by teachers with a master's or higher degree (appendix table 1-12). Furthermore, the majority of fifth and eighth grade students (90% and 84%, respectively) had teachers of mathematics and science with a regular or advanced teaching certificate (regardless of the field in which the certification was awarded).

Subject Area Preparation

Adequate subject matter knowledge and skills are critical for teachers to teach their subjects well (The Education Trust 2008; Goe 2008; Ingersoll 2003). NCLB mandates that all students be taught by teachers who not only are fully certified and possess at least a bachelor's degree, but also demonstrate competence in subject knowledge and teaching. In its 2007 policy recommendations regarding STEM education, the National Science Board (NSB) emphasized that STEM teachers should receive adequate STEM content knowledge that is aligned with what they are expected to teach (NSB 2007). Similarly, a report from the National Research Council of the National Academies (2007) advocated that teacher preparation and professional development programs focus on boosting teachers' knowledge of science, how students learn the subject, and methods and technologies that aid science learning for all. However, neither NCLB nor these reports' policy recommendations provide specific guidance or criteria regarding "adequate" preparation to teach mathematics and science at various grade levels.

While most states require those who teach mathematics and science at the high school level to have a degree or certification in their subject area, state laws and regulations regarding preparation of middle school teachers (eighth grade teachers fall in this group) vary, with some states allowing general education preparation and others requiring subject area preparation. As for elementary school teachers, who typically teach multiple subjects, most state policies consider teachers with a degree or certification in general elementary education to be "qualified" to teach elementary school mathematics and science (and other subjects), although some question whether elementary school teachers with general education preparation have sufficiently rigorous preparation for teaching mathematics and science (Greenberg and Walsh 2008).

Recent research efforts have focused on matching teachers' formal preparation (as indicated by degree major and certification field) with their teaching field to determine whether teachers have subject-specific preparation for the fields they teach (McGrath, Holt, and Seastrom 2005; Morton et al. 2008). Following this line of research, four levels of teachers' formal preparation for teaching mathematics and science at fifth and eighth grade levels were distinguished. In order of decreasing rigor of preparation, they are as follows:

- **In-field:** Teachers who taught mathematics and had a degree and/or certificate in mathematics or mathematics education. Teachers who taught science and had a degree major and/or certificate in science or science education.
- **Related-field:** Teachers who taught mathematics and had a degree and/or certificate in a field related to their teaching field (such as science, science education, computer sciences). This category is omitted for teachers of science in ECLS-K because these teachers were not asked about their degrees or certificates in specific science fields such as physics, chemistry, or biology.
- **General education:** Teachers who taught mathematics or science and had a degree and/or certificate in general elementary or secondary education. Such teachers usually undergo some pedagogical training in mathematics and science.
- **Other:** Teachers who taught mathematics or science but did not have a degree or certificate in their teaching field, a related field, or general elementary or secondary education.

In-field teaching in mathematics and science was less prevalent at lower grade levels than at higher grade levels. For example, in 2004, about 40% of fifth grade students in public schools were taught mathematics and science by in-field teachers (table 1-9; appendix table 1-13). Most students at this level (54%) had teachers with general education preparation. When students reached eighth grade in 2007, more than 80% of them had in-field teachers in their mathematics and science classes, and 9–10% were taught mathematics and science by teachers with general education preparation.

Similar patterns were also revealed using the teacher data from the 2003–04 and 2007–08 Schools and Staffing Survey (SASS).[12] In 2003, 53% of teachers of mathematics and 67% of teachers of science in public middle schools were teaching in field (table 1-10).[13] Partly reflecting the impact of NCLB on teacher qualifications, in-field mathematics teachers in public middle school increased to 64% in 2007, representing a significant 11 percentage point increase from 2003. Seventy percent of teachers of science in public middle schools were teaching in field in 2007, but this does not represent a significant increase from the 67% in 2003. In both years, between 27% and 38% of middle school teachers were teaching mathematics and science with general education preparation.

Moving up to the high school level, in-field teaching became more common. For example, in-field teaching in 2007 ranged from 82% of teachers of physical sciences and 88% of teachers of mathematics to 93% of teachers of biology/life sciences. The share of teachers with general education preparation declined to 3% or lower. Similar percentage ranges also were found among public high school mathematics and science teachers in 2003.

Teaching Experience

Experienced teachers are, generally, more effective than novices in helping students learn (Boyd et al. 2006; Clotfelter, Ladd, and Vigdor 2007; Hanushek et al. 2005; Harris and Sass 2008; Rice 2003; Rockoff 2004; Rowan, Correnti, and Miller 2002; Wayne and Youngs 2003). Overall, teachers with more than 3 years of teaching experience make up a large majority of the mathematics and science teaching force in public schools (NSB 2008; NCES 2007a). Likewise, between 82% and 88% of public school fifth and eighth grade students in 2004 and 2007 were taught mathematics and science by teachers with more than 3 years of teaching experience (appendix table 1-14). The majority of these students had teachers with 3 or more years of experience in the specific grade level or subject matter in question: 63%–65% of fifth grade students were taught mathematics and science by teachers with more than 3 years of experience in teaching fifth grade classes, and 76%–78% of eighth grade students had science and mathematics teachers who had taught their respective subject for more than 3 years.

Differences in Student Access to Qualified Teachers in Science and Mathematics

Access to better-qualified teachers was not equally distributed among students. In general, black and Hispanic students, students from less-educated and low-income families, and students with low levels of prior achievement had less access to teachers who were highly educated, fully certified, and had more experience and better preparation in the subject field than their counterparts (appendix tables 1-12, 1-13, and 1-14). For example, fifth grade black and Hispanic students were less likely than their white peers to be taught mathematics by teachers with a master's or advanced degree (39% and 42% vs. 51%, respectively), a regular or advanced teaching certificate (86% and 85% vs. 92%), and more than 3 years of experience in teaching the fifth grade (48% and 58% vs. 68%) (table 1-11). Students living in low-income families were less likely than their peers from higher-income families to be taught mathematics by teachers with a master's or advanced degree (35% vs. 50%, respectively). Also among fifth graders, a third of those in the lowest achievement quartile in grade 3 were taught mathematics by in-field teachers. In contrast, 41% of fifth graders in the top achievement quartile in grade 3 had such teachers.

Table 1-9
Public school students in grades 5 and 8 taught mathematics and science by teachers with various levels of subject area preparation: 2004 and 2007
(Percent distribution)

Grade/field	All levels	In field	Related field	General education	Other
Grade 5 (2004)					
Mathematics	100	38	4	54	4
Science	100	43	na	54	3
Grade 8 (2007)					
Mathematics	100	85	2	10	4
Science	100	88	na	9	3

na = not applicable

NOTE: Percentages may not add to 100% because of rounding.

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99, 2004, and 2007; and National Science Foundation, Division of Science Resources Statistics. See appendix table 1-13.

Science and Engineering Indicators 2010

Table 1-10
Public middle and high school teachers of mathematics and science with various levels of subject area preparation: 2003 and 2007
(Percent distribution)

		2003				2007			
School level and teaching field	All levels	In field	Related field	General education	Other	In field	Related field	General education	Other
Middle school									
Mathematics	100	53	4	38	5	64	2	31	3
Science	100	67	na	29	4	70	na	27	3
High school									
Mathematics	100	87	2	3	7	88	1	3	7
Biology/life sciences	100	92	4	1	3	93	4	1	2
Physical sciences	100	78	20	1	1	82	15	1	2

na = not applicable

NOTE: Percentages may not add to 100% because of rounding.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04 and 2007–08; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

In eighth grade, students whose mothers had not earned a high school diploma were less likely than those whose mothers had a bachelor's or higher degree to be taught science by teachers who had a master's or advanced degree (46% vs. 57%, respectively), a regular or advanced teaching certificate (79% vs. 87%), an in-field degree or certificate (84% vs. 93%), and more than 3 years of experience in teaching science (69% vs. 83%) (appendix tables 1-12, 1-13, and 1-14). Differences existed when looking at family income as well: eighth grade students from families with incomes below the poverty threshold were less likely than those from higher-income families to be taught science by teachers with a regular or advanced teaching certificate (79% vs. 86%, respectively), an in-field degree or certificate (84% vs. 89%), and more than 3 years of experience in teaching science (69% vs. 79%). In addition, 92% of students with high achievement in fifth grade were taught mathematics by in-field teachers, compared with 76% of those with low fifth-grade achievement who had such teachers.

Professional Development

Teachers rely on professional development to update their knowledge, sharpen their skills, and acquire new teaching techniques, all of which may enhance the quality of teaching and learning (Richardson and Placier 2001; Davis, Petish, and Smithey 2006). During the past decade, researchers have put significant effort into identifying features of high-quality professional development programs (Banilower et al. 2006; CCSSO 2008; Clewell et al. 2004; Desimone et al. 2002; Garet et al. 2001; Hawley and Valli 2001; Harris and Sass 2007; Heck, Rosenberg, and Crawford 2006; Penuel et al. 2007; Porter et al. 2000). They have come to general agreement that professional development is most effective if it

- Focuses on subject content
- Provides an intensive and sustained approach
- Is presented in a format of teacher network, study group, mentoring, and coaching as opposed to a traditional workshop or conference
- Is connected or related to teachers' daily work
- Emphasizes a team approach and collaboration
- Provides opportunities for active learning

When professional development is conducted in these ways, teachers are more likely to change their instructional practice, gain greater subject-matter knowledge, and improve their teaching (see, for example, the sidebar "Local Systemic Change Through Teacher Enhancement Program"). Consequently, there is increased potential for the professional development to have an effect on student achievement (Correnti 2007; Darling-Hammond and Youngs 2002; Wenglinsky 2002).

Table 1-11

Public school students in grade 5 who were taught mathematics by teachers with various qualifications, by student characteristics: 2004

(Percent)

Student characteristic	Master's or higher degree	Regular/advanced certificate	Degree or certificate in mathematics (in field)	More than 3 years in teaching grade 5
All students	47	90	38	63
Race/ethnicity				
White, non-Hispanic	51	92	39	68
Black, non-Hispanic	39	86	33	48
Hispanic	42	85	39	58
Mother's education				
Less than high school	34	86	37	61
Bachelor's or higher degree	56	91	34	69
Family poverty status[a]				
Below poverty threshold	35	88	37	59
Above poverty threshold	50	90	39	65
Achievement in grade 3[b]				
Low	38	84	33	60
High	50	92	41	71

[a] Federal poverty thresholds define households below poverty level based on household income and number of household members.

[b] Composite of reading, mathematics, and science achievement test scores. Low level includes students in bottom quartile of achievement distribution; high level includes top quartile.

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K), spring 2004; and National Science Foundation, Division of Science Resources Statistics. See appendix tables 1-12, 1-13, and 1-14.

Science and Engineering Indicators 2010

Evidence from the most recent national teacher survey in 2003−04 indicates that almost all mathematics and science teachers in public middle and high schools participated in some form of professional development activities during the school year (NSB 2008). However, the programs these teachers attended consisted mostly of short-term workshops, conferences, and training sessions. In general, teachers had less exposure to professional development with features identified by research as effective in bringing about positive changes in teaching practices.

Data from ECLS indicate that in 2004, the percentage of fifth graders whose teachers of mathematics and science reported that they had participated in staff development related to their subject content or pedagogy during the past school year was 73% and 53%, respectively (table 1-12). On average, teacher participants spent about 14 hours on subject-focused staff development during the entire school year. Furthermore, among students whose teachers participated in this staff development, about 40% had teachers rating this activity as very useful.

The 2007 TIMSS provides further evidence regarding the extent to which elementary school teachers participate in professional development in mathematics and science (Miller et al. 2009). In 2007, the percentage of fourth graders whose teachers participated in professional development on various aspects of mathematics during the previous 2 years ranged from 47% for assessment and 50% for pedagogy/instruction to 60% for mathematics content (figure 1-9). Participation in professional development relating to science was even lower among teachers of fourth graders: 24%–42% of students had teachers who participated in professional development on science content (42%), pedagogy/instruction (29%), and assessment (24%).

Teachers' Salaries

Adequate pay is important to attracting and retaining teachers (Guarino, Santibanez, and Daley 2006). Thus, policymakers often propose increasing teacher salaries to lower attrition and improve the quality of the teaching pool, arguing that if teachers could earn higher pay both when entering the profession and over time, stronger candidates would be drawn to teaching and more effective teachers might be retained (Johnson, Berg, and Donaldson 2005; Loeb and Reininger 2004; Stronge, Gareis, and Little 2006).

Local Systemic Change Through Teacher Enhancement Program

Local Systemic Change (LSC) Through Teacher Enhancement is a teacher professional development program that aims to improve K–12 instruction in science, mathematics, and technology. LSC embraces many characteristics of effective professional development—it requires all mathematics and science teachers from schools or districts to participate in a minimum of 130 hours of professional development over the course of the project, provides ongoing support during the school year, adopts a range of formats, emphasizes subject content and pedagogy, offers active learning opportunities, and promotes efforts to build a supportive environment for change.

A decade's worth of data indicate that LSC has had a positive impact in many areas, including teachers' attitudes toward reform-oriented teaching, perceptions of their pedagogical preparedness, and adoption of reform-oriented teaching practices in the classroom; the quality of instruction delivered to students; and student achievement, attitudes, and coursetaking patterns in mathematics and science (Banilower et al. 2006; Heck, Rosenberg, and Crawford 2006; Shimkus and Banilower 2004). Moreover, the program's impact increased as teachers accrued more professional development hours (although there appeared to be a limited increase in impact beyond 80 hours).

Table 1-12

Public school students in grade 5 who were taught mathematics and science by teachers who had participated in staff development relating to their subject content or pedagogy during the past school year: 2004

(Percent)

Subject	Participated (%)	Average hours spent	Thought staff development was very useful (%)
Mathematics	73	14	41
Science	53	14	42

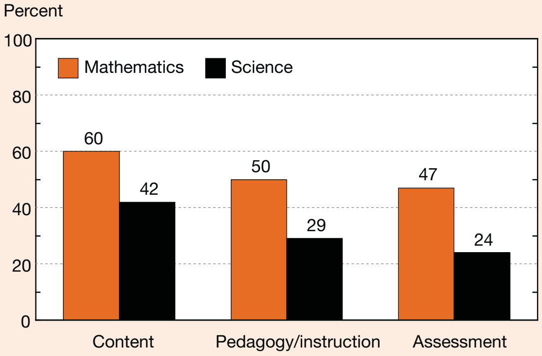
SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99, spring 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

According to the latest annual teacher salary survey conducted by the American Federation of Teachers (AFT),[14] the average salary for all public K–12 teachers in 2006–07 was about $51,000 (AFT 2008). After adjustment for inflation, teacher salaries grew by 2.8% from 1996–97 to 2006–07. During this 10-year period, 18 states experienced declines in inflation-adjusted teacher salaries.

Using data from the Current Population Survey of the Bureau of Labor Statistics, Allegretto, Corcoran, and Mishel (2008) compared the weekly wages[15] of full-time public school teachers with those of people working in occupations requiring comparable education and skills, such as accountants, reporters, registered nurses, and computer programmers.[16] Their analyses showed that in 2006, full-time public school teachers earned 86% as much in weekly wages as did those in this set of comparable occupations. Furthermore, between 1996 and 2006, the gap in weekly wages between full-time teachers and those in comparable occupations widened from $7 to $153, in constant dollars (figure 1-10). A similar conclusion has been drawn about mathematics and science teachers—that is, their pay fell behind that of many professions with comparable educational backgrounds, and the gap widened substantially in recent years (NSB 2008).

Figure 1-9
Students in grade 4 whose teachers participated in various professional development activities in mathematics and science in the past 2 years: 2007



SOURCE: Miller DC, Sen A, Malley LB, Burns SD, Comparative Indicators of Education in the United States and Other G-8 Countries: 2009. NCES 2009-039 (2009), figures 18 and 19.

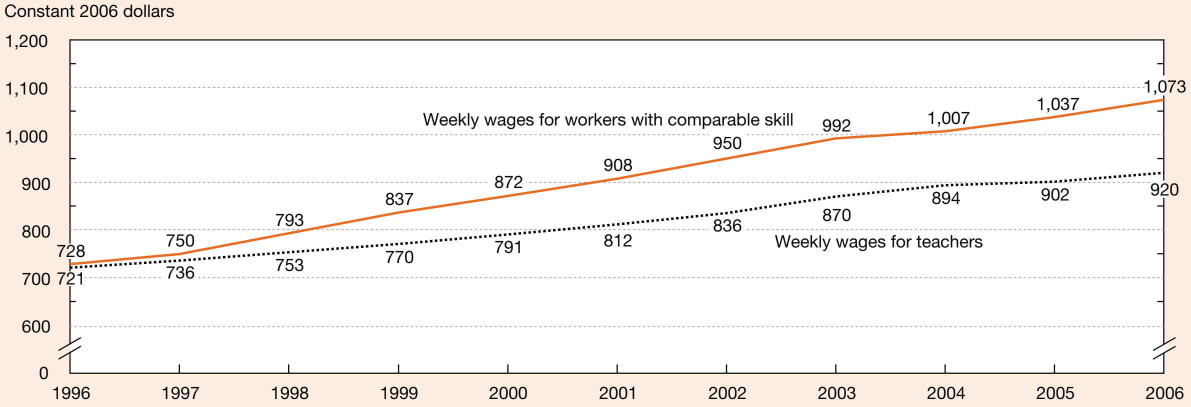
Science and Engineering Indicators 2010

Working Conditions

Poor working conditions can cause stress and dissatisfaction and may lead teachers to leave the teaching profession altogether (Hanushek, Kain, and Rivkin 2004; Hanushek and Rivkin 2007; Ingersoll 2001; Johnson, Berg, and Donaldson 2005). The working conditions that matter most to teachers include administrative leadership at their school, working relationships among colleagues, level of parental support, teaching loads, and student discipline problems (Guarino, Santibanez, and Daley 2006).

Most public middle and high school teachers have positive perceptions about their school conditions (NSB 2008). Such positive perceptions are also widely held among fifth and eighth grade students' teachers. In 2004, for example, for a large majority of fifth grade students (94%), the teachers who taught them mathematics and science felt accepted and respected by their school colleagues (appendix table 1-15).

Figure 1-10
Weekly wages of full-time public school teachers and comparable workers: 1996–2006



NOTES: Data on weekly wages drawn from Current Population Survey of Bureau of Labor Statistics (BLS). As part of National Compensation Survey, BLS collects specific occupational skill information and rates each occupation on level of skills required across 10 different dimensions (e.g., knowledge, complexity). Among 16 occupations identified as having comparable skill ratings as teaching, six most common occupations (accountants, reporters, registered nurses, computer programmers, clergy, and personnel officers) used to form category of comparable workers in study of Allegretto, Corcoran, and Mishel (2008).

SOURCE: Allegretto SA, Corcoran SP, Mishel L, The Teaching Penalty: Teacher Pay Losing Ground, table 6, Economic Policy Institute (2008).

Science and Engineering Indicators 2010

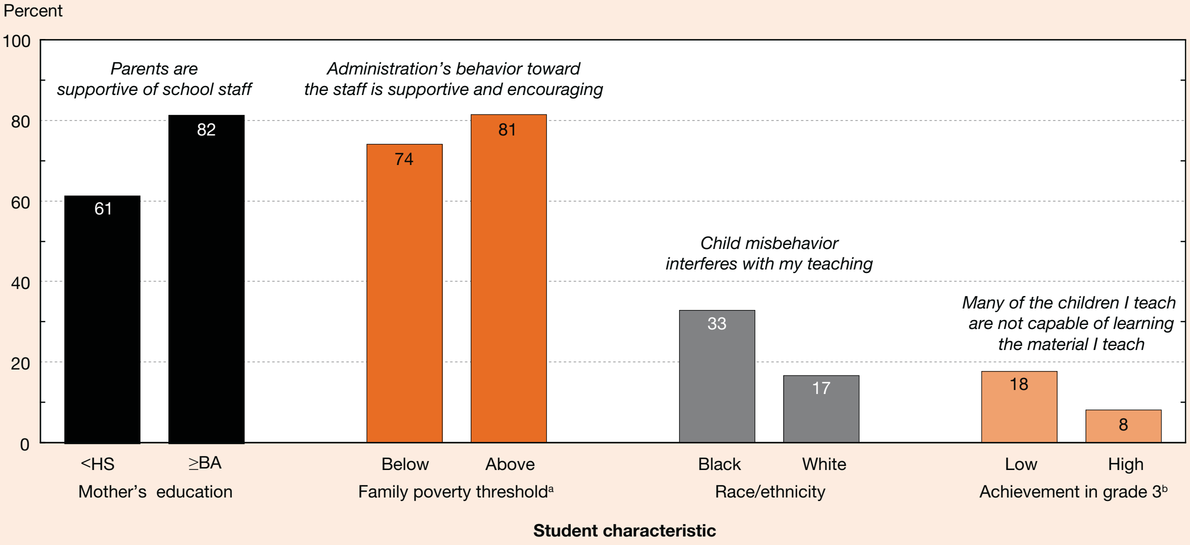
Large majorities of these students had teachers who believed that teachers in their schools were continually learning and seeking new ideas (86%);[17] that staff members had school spirit (81%) and agreed about the central mission of the school (75%); that school administrators knew the direction of the school and communicated it to staff (81%) and were supportive and encouraging (80%); and that parents were supportive of school staff (70%). Furthermore, relatively few students' teachers reported various learning and behavioral problems among students (12%–21%). Reports from eighth grade teachers were similar (appendix table 1-16), although eighth grade teachers were more likely than fifth grade teachers to report such problems as student misbehavior interfering with teaching (30% vs. 21%, respectively) and many children not being capable of learning (19% vs. 14%).

Positive perceptions of school conditions were less widely held among teachers of minority, socioeconomically disadvantaged, and low-achieving students. For example, fifth grade students whose mothers had less than a high school education were less likely than students whose mothers had a bachelor's or higher degree to have teachers who described parents in their school as "supportive" (61% vs. 82%, respectively) (figure 1-11). About 74% of fifth grade students from low-income families, compared with 81% of students from more financially advantaged families, had teachers reporting supportive school administrators. Compared with 17% of fifth grade white students, 33% of black students had teachers whose teaching was interrupted by child misbehavior. In addition, compared with 8% of high-achieving students, 18% of low-achieving students were taught mathematics and science by teachers who reported that many of their students were not capable of learning the materials they taught.

Instructional Technology in Education

National organizations have endorsed, and federal and state policies have encouraged, the incorporation of technology into education. In the context of elementary/secondary education, technology is commonly understood to include a range of computer applications such as word processing, presentation software, spreadsheets, databases, Internet search capability, distance education, virtual schools, interactions with simulations and models, and collaboration over local and global networks (Dynarski et al. 2007). The Enhancing Education Through Technology Act of 2001, a component of the No Child Left Behind Act, emphasized developing technology infrastructure within schools, integrating technology into curriculums, and training teachers in its use. In 2005, the U.S. Department of Education released a National Education Technology Plan, touting the transformative potential of technology in teaching and learning and outlining steps to incorporate technology into schools (Office of Educational

Figure 1-11
Public school students in grade 5 whose teachers of mathematics and science agreed or strongly agreed with selected statements about their schools, by student characteristics: 2004



<HS = less than high school; ≥BA = bachelor's degree or higher

[a] Federal poverty thresholds define households below poverty level based on household income and number of household members.

[b] Composite of reading, mathematics, and science achievement test scores. Low level includes students in bottom quartile of achievement distribution and high level includes top quartile.

SOURCES: National Center for Education Statistics, Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K), spring 2004; and National Science Foundation, Division of Science Resources Statistics. See appendix table 1-15.

Science and Engineering Indicators 2010

Technology 2004). More recently, the American Recovery and Reinvestment Act of 2009 included $650 million for additional grants through the Ed-Tech state program, which supports various state and local projects related to the use of technology in education.

The applications of technology in education are vast, but this section focuses specifically on instructional technology—that is, technology products and tools designed to assist teaching and learning in elementary and secondary schools. (Technology use can be a competency itself, as well as a tool toward other knowledge acquisition. For a discussion of technology literacy among students and teachers, see sidebar "Student and Teacher Technology Literacy.") It begins by discussing recent research on the effectiveness of technology as an instructional tool. In the context of this research, it then presents data on eighth graders' use of instructional technology in school, updates national estimates of access to computers and the Internet, and examines the prevalence of distance education, an instructional application of technology that can potentially increase students' access to subject matter and qualified instructors.

Student and Teacher Technology Literacy

National and international organizations endorse technology as both a tool for instruction in various academic subjects and an important area in which K–12 students should achieve some competency. The National Governors Association (NGA) recently argued that the prevalence of technology in most professions requires all students to have a strong foundation in using technology—along with other science, technology, engineering, and mathematics (STEM) competencies—to compete in a 21st century economy (NGA 2007). Several organizations, including the International Technology Education Association (ITEA), have developed technology standards outlining what students should know about various types of technologies, the concepts behind them, and their significance to society (ITEA 2007). The International Society for Technology in Education (ISTE) has developed technology standards for teachers and students that have been widely adopted by states and districts interested in integrating technology into their educational goals (ISTE 2007; Trotter 2009). Beginning in 2012, the National Assessment of Educational Progress (NAEP) will pilot a computer-based evaluation of students' understanding of all technologies, including their information technology literacy (Kerr 2008).

State policies also reflect a growing emphasis on K–12 students' learning about technology and the use of technology in education (table 1-A; appendix table 1-18). In the 2008–09 school year, 46 states included technology in their teaching standards, and 21 states required teachers to complete technology coursework or to pass a test on technology use for initial teacher certification (Editorial Projects in Education Research Center 2009a). Ten states required technology-related professional development for teachers or testing for recertification. Curriculum standards in all 50 states included technology as a subject in which students should be educated, and 13 tested students on those technology standards, up from just 5 the previous year.

Table 1-A
State standards and policies regarding K–12 teaching with and learning about technology, by academic year: 2004–09
(Number of states)

Standard/policy	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	Change, 2004–09
Standards for students include technology	45	48	48	48	48	50	+5
Students tested on technology	3	3	4	4	5	13	+10
Standards for teachers include technology	38	40	40	45	44	46	+8
Requirements for intitial teaching license include technology coursework or test	22	20	21	19	19	21	-1
Technology training or testing, or participation in technology-related professional development required for recertification	10	10	9	9	10	10	0

SOURCES: Editorial Projects in Education Research Center, "Breaking Away from Tradition: E-Education Expands Opportunities for Raising Achievement," Education Week: Technology Counts 2009 28(26) (2009); Editorial Projects in Education Research Center, "STEM: The Push to Improve Science, Technology, Engineering, and Mathematics," Education Week: Technology Counts 2008 27(30) (2008); Editorial Projects in Education Research Center, "A Digital Decade," Education Week: Technology Counts 2007 26(30) (2007); Editorial Projects in Education Research Center, "The Information Edge: Using Data to Accelerate Achievement," Education Week: Technology Counts 2006 25(35) (2006); Editorial Projects in Education Research Center, "Electronic Transfer: Moving Technology Dollars in New Directions," Education Week: Technology Counts 2005 24(35) (2005); Editorial Projects in Education Research Center, "Global Links: Lessons from the World," Education Week: Technology Counts 2004 23(35) (2004). Based on annual surveys of chief state technology officials. See appendix table 1-18.

Science and Engineering Indicators 2010

Technology as an Instructional Tool

The Internet offers students access to more, and more recent, information than individual schools can provide, but it is only one potential application of instructional technology to enhance educational outcomes. Computer applications, either alone or in concert with traditional instruction, may improve achievement by tailoring lessons and skill practice to individual students' needs or by offering students additional opportunities to interact with information. Additionally, computerized assessment may provide more precise and efficient feedback on student learning, allowing teachers to adapt instruction to student needs (Tucker 2009).

Research on whether and how these tools improve student achievement, however, continues to yield mixed results. Some computer applications appear to enhance students' achievement on standardized tests, while others do not (NSB 2006).

An NCLB study of the effectiveness of instructional technology failed to find any statistically significant effects of several specific instructional technologies on student achievement (Dynarski et al. 2007). Researchers tested three grade 6 math products in 28 schools and three algebra products in 23 schools. Teachers in selected schools volunteered to participate and were randomly assigned to use or not use the educational software; researchers compared students' test results and other outcomes. No effects on sixth grade mathematics or algebra achievement were observed. During the second year of the evaluation, two sixth grade math products and two algebra products were tested, and again researchers observed no significant effects on student achievement (Campuzano et al. 2009). No science products were tested.

In contrast, a meta-analysis that used statistical procedures to aggregate the results of 42 studies published in peer-reviewed journals found that incorporating instructional technology into teaching and learning had a small, positive effect on achievement when compared with instruction without technology (Waxman, Lin, and Michko 2003). However, the studies included in the meta-analysis were conducted prior to 2003, some based on projects from the early 1990s. Given the fast pace of change in instructional technology, the results may be less relevant than more recent studies. Small-scale recent studies of specific instructional technology applications suggest that educational computer programs and videogames may promote student engagement and learning when they make use of proven pedagogical techniques (Steinkuehler and Duncan 2008; Ketelhut 2007; Nelson 2007; Barab et al. 2007; Neulight et al. 2007). In its final report, the National Mathematics Advisory Panel (2008) recommended that several types of high-quality computer-assisted instruction be considered potentially useful educational tools and that further research be conducted.

Computer Use in Eighth Grade Mathematics and Science

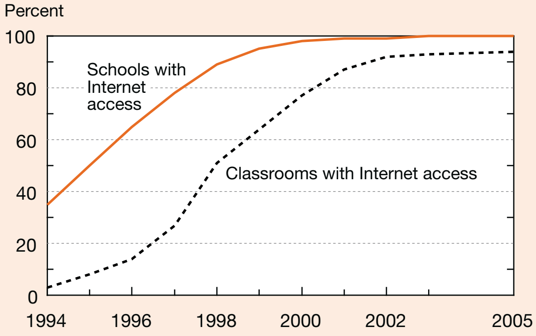
According to their teachers, eighth grade students use computers in science classes substantially more often than in their mathematics classes. More than 70% of students used computers in science at least once per month, compared with less than 40% in mathematics, according to the 2007 followup of the ECLS-K cohort (appendix table 1-17). Use of computers varies with student characteristics, but not consistently. Students with the highest mathematics assessment scores were more likely to use computers in science class but less likely to use them in mathematics class. Conversely, black students were significantly more likely to "never or hardly ever" use computers in science class, compared with their white and Asian peers, and more likely to use computers "almost every day" in mathematics class.

Until research yields some consensus on the optimal uses of computer-based technology for various subjects, grade levels, and types of students, its contributions to patterns of achievement will remain unclear.

Internet Access

Access to the Internet is nearly universal among public elementary and secondary schools in the United States. In 2005, 100% of public schools had Internet access, and 97% of these schools used broadband connections to access the Internet (Wells and Lewis 2006). Access was nearly universal not only for schools, but also for classrooms and students: 94% of classrooms in public schools had computers with Internet access, and the ratio of students to instructional computers was 4:1.[18] Moreover, change has been swift: 35% of schools and 3% of classrooms had Internet access in 1994 (figure 1-12), and the student-to-computer ratio was 12:1 in 1998 (Wells and Lewis 2006).

Figure 1-12
Schools and classrooms with Internet access, 1994–2005



NOTE: Data not available for 2004.

SOURCE: Wells J, Lewis L, Internet Access in U.S. Public Schools and Classrooms: 1994–2005, NCES 2007-020, Institute of Education Sciences, U.S. Department of Education (2006).

Science and Engineering Indicators 2010

Furthermore, equity in Internet access appears to have been achieved. Since the beginning of the century, public schools' access to the Internet has not varied with minority enrollment or student poverty, and by 2005, neither did classrooms' Internet access (Wells and Lewis 2006).

Distance Education

Technology may provide students with access to courses they would otherwise be unable to take by facilitating distance education: instruction in which the teacher and students are in different locations. Distance education may include videoconferencing and televised or audiotaped courses, but Internet courses are the most widespread and fastest-growing mode of delivery (Zandberg and Lewis 2008). While distance courses preclude some experiential learning (e.g., laboratory experiments), well-designed electronic alternatives (e.g., remotely operated laboratories [Nickerson et al. 2007])—may be able to fill that gap. Thus far, several meta-analyses have found no significant difference between the student learning that occurs in online versus regular classroom instruction (Cavanaugh 2001; Bernard et al. 2004; Cavanaugh et al. 2004), suggesting that distance education courses may provide students with access to additional courses without compromising the quality of instruction.

Goals of Distance Education

NCLB describes distance education as an innovative tool to promote access to rigorous academic courses, particularly for students in isolated geographic regions (NCLB Title II, Part D), and the National Education Technology Plan lists distance learning as one of seven major action steps designed to improve student achievement through technology. District administrators cited "offering courses not otherwise available at the school" as the most important reason to provide online learning opportunities (Picciano and Seaman 2007). Schools and districts also provide distance learning options to ease crowding in schools, increase course access for physically disabled students, allow students to retake courses for graduation, expand student access to AP and college-level courses, and tutor students for high-stakes graduation exams (Education Technology Cooperative 2007; Zandberg and Lewis 2008).

Distance education provides one strategy for managing shortages of mathematics and science teachers, particularly in rural or inner-city areas where attracting and retaining them are chronically difficult (Picciano and Seaman 2007). For example, Louisiana has implemented a Web-based algebra course targeted at schools with uncertified mathematics teachers. The course provides students with access to a certified instructor and offers teachers professional development opportunities (Watson, Germin, and Ryan 2008).

Access and Participation in Distance Education

The availability of distance education, most commonly provided by postsecondary institutions, independent vendors, states, and school districts (Picciano and Seaman 2007), has grown substantially over this decade. In 2005, 57% of secondary schools nationwide provided opportunities for online distance learning to their students (Wells and Lewis 2006). In 2008, students in 44 states had access to full-time or supplemental online learning opportunities, and 34 states sponsored programs and initiatives. While state-led programs primarily serve secondary students, opportunities for students in grades K–8 are increasingly common (Watson, Germin, and Ryan 2008). Beyond its accessibility, however, it is difficult to draw conclusions about nationwide distance education because programs and policies vary so widely. For example, two states—Michigan and Alabama—now require students to participate in online learning to graduate from high school, while six states do not have online opportunities that are accessible to every student (Watson, Germin, and Ryan 2008). Policies regarding tuition and partnerships with private schools and home-school organizations also vary (Watson, Germin, and Ryan 2008; Education Technology Cooperative 2008).

Participation in distance education has increased dramatically. Primary and secondary school enrollment in distance education across all subjects grew from 317,070 students in 2002−03 to 506,950 students in 2004−05, an increase of 60% (Zandberg and Lewis 2008).[19] In addition, a nationwide survey of school district administrators indicated that approximately 700,000 public school students, about two-thirds of whom were in grades 9−12, were enrolled in courses that involved a substantial proportion of online learning during the 2005−06 school year (Picciano and Seaman 2007). Postsecondary institutions were the leading providers of distance education to secondary students in 2005 (Zandberg and Lewis 2008), and 12% of 2- and 4-year postsecondary institutions reported offering courses, primarily academic high school courses, to elementary and secondary students in 2006–07 (Parsad and Lewis 2008).

Despite these recent reports, national indicators pointing to elementary and secondary science and mathematics education are unavailable. No national data exist on distance course taking in math, science, or any particular subject area. Likewise, data that identify elementary and secondary students among postsecondary distance education enrollments are also as yet unavailable.

Virtual Schools

State-sponsored virtual schools are growing sources for distance education. In 1997, five states had virtual school programs, which use technology to offer individual courses or supplements to courses taught in traditional schools (Tucker 2007). As of 2008, 29 states had established virtual school programs (Editorial Projects in Education Research Center 2009a). All the members of the Southern Regional Education Board (SREB) sponsor virtual schools, and their annual surveys indicate that enrollment in these schools has been increasing steadily (Education Technology Cooperative 2008).

Although there are no nationwide data on distance education course offerings or participation in STEM subjects, the Education Technology Cooperative at SREB tracks this information for its member states' virtual schools (table 1-13). In the absence of more comprehensive data, it provides an indicator of distance education in math and science specifically. These virtual schools provide students with advanced courses: 10 of the 14 virtual schools offer several AP courses in math or science. Virtual schools offer courses at a range of levels, however, including regular and honors levels, and offer various electives such as business-focused math, computer science, and specialized sciences (e.g., oceanography). In a few states, the virtual school plays a role in remediation as well. For example, Alabama offers online remediation for the math and science components of the high school graduation exam; more than 1,000 students are enrolled in each of those courses, compared with an average of about 200 students in the other math and science courses offered.

Transition to Higher Education

One role of high school education in the United States is to prepare students for further education. This section presents indicators of how well prepared high school graduates are, especially in math and science, to engage in postsecondary education.

Although calculating accurate high school graduation rates has been a perennial challenge, existing data indicate that less than three-quarters of students graduate from high school in 4 years. On the other hand, a small but growing number of students earn college credit during high school by passing AP tests. For those students who complete high school, this section presents indicators of their movement into postsecondary education. It begins with data on the association of students' high school mathematics and science coursetaking and achievement with their postsecondary enrollment and remediation; then it examines long-term trend data on students' immediate enrollment in postsecondary education and presents current data in the context of international rates. Together, these indicators describe high school students' preparation for and transition into postsecondary education.

High School Completion

In 2006, the national on-time high school graduation rate—the percentage of entering ninth graders who graduated 4 years later—was 73% (Stillwell and Hoffman 2008). About three-quarters of students have completed high school on time since 2003. Differences in on-time graduation rates between students in various racial/ethnic groups remain large: the graduation rate for white students was approximately 20 percentage points higher than the rates for black, Hispanic, and American Indian/Alaska Native students in 2006 (figure 1-13). The Asian/Pacific Islander rate was higher than that of all other groups.[20]

Some students who fail to graduate from high school on time eventually earn a high school diploma or alternative award such as a General Educational Development (GED)

Table 1-13
Science and mathematics courses offered at state-sponsored virtual schools, by state: 2008

	Mathematics and science courses			
State	Mathematics	Science	AP[a]	Students enrolled[b]
Alabama	11	9	4	5,730
Arkansas	6	7	0	537
Florida	17	17	2	35,243
Georgia	20	12	6	2,276
Kentucky	8	11	8	256
Louisiana	8	8	2	1,185
Maryland	15	9	8	297
Mississippi	11	11	8	1,756
North Carolina	7	10	5	1,621
Oklahoma	7	8	0	466
South Carolina	7	1	0	1,287
Tennessee	7	6	0	871
Virginia	4	7	7	417
West Virginia	30	21	7	145

AP = Advanced Placement

[a] AP courses also counted in mathematics and science columns.
[b] Includes students enrolled in all mathematics or science courses. Students may be double counted if they are enrolled in more than one course.

SOURCE: Special analysis for the National Science Foundation from the Educational Technology Cooperative at the Southern Regional Education Board, 2009.

Science and Engineering Indicators 2010

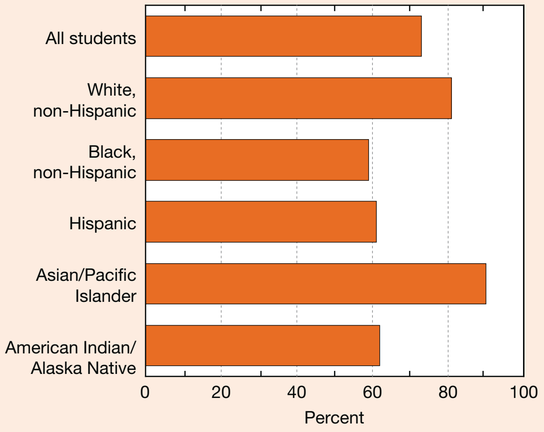
credential. In 2006, 88% of 18- through 24-year-olds who were not enrolled in high school, institutionalized, or incarcerated had earned a high school diploma or other credential, continuing a rising trend that began in 1980 (Laird et al. 2008).[21]

Graduation Rate Standards

NCLB requires states to set both standards for graduation rates and annual improvement targets for schools or groups not meeting the standard, but the act provides no minimum for either measure, and states' targets for this measure vary considerably. (See sidebar "Measuring High School Graduation Rates.") Nearly half the states (23) and the District of Columbia set graduation rate goals for the class of 2007 at or below 75%, and more than half of states defined their improvement targets as "any progress," or even none, as long as their rates did not decline. Thirty-six states had annual improvement targets of 0.1% or less in 2008, or less than one additional graduate per year for an average-sized high school (Alliance for Excellent Education 2008).

Since 2002, states have reported graduation rates disaggregated by racial/ethnic group, family income, disability status, and English-language proficiency. Until 2008, however, the determination of whether schools and districts have made adequate yearly progress under NCLB rested only on overall graduation rates. Regulations issued in 2008 require that, beginning in 2011–12, schools and districts must meet graduation rate goals for all subgroups to achieve adequate yearly progress.[22]

Figure 1-13
On-time graduation rates of U.S. public high school students, by race/ethnicity: 2006



NOTE: On-time high school graduation rate is percentage of entering ninth graders who graduated 4 years later.

SOURCE: Stillwell R, Hoffman L, Public School Graduates and Dropouts From the Common Core of Data: School Year 2005–06, 2008-353, Institute of Education Sciences, U.S. Department of Education (2008).

Science and Engineering Indicators 2010

Graduation Rates in the United States and in Other OECD Nations

Difficulties in establishing precise U.S. graduation rates notwithstanding, broad comparison can be made of the United States and other OECD member countries. Among the 23 OECD countries for which graduation data were available, the United States ranked 17th in secondary school graduation rates in 2006 (OECD 2008) (figure 1-14).

Participation and Performance in the Advanced Placement Program

A relatively small but increasing number of secondary students take AP courses, which are designed to be equivalent to some college courses. Students who complete an AP course may take the test offered in that subject, and those who earn a passing score can earn college credits. Growth

Measuring High School Graduation Rates

Historically, state education agencies have used different methods for estimating graduation rates, rendering state-by-state comparisons problematic. Experts disagree on the best method to calculate these rates, but there is wide consensus that the current calculations are badly flawed (Greene 2002; Swanson and Chapman 2003; NGA 2005).

To facilitate comparability, the National Governors Association (NGA) endorsed an adjusted cohort method in 2005, and all 50 governors agreed to work toward implementing that method (NGA 2005). Using this method, the high school graduation rate is calculated by dividing the number of graduates in a given year by the number of students who entered ninth grade 4 years earlier, adjusting the denominator for migration into and out of the state over those 4 years.

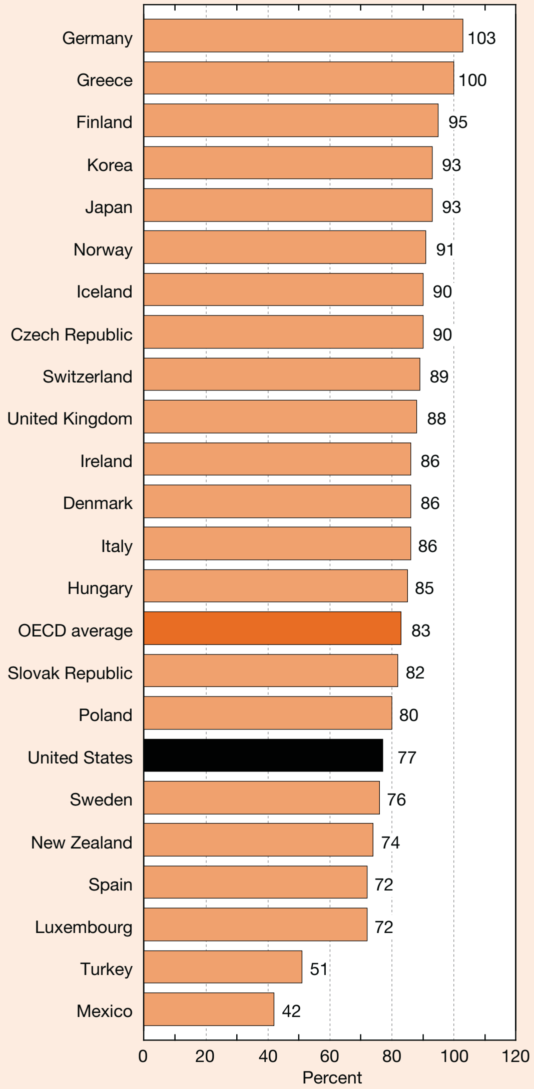
States require substantial time and funding to develop data collection, storage, and analysis procedures before they can use this method. In 2008, 16 states were calculating graduation rates using the cohort method (NGA 2008). Another 29 states planned to implement data procedures to enable such reporting by 2012. The remaining 5 states either lacked necessary data capacity or had no plans in mid-2008 to calculate rates according to this formula.

In 2008, the U.S. Department of Education directed states to use a cohort method that tracks individual students, beginning with reports for academic year 2010–11.* The following year, states must include this graduation rate as one of the measures used to document adequate yearly progress for schools that include 12th grade.

---

*Title I—Improving the Academic Achievement of the Disadvantaged, Final Rule (73 Fed. Reg. 64435 [2008]).

Figure 1-14
High school graduation rates, by OECD country: 2006



OECD = Organisation for Economic Co-operation and Development

NOTES: High school graduation rate is percentage of population at typical upper secondary graduation age (e.g., 18 years old in United States) completing upper secondary education programs. OECD average based on all OECD countries with available data. To generate estimates that are comparable across countries, rates are calculated by dividing the number of graduates in the country by the population of the typical graduation age. This can produce estimates higher than 100% if, for example, a significant number of students graduated early or late in a particular year.

SOURCE: OECD, Education at a Glance: OECD Indicators 2008 (2008).

Science and Engineering Indicators 2010

in the number of students taking AP tests was faster than growth in the number of 11th and 12th grade students: 15% of the class of 2008 earned a score of 3 or higher on at least one AP test during high school, up from 12% in the class of 2003 (College Board 2009).

The number of students taking AP tests in mathematics and science subjects has increased steadily (table 1-14; appendix table 1-19). In most subjects, this increase has been substantial, rising by at least fivefold in many subjects since 1990. The AP statistics test stands out as experiencing especially rapid growth: in 1997 slightly fewer than 7,600 students took the test, rising to more than 106,000 students in 2008. In sum, proportionately more students are taking tests, but the AP program continues to involve a relatively small proportion of high school students.

As the number of students taking AP tests has increased, so has the number passing each exam (i.e., receiving a score of 3, 4, or 5 on a scale of 1–5). Almost 250,000 students passed a mathematics AP exam in 2008, compared with a little more than 50,000 in 1990. More than 200,000 passed a science AP exam in 2008, compared with about 100,000 in 1997 and fewer than 50,000 in 1990.

While increasing numbers of students are taking and passing AP exams, passing rates have declined or remained steady in most subjects. The percentage of students passing the calculus AB, biology, and chemistry tests dropped by at least 9 points between 1990 and 2008, and in only one subject, computer science A, did the passing rate increase by more than 2 percentage points.

Generally, more students of both sexes and all racial/ethnic groups took AP tests in these subjects in 2008 than in 1997 (appendix table 1-19). Passing rates did not change by more than about 3 percentage points for most of these groups in most subjects.

Relationship of High School Courses Taken to Postsecondary Success

The rigor of states' academic standards and graduation requirements and student enrollment in advanced mathematics and science courses other than AP courses continue to increase.[23] The number of students taking advanced math and science courses increased on average between 1990 and 2005, although most of the gains in science leveled off after 2000 (NSB 2008). At 29%, precalculus/analysis had the highest completion rate among advanced mathematics courses; chemistry was the most commonly completed science course at 54%. Overall, state policies have shifted to increase the rigor of high school standards and improve preparation for college. Twenty states have published definitions of college readiness, and 11 more are working on such definitions (Editorial Projects in Education Research Center 2009b). In 2009, 23 states had aligned K–12 standards with college and employer expectations, up from only four in 2006, according to benchmarks established by the American Diploma Project, an initiative that promotes high expectations for high school graduates to prepare them for college (Achieve, Inc. 2009). Twenty states and the District

Table 1-14
Students who took Advanced Placement tests in mathematics and science and number and percentage with passing scores, by subject: 1990, 1997, and 2008

	Students taking test (*n*)			Students who passed (*n*)			Students who passed (%)		
Subject	1990	1997	2008	1990	1997	2008	1990	1997	2008
Mathematics									
Calculus AB	62,676	108,437	215,086	44,908	64,322	130,413	71.7	59.3	60.6
Calculus BC	13,096	22,349	66,785	10,728	17,630	53,370	81.9	78.9	79.9
Statistics	NA	7,551	106,534	NA	4,686	62,928	NA	62.1	59.1
Science									
Biology	32,643	69,468	150,724	20,083	46,765	75,045	61.5	67.3	49.8
Chemistry	19,289	40,803	96,458	12,366	23,693	53,103	64.1	58.1	55.1
Computer science A	NA	6,992	15,014	NA	3,288	8,537	NA	47.0	56.9
Computer science AB	NA	4,367	4,815	NA	3,129	3,526	NA	71.7	73.2
Physics B	8,826	20,610	55,227	5,375	12,320	32,848	60.9	59.8	59.5
Physics C: electricity and magnetism	3,351	5,717	11,712	2,264	3,767	8,132	67.6	65.9	69.4
Physics C: mechanics	5,499	11,740	27,237	4,086	8,309	19,911	74.3	70.8	73.1

NA = not available

NOTE: Passing scores defined as 3, 4, or 5 on scale of 1–5.

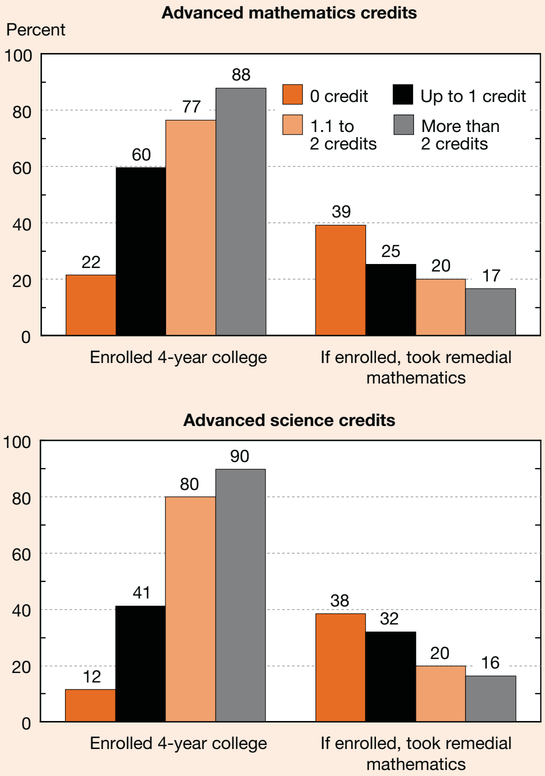
SOURCE: *Advanced Placement Program National Summary Reports, 1990, 1997–2008*. Copyright © 1997–2008, the College Board. Reproduced with permission. All rights reserved.

Science and Engineering Indicators 2010

of Columbia have raised course-taking requirements to meet standards consistent with that initiative. Nearly half of states required the class of 2008 to pass exit exams, 23 of which included math and 12 of which included science, to earn a diploma (Editorial Projects in Education Research Center 2009b). The most recent available data on courses required for high school graduation indicate that the majority of states require 3–4 math courses (36 states) and 3–4 science courses (30 states) to graduate. In addition, 26 states require specific math courses and 21 states require specific science courses. The most commonly required courses are algebra and biology. However, only a few states require advanced courses, for example, nine require algebra II (CCSSO 2009).

Taking certain high school courses, particularly advanced mathematics, is linked to postsecondary enrollment and outcomes, as many studies have shown (Adelman, Daniel, and Berkovits 2003; Horn 1997; Horn and Kojaku 2001; Horn and Nuñez 2000; Laird, Chen, and Levesque 2006; Sadler and Tai 2007). Although they do not imply causality, data from the high school class of 2004 show that the highest course students completed in mathematics and science and whether they earned advanced credits in these subjects were closely related to whether students had enrolled in a postsecondary institution by 2006 (appendix table 1-20). These indicators of better preparation in high school were also associated with a greater likelihood of enrolling in a 4-year program. For example, among students whose highest mathematics course was below algebra II (the lowest level, which also includes students with no high school mathematics course), 9% had enrolled in a 4-year program by 2006, compared with 83% of those who studied calculus. Among students with more than two advanced mathematics or science credits, 88% and 90%, respectively, had enrolled in a 4-year college (figure 1-15). High mathematics achievement

Figure 1-15
Postsecondary experiences of the class of 2004, by advanced mathematics and science credits in high school: 2006



SOURCE: National Center for Education Statistics, Education Longitudinal Study of 2002, 2006 followup (ELS: 2002/06). See appendix table 1-20.

Science and Engineering Indicators 2010

was also associated with enrollment in a 4-year institution: 76% of those with scores in the highest mathematics quartile enrolled in a 4-year college, compared with 13% of students who scored in the lowest quartile.

Conversely, taking lower-level mathematics courses was associated with enrolling in a 2-year college. Among students with no advanced mathematics credits, 33% had enrolled in a 2-year college by 2006, compared with 6% of students with two or more advanced mathematics credits.

Among 2004 high school graduates who had enrolled in postsecondary education by 2006, 30% reported that they had taken a remedial course in mathematics at the postsecondary level. Students who completed advanced mathematics and science courses were less likely to undertake postsecondary remediation in mathematics.[24] More than 40% of students whose highest high school mathematics course was less advanced than algebra II reported taking remedial mathematics at the postsecondary level, compared with 17% of students who took calculus in high school. Achievement on mathematics assessments was also related to postsecondary remediation rates: 45% of those who scored in the bottom quartile of the twelfth grade mathematics test took a remedial mathematics course in college, compared with 18% of those who scored in the top quartile.[25]

Immediate Enrollment in Postsecondary Education

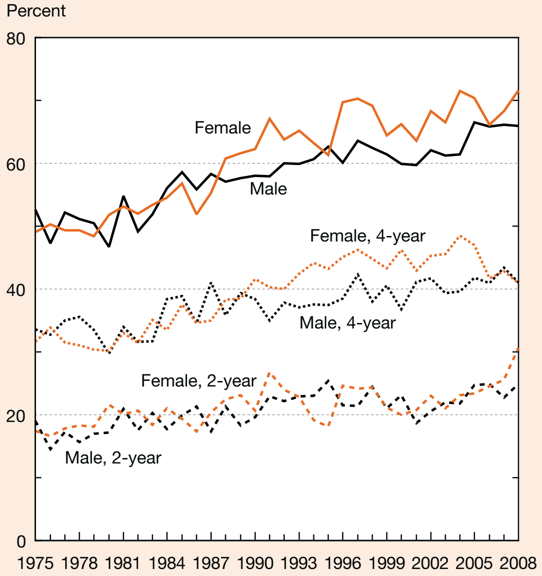
Most secondary students expect to attain a postsecondary degree. In 2007, 95% of eighth graders expected to attain a postsecondary education, and 70% planned to complete at least a bachelor's degree (Walston and Rathburn 2008). Not all meet these expectations, however: in 2008, 69% of students who completed high school (already a subset of all high school students) had enrolled in a postsecondary institution by the October following high school completion (appendix table 1-21). Wide differences in enrollment rates by family income, race/ethnicity, and parents' education persisted. In 2008, females outpaced men in immediate college enrollment 72% to 66%; most of this difference in immediate enrollment rates was accounted for by enrollment in 2-year colleges, where 31% of recently-graduated women and 25% of their male counterparts were enrolled in 2008 (figure 1-16).

Postsecondary Enrollment in an International Context

Only broad comparisons of postsecondary enrollment rates in the United States and other OECD countries are possible. By one measure, immediate entry rates, U.S. students ranked ninth, above the OECD average (table 1-15) (OECD 2009). In most OECD countries, including the United States, female enrollment rates were higher than those of males. These comparisons are complicated by differences among education systems, types of degrees awarded, and methodological issues with the measure itself.[26]

Figure 1-16

High school graduates enrolled in college in October after completing high school, by sex and type of institution: 1975–2008



NOTE: Includes students ages 16–24 completing high school in survey year.

SOURCES: National Center for Education Statistics (NCES), The Condition of Education 2009, NCES 2009-081 (2009b); U.S. Bureau of Labor Statistics, Current Population Survey (CPS), 2008 October supplement; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Conclusion

Longitudinal data from ECLS-K illustrate gaps among groups within one cohort of elementary students: students of different racial/ethnic and socioeconomic backgrounds began kindergarten with varying levels of achievement, and these gaps increased through grade 3 or 5, then stabilized through grade 8. The 2007 NAEP mathematics assessments indicate improvement in fourth and eighth graders' mathematics achievement, continuing a trend observed since 1990. Although some achievement gaps between students of different racial/ethnic backgrounds or family income decreased with this assessment, significant gaps remained.

Results of international assessments of student achievement in math and science were more mixed. U.S. fourth and eighth grade students improved in mathematics on TIMSS: 2007, both in their average score and in their standing relative to other nations' students, although their relative standing rose only slightly. In science, U.S. students' performance on TIMSS did not change, but their standing relative to their counterparts in other nations did: U.S. fourth graders lost ground to other nations' fourth graders, while U.S. eighth graders gained slightly. Among 15-year-olds, U.S. students' standing declined rela-

Table 1-15

First-time entry rates into postsecondary education in OECD countries, by sex: 2007

(Percent)

Country	Both sexes	Male	Female
Australia	86	75	96
Poland	78	72	85
New Zealand	76	63	90
Slovak Republic	74	61	87
Iceland	73	55	92
Sweden	73	62	85
Finland	71	62	80
Norway	66	52	81
United States	65	57	72
Portugal	64	57	72
Hungary	63	55	71
Korea	61	63	59
Netherlands	60	56	65
Denmark	57	45	71
OECD average	56	50	63
United Kingdom	55	48	63
Czech Republic	54	47	60
Italy	53	45	61
Japan	46	52	40
Ireland	44	41	48
Greece	43	33	55
Austria	42	38	45
Spain	41	35	48
Switzerland	39	38	40
Germany	34	34	35
Mexico	32	32	32
Belgium	30	29	31
Turkey	29	32	26

OECD = Organisation for Economic Co-operation and Development

NOTES: Table includes data on programs that provide education that is largely theoretical and is intended to provide sufficient qualifications for gaining entry to advanced research programs and professions with high-skill requirements. Entry into these programs normally requires successful completion of upper secondary education (e.g., high school); admission is competitive in most cases. Minimum cumulative theoretical duration at this level is 3 years of full-time enrollment. OECD calculates entry rates by dividing number of first-time entrants of specific age in each type of tertiary program by total population in corresponding age group and then adding results for each single year of age. Mismatches between coverage of population data and student/graduate data mean participation/graduation rates for countries that are net exporters of students may be underestimated and countries that are net importers may be overestimated.

SOURCE: OECD, Education at a Glance: OECD Indicators 2008 (2008).

Science and Engineering Indicators 2010

tive to that of other nations' students on the most recent PISA assessments in both mathematics and science.

Efforts to improve student achievement include ensuring that all students have access to highly qualified teachers, although consensus definitions of "highly qualified" in individual subjects at various grade levels have yet to emerge. From the student perspective, while 40% of fifth grade students in 2004 were taught mathematics and science by teachers with either a degree or certificate in their teaching field (i.e., in-field teachers), most students at this level (about 54%) had teachers with general education preparation. When these students reached eighth grade in 2007, more than 80% of them were taught mathematics and science by in-field teachers, and the percentage taught by mathematics and science teachers with general education preparation fell to 9%–10%. Gaps in access to teachers with these qualifications were observed, however: black and Hispanic students, students from low-income families, and students whose prior achievement was low were less likely than their counterparts to have teachers with the highest qualifications or greatest experience.

Teachers' professional development activities can strengthen subject matter knowledge and teaching abilities acquired through their formal education. Many fifth graders' teachers of mathematics and science, however, had not participated in professional development in mathematics or science. Those who had participated reported that their activities were of relatively short duration, and less than half of participants reported their activities as very useful.

Although teachers' salaries have not kept pace with those of employees in occupations with similar training requirements and responsibilities, most teachers of fifth grade students had favorable perceptions of their working conditions. Again, however, teachers of some groups of students were less likely than others to have such positive perceptions, and the differences fell along student racial/ethnic and socioeconomic lines.

By 2005, access to computers and the Internet was virtually universal and did not vary with such student characteristics. Most states include technology in their curriculum standards. In addition, increasing numbers of states are providing virtual schools and other opportunities for distance education via technology, largely at the secondary level.

In 2006, the on-time (4-year) high school graduation rate was 73%, with significant gaps observed by race/ethnicity. Looking at secondary school completion in international terms, the United States ranked 17th among 23 OECD countries with available data. New federal regulations, effective in 2011, will improve accuracy and comparability of data concerning on-time graduation among the 50 states.

Rates of immediate entry into postsecondary education after high school completion have increased substantially since 1975. Longitudinal data indicate that students who took more advanced mathematics and science courses in high school were more likely than others to undertake postsecondary education within 2 years of completing high school. Once enrolled, such students were also less likely to have reported taking remedial courses at the postsecondary level.

Notes

1. Differences between two estimates were tested using Student's *t*-test statistic to minimize the chances of concluding that a difference exists based on the sample when no true difference exists in the population from which the sample was drawn. These tests were done with a significance level of 0.05, which means that a reported difference would occur

by chance no more than once in 20 samples when there was no actual difference between the population means.

2. About 89% of the students were in eighth grade in 2006–07 because some were held back one or more grades and a very small number advanced an extra grade. The cohort members are referred to as eighth graders in 2007, and in earlier years by that year's modal grade, for ease of reading. In subsequent sections of this chapter, students called eighth graders (and information about their teachers) are restricted to those actually in eighth grade during that year.

3. These recent trends are based on data from the national NAEP program. The current national mathematics assessment for grades 4 and 8 was first administered in 1990 and was given again in 1992, 1996, 2000, 2003, 2005, and 2007. The assessment using the current grade 12 mathematics framework has been administered only once, in 2005. Recent trend analyses for grade 12 mathematics are therefore not available. The current national science assessment was first administered in 1996 and again in 2000, 2005, and the spring of 2009. Results from the 2009 administration will be available in early 2010.

4. Although the skills and knowledge tested remained similar throughout the LTT testing program, some changes were made in 2004, including replacing some test questions that used out-of-date contexts, adopting some new testing procedures, and accommodating some students' disabilities or limited English skills.

5. Trend changes for the United States' standing are shown only in two figures, 1-7 and 1-8. Text and appendix tables show data only for the most recent year for the TIMSS and PISA assessments. Thus, fewer nations in each category may appear in figures 1-7 and 1-8 compared with the relevant tables. In addition, text tables for these international tests show only nations in the selected comparison group and, for TIMSS, only those that met all of the testing body's standards. The corresponding appendix tables include all nations in the report and therefore have more nations in each category.

6. See endnote 5.

7. Teaching certification is generally awarded by state education agencies to teachers who have completed specific requirements. These requirements vary across states but typically include completing a bachelor's degree, completing a period of practice teaching, and passing some type of formal tests. States also issue other types of certification besides regular or standard certification. For example, probationary certification is generally awarded to those who have completed all the requirements except for a probationary teaching period. Provisional or temporary certification is awarded to those who still have requirements to meet. Emergency certification is issued to those with insufficient teacher preparation who must complete a regular certification program to continue teaching (Henke et al. 1997).

8. Specifically, NCLB defines a *highly qualified* elementary or secondary school teacher as someone who holds a bachelor's degree and full state-approved teaching certificate or license (excluding emergency, temporary, and provisional certificates) and who demonstrates subject-matter competency in each academic subject taught by having an undergraduate or graduate major or its equivalent in the subject; passing a test on the subject; holding a full teaching certificate in the subject; or meeting some other state-approved criteria. NCLB requires that newly hired elementary school teachers pass tests in subject-matter knowledge and teaching skills in mathematics, reading, writing, and other areas of the basic elementary school curriculum. Newly hired middle and high school teachers must either pass a rigorous state test in each academic subject they teach or have the equivalent of an undergraduate or graduate major or teaching certification in their fields.

9. In previous editions, data from the National Center for Education Statistics' Schools and Staffing Survey (SASS) have been used to highlight various aspects of teachers and teaching. However, the 2007−08 SASS data were not available for analyses at the time this chapter was prepared.

10. Typically, fifth grade teachers teach not only mathematics and science but also language arts, social studies, and other academic subjects and therefore cannot strictly be considered mathematics or science teachers. To refer to teachers who taught mathematics and science more accurately, the text uses such phrases as "teachers of mathematics and science," "teachers who taught mathematics and science," or "students who were taught mathematics and science by teachers" interchangeably.

11. Alternatives to traditional teacher education have increased in number and scope. Among various alternative programs, Teach for America (TFA) is the most prominent one (Decker, Mayer, and Glazerman 2004). TFA is designed to recruit top graduates from some of the most competitive colleges to teach in the most challenging K−12 schools throughout the nation. Although TFA has been successful in attracting college graduates (e.g., from 2000 to 2003, the number of TFA applicants grew almost fourfold, from about 4,000 to 16,000) (Decker, Mayer, and Glazerman 2004), studies that have addressed the effectiveness of TFA teachers yielded mixed results from no to significant effects (Decker, Mayer, and Glazerman 2004; Kane, Rockoff, and Staiger 2006; Xu, Hannaway, and Taylor 2007).

12. SASS teachers responded to a much longer list of possible fields for their degree major and certification than ECLS teachers, allowing more refined categorization of the variable. For more information about the definition of the subject area preparation variable in SASS, see the sidebar "In-Field and Out-of-Field Teaching" in the 2008 edition of *Science and Engineering Indicators* (NSB 2008).

13. SASS collects data on teachers, whereas ECLS collects data on students, including data about those students' teachers. This difference may contribute to the different in-field teaching estimates in the two surveys. Another difference is that SASS includes all middle school teachers, whereas ECLS data refer only to those who teach eighth grade students.

14. The Federation collects teacher salary data from each state's department of education.

15. Because teachers' annual work schedules are different from those of other professions, these researchers compared wages earned for a week of work, rather than for the entire year. Critics of this method (e.g., Podgursky and Tongrut 2006) argue that the use of weekly wages to compare teachers with other workers may bias teacher earnings downward, in that teachers report a weekly wage that may be an annual salary divided over a full year rather than the partial year they actually work. To address this concern, Allegretto, Corcoran, and Mishel (2008) used several alternative methods to compare the salaries of teachers and other workers in their 2008 study and concluded that this bias is small.

16. As part of the National Compensation Survey, the Bureau of Labor Statistics collects specific occupational skill information and rates each occupation on the level of skills required across 10 different dimensions (e.g., knowledge, complexity). Allegretto, Corcoran, and Mishel (2008) used the 6 most common occupations among the 16 identified as having skill ratings comparable to those of teachers to form the group of comparable occupations in their 2008 study. These 6 occupations are accountants, reporters, registered nurses, computer programmers, members of the clergy, and personnel officers, accounting for 83% of the employment in 16 occupations with skill ratings comparable to teaching.

17. That is, 86% of fifth grade students had teachers of mathematics and science reporting this condition.

18. "Classrooms" includes computer and other labs, library/media centers, regular classrooms, and any other rooms used for instructional purposes.

19. These numbers are counts of enrollments in each course: if students enroll in more than one course, they are counted more than once.

20. There are several other widely accepted estimates of on-time graduation rates. Using the Cumulative Promotion Index, the annual Diploma's Count report reported a nationwide rate of 69.2% (Editorial Projects in Education Research Center 2009b).

21. This measure of high school completion has its critics, however. Some believe that those who earn General Educational Development credentials should not be included with high school graduates in measures of graduation rates and also object to the base for the calculation. Because the base typically excludes incarcerated or institutionalized dropouts, critics believe this measure overestimates the high school completion rate for young people overall (Heckman and LaFontaine 2008; Pinkus 2006; Greene 2002).

22. Cited in Title I—Improving the Academic Achievement of the Disadvantaged, Final Rule (73 Fed. Reg. 64435 [2008]).

23. Advanced courses referenced in this section are defined as courses that not all students complete and that are not, as a rule, required for graduation. They include trigonometry or algebra III, precalculus or analysis, statistics or probability, any calculus, AP/IB calculus, advanced biology, chemistry, physics, environmental science, engineering, and engineering or science technologies.

24. Postsecondary transcript data are not yet available, and so information about taking remedial courses comes from student reports, which may be less accurate.

25. While rates of remediation are lower for students who achieve on tests and take courses at the highest levels, almost one in five of those students still reports taking remedial math. In part, this may be due to a lack of alignment in academic expectations between secondary and postsecondary institutions. The Education Commission of the States (ECS) tracks states' efforts to resolve these discrepancies by means of P-16 or P-20 councils, which involve stakeholders from early childhood education through college or graduate school and work to align expectations and provide seamless transitions between levels of education (ECS 2008). As of May 2008, 38 states had established a P-16 or P-20 council, and 5 more had consolidated agencies or boards that perform essentially the same function. The scope and mission of these councils vary widely, however, and there is no nationwide indicator of their accomplishments.

26. OECD measures of enrollment rates shown in table 1-15 are imperfect and have been criticized by some researchers in the United States and Europe (Wellman 2007; Adelman 2008; Kaiser and O'Heron 2005), who argue that the OECD methodology—dividing total tertiary enrollment by the population at the most common age of entry—penalizes countries, such as the United States, whose population is growing. They also contend that the differences between education systems and types of degrees awarded across countries make international comparisons problematic.

Glossary

Student Learning in Mathematics and Science

Eligibility for National School Lunch Program: Student eligibility for this program, which provides free or reduced-price lunches, is a commonly used indicator for family poverty. Eligibility information is part of the administrative data kept by schools and is based on parent-reported family income and family size.

Longitudinal studies: Researchers follow the same group of students over a period of years, such as from kindergarten through fifth grade. These studies can show achievement gains in a particular subject from grade to grade.

Repeating cross-sectional studies: This type of research focuses on how a specific group of students performs in a particular year then looks at the performance of a similar group of students at a later point in time. An example would be comparing fourth graders in 1990 to fourth graders in 2005.

Scale score: Scale scores place students on a continuous achievement scale based on their overall performance on the assessment. Each assessment program develops its own scales.

Teachers of Mathematics and Science

High schools: Schools that have at least one grade higher than 8 and no grade in K–6.

Main teaching assignment field: The field in which teachers teach the most classes in school.

Major: A field of study in which an individual has taken substantial academic coursework at the postsecondary level, implying that the individual has substantial knowledge of the academic discipline or subject area.

Middle schools: Schools that have any of grades 5–8 and no grade lower than 5 and no grade higher than 8.

Secondary schools: Schools that have any of grades 7–12 and no grade in K–6.

Teaching certification: A license or certificate awarded to teachers by the state to teach in a public school. The SASS surveys include five types of certification: (1) regular or standard state certification or advanced professional certificate; (2) probationary certificate issued to persons who satisfy all requirements except the completion of a probationary period; (3) provisional certificate issued to persons who are still participating in what the state calls an "alternative certification program"; (4) temporary certificate issued to persons who need some additional college coursework, student teaching, and/or passage of a test before regular certification can be obtained; and (5) emergency certificate issued to persons with insufficient teacher preparation who must complete a regular certification program to continue teaching.

Transition to Higher Education

Postsecondary education: The provision of a formal instructional program with a curriculum designed primarily for students who have completed the requirements for a high school diploma or its equivalent. These programs include those with an academic, vocational, or continuing professional education purpose and exclude vocational and adult basic education programs.

Advanced Placement: Courses that teach college-level material and skills to high school students who can earn college credits by demonstrating advanced proficiency on a final course exam. The curricula and exams for AP courses, available for a wide range of academic subjects, are developed by the College Board.

References

Achieve, Inc. 2009. Closing the Expectations Gap 2009. Washington, DC. http://www.achieve.org/files/50-state-2009.pdf. Accessed March 2009.

Adelman C. 2008. The Propaganda of International Comparisons. Inside Higher Ed (December 15). http://insidehighered.com/views/2008/12/15/adelman. Accessed 11 June 2009.

Adelman C, Daniel B, Berkovits I. 2003. Postsecondary Attainment, Attendance, Curriculum, and Performance: Selected Results From the NELS:88/2000 Postsecondary Education Transcript Study (PETS), 2000. NCES 2003-394. Washington, DC: National Center for Education Statistics.

Allegretto SA, Corcoran SP, Mishel L. 2008. The Teaching Penalty: Teacher Pay Losing Ground. Washington, DC: Economic Policy Institute. http://www.epi.org/books/teaching_penalty/teaching-penalty-full-text.pdf. Accessed October 2008.

Alliance for Excellent Education. 2008. Every Student Counts: The Case for Graduation Rate Accountability (Policy Brief). Washington, DC.

American Federation of Teachers (AFT). 2008. Survey and Analysis of Teacher Salary Trends 2008. Washington, DC. http://www.aft.org/salary/2007/download/AFT2007SalarySurvey.pdf. Accessed January 2009.

Angrist JD, Guryan J. 2008. Does teacher testing raise teacher quality? Evidence from state certification requirements. *Economics of Education Review* 27(5):483–503.

Baldi S, Jin Y, Skemer M, Green PJ, Herget D. 2007. Highlights From PISA 2006: Performance of U.S. 15-Year-Old Students in Science and Mathematics Literacy in an International Context. NCES 2008-016. Washington, DC: National Center for Education Statistics.

Banilower ER, Boyd SE, Pasley JD, Weiss IR. 2006. Lessons From a Decade of Mathematics and Science Reform: A Capstone Report for the Local Systemic Change through Teacher Enhancement Initiative. Chapel Hill, NC: Horizon Research, Inc. http://www.pdmathsci.net/reports/capstone.pdf. Accessed October 2008.

Barab SA, Sadler TD, Heiselt C, Hickey D, Zuiker S. 2007. Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology* 16(1):59–82. http://www.springerlink.com/content/565g824721222772/fulltext.pdf. Accessed January 2009.

Beaton AE, Gonzalez EJ. 1993. Comparing the NAEP trial state assessment results with the IAEP international results. In: Glaser R, Linn R, Bohrnstedt G, editors. *The Trial State Assessment: Prospects and Realities: Background Studies 1993.* The Third Report of the National Academy of Education Panel on the Evaluation of the NAEP Trial State Assessment: 1992 Trial State Assessment. Washington, DC: National Academy of Education.

Belfield CR. 2004. Home Schooling in the United States. New York: National Center for the Study of Privatization in Education, Teachers College, Columbia University.

Bernard RM, Abrami PC, Lou Y, Borokhovski E, Wade A, Wozney L, Wallet PA, Fiset M, Huang B. 2004, October 27. How Does Distance Education Compare to Classroom Instruction? A meta-analysis of the empirical literature. *Review of Educational Research* 74(3):379-439.

Bielick S. 2008. 1.5 Million Homeschooled Students in the United States in 2007. NCES 2009-030. Washington, DC: National Center for Education Statistics.

Bourque ML, Byrd S, editors. 2000. Student Performance Standards on the National Assessment of Educational Progress: Affirmations and Improvements. Washington, DC: National Assessment Governing Board.

Boyd D, Grossman P, Hamilton L, Loeb S, Wyckoff J. 2008. Teacher Preparation and Student Achievement. Working Paper No. 14314. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w14314.pdf. Accessed October 2008.

Boyd D, Grossman P, Lankford H, Loeb S, Wyckoff J. 2006. How changes in entry requirements alter the teacher workforce and affect student achievement. *Education Finance and Policy* 1(2):176–215.

Campbell ME, Haveman R, Wildhagen T, Wolfe BL. 2008. Income inequality and racial gaps in test scores. In: Magnuson K, Waldfogel J, editors. *Steady Gains and Stalled Progress: Inequality and the Black-White Test Score Gap.* New York: Russell Sage Foundation. p 110–36.

Campuzano L, Dynarski M, Agodini R, Rall K. 2009. Effectiveness of Reading and Mathematics Software Products: Findings from Two Student Cohorts. NCES 2009-4041. Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute for Education Sciences, U.S. Department of Education.

Cavanaugh C. 2001. The effects of interactive distance education technologies in K–12 learning: A meta-analysis. *International Journal of Educational Telecommunications* 7(1):73–88.

Cavanaugh C, Gillan KJ, Kromrey K, Hess M, Blomeyer R. 2004. *The Effects of Distance Education on K–12 Student Outcomes: A Meta-Analysis.* Naperville, IL: Learning Point Associates.

Clewell BC, Cohen CC, Campbell PB, Perlman L, Deterding N, Manes S, Tsui L, Rao SNS, Branting B, Hoey L, Carson R. 2004. Review of Evaluation Studies of Mathematics and Science Curricula and Professional Development Models. Washington, DC: The Urban Institute. http://www.urban.org/UploadedPDF/411149.pdf. Accessed October 2008.

Clotfelter CT, Ladd HF, Vigdor JL. 2007. How and Why Do Teacher Credentials Matter for Student Achievement? Working Paper No. 12828. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w12828.pdf. Accessed October 2008.

College Board AP. 2009. AP Report to the Nation. New York. http://www.collegeboard.com/apreport. Accessed June 2009.

Corcoran SP, Evans WN. 2008. The role of inequality in teacher quality. In: Magnuson K, Waldfogel J, editors. *Steady Gains and Stalled Progress: Inequality and the Black-White Test Score Gap*. New York: Russell Sage Foundation. p 212–49.

Correnti R. 2007. An empirical investigation of professional development effects on literacy instruction using daily logs. *Educational Evaluation and Policy Analysis* 29(4):262–95.

Council of Chief State School Officers (CCSSO). 2008. Does Teacher Professional Development Have Effects on Teaching and Learning? Evaluation Findings from Programs in 14 States. Washington, DC. http://hub.mspnet.org/media/data/Final_CCSSO_PD_final_cross_state_report_4_15_08_.pdf?media_000000002704.pdf. Accessed June 2009.

Council of Chief State School Officers (CCSSO). (2009). Key State Policies on PK-12 Education: 2007–2008. Washington, DC.

Cronin J, Dahlin M, Adkins D, Kingsbury GG. 2007. The Proficiency Illusion. Washington, DC: Thomas B. Fordham Institute and Northwest Evaluation Association.

Croninger RG, Rice JK, Rathbun A, Nishio M. 2003. Teacher Qualifications and First Grade Achievement: A Multilevel Analysis. College Park, MD: Center for Education Policy and Leadership, University of Maryland. http://www.education.umd.edu/EDPA/CEPAL/pdf/oc-papers/CEPAL-OP-03-2.pdf. Accessed October 2008.

Darling-Hammond L. 2000. Solving the Dilemmas of Teacher Supply, Demand, and Standards: How We Can Ensure a Competent, Caring, and Qualified Teacher for Every Child. New York: National Commission on Teaching & America's Future.

Darling-Hammond L, Holtzman DJ, Gatlin SJ, Heilig JV. 2005. Does teacher preparation matter? Evidence about teacher certification, Teach for America, and teacher effectiveness. *Education Policy Analysis Archives* 13(42). http://epaa.asu.edu/epaa/v13n42/. Accessed October 2008.

Darling-Hammond L, Youngs P. 2002. Defining "highly qualified teachers": What does "scientifically-based research" actually tell us? *Educational Researcher* 31(9):13–25.

Daro P, Stancavage F, Ortega M, DeStefano L, Linn R. 2007. Validity Study of the NAEP Mathematics Assessment: Grades 4 and 8. Palo Alto, CA: NAEP Validity Studies Panel.

Davis EA, Petish D, Smithey J. 2006. Challenges new science teachers face. *Review of Educational Research* 76(4):607–51.

Decker PT, Mayer DP, Glazerman S. 2004. Effects of Teach For America on Students: Findings from a National Evaluation. No. 8792-750. Princeton, NJ: Mathematica Policy Research, Inc. http://www.mathematica-mpr.com/publications/pdfs/teach.pdf. Accessed February 2009.

Desimone L, Porter AC, Garet M, Yoon KS, Birman B. 2002. Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis* 24(2):81–112.

Dynarski M, Agodini R, Heaviside S, Novak T, Carey N, Campuzano L, Means B, Murphy R, Penuel W, Javitz H, Emery D, Sussex W. 2007. Effectiveness of Reading and Mathematics Software Products: Findings from the First Student Cohort. Washington, DC: National Center for Education Evaluation, Institute for Education Sciences, U.S. Department of Education. http://ies.ed.gov/ncee/pdf/20074006.pdf. Accessed January 2009.

Editorial Projects in Education Research Center. 2009a. Technology Counts 2009: Breaking away from tradition: E-Education expands opportunities for raising achievement. *Education Week* 28(26).

Editorial Projects in Education Research Center. 2009b. Diplomas Count 2009: Broader Horizons. *Education Week* 28(34). http://www.edweek.org/ew/toc/2009/06/11/index.html. Accessed June 2009.

Education Commission of the States (ECS). 2008. State Notes. Denver, CO. http://mb2.ecs.org/reports/Report.aspx?id=910. Accessed 11 June 2009.

Education Technology Cooperative, Southern Regional Education Board. 2007. Report on State Virtual Schools. Atlanta, GA. http://www.sreb.org/programs/edTech/SVS/2007_report_on_state_virtual_schools.pdf. Accessed July 2008.

Education Technology Cooperative, Southern Regional Education Board. 2008. Report on State Virtual Schools. Atlanta, GA. http://www.sreb.org/programs/EdTech/SVS/2008_report_on_state_virtual_schools.pdf. Accessed January 2009.

The Education Trust. 2008. Core Problems: Out-of-Field Teaching Persists in Key Academic Courses and High-Poverty Schools. Washington, DC: The Education Trust. http://www2.edtrust.org/NR/rdonlyres/0D6EB5F1-2A49-4A4D-A01B-881CD2134357/0/SASSreportCoreProblems.pdf. Accessed November 2008.

Garet MS, Porter AC, Desimone L, Birman BF, Yoon KS. 2001. What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal* 38(4):915–45.

Gitomer DH. 2007. Teacher Quality in a Changing Policy Landscape: Improvements in the Teacher Pool. Princeton, NJ: Educational Testing Service. http://www.ets.org/Media/Education_Topics/pdf/TQ_full_report.pdf. Accessed February 2009.

Goe L. 2008. Using Value-Added Models to Identify and Support Highly Effective Teachers. Washington, DC: The National Comprehensive Center for Teacher Quality. http://www2.tqsource.org/strategies/het/UsingValueAddedModels.pdf. Accessed October 2008.

Goldstein H. 2004. International comparisons of student attainment: Some issues arising from the PISA study. *Assessment in Education: Principles, Policy & Practice* 11(3):319–30. http://www.informaworld.com/smpp/content~db=all~content=a713667538. Accessed 28 September 2009.

Gonzales P, Guzman JC, Partelow L, Pahlke E, Jocelyn L, Kastberg D, Williams T. 2004. Highlights From the Trends in International Mathematics and Science Study: TIMSS 2003. NCES 2005-005. Washington, DC: National Center for Education Statistics.

Gonzales P, Williams T, Jocelyn L, Roey S, Kastberg D, Brenwald S. 2008. Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context. NCES 2009–001. Washington, DC: National Center for Education Statistics.

Greenberg J, Walsh K. 2008. No Common Denominator. Washington, DC: National Council on Teacher Quality.

Greene JP. 2002. High School Graduation Rates in the United States. New York: The Manhattan Institute for Policy Research. http://www.manhattan-institute.org/html/cr_baeo.htm. Accessed January 2009.

Grissmer D, Eiseman E. 2008. Can gaps in the quality of early environments and noncognitive skills help explain persisting black-white achievement gaps? In: Magnuson K, Waldfogel J, editors. *Steady Gains and Stalled Progress: Inequality and the Black-White Test Score Gap.* New York: Russell Sage Foundation. p 139–80.

Guarino CM, Hamilton LS, Lockwood JR, Rathburn AH. 2006. Teacher Qualifications, Instructional Practices, and Reading and Mathematics Gains of Kindergartners. NCES 2006-031. Washington, DC: National Center for Education Statistics.

Guarino CM, Santibanez L, Daley GA. 2006. Teacher recruitment and retention: A review of the recent empirical literature review. *Review of Educational Research* 76(2):173–208.

Hanushek EA, Kain JF, O'Brien DM, Rivkin SG. 2005. The Market for Teacher Quality. Working Paper No. 11154. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w11154. Accessed November 2008.

Hanushek EA, Kain JF, Rivkin SG. 2004. Why public schools lose teachers. *Journal of Human Resources* 39(2):326–54.

Hanushek EA, Rivkin SG. 2007. Pay, Working Conditions, and Teacher Quality. Palo Alto, CA: Hoover Institution, Stanford University. http://edpro.stanford.edu/hanushek/admin/pages/files/uploads/FOC_publication%20version.pdf. Accessed January 2009.

Harris DN, Sass TR. 2007. The Effects of NBPTS-Certified Teachers on Student Achievement. Working Paper No. 4. Washington, DC: National Center for Analysis of Longitudinal Data in Education Research, The Urban Institute. http://www.caldercenter.org/PDF/1001060_NBPTS_Certified.pdf. Accessed October 2008.

Hawley WD, Valli L. 2001. The essentials of effective professional development: A new consensus. In: Boesel D, editor. *Continuing Professional Development.* Washington, DC: National Library of Education. p 1–17.

Heck DJ, Rosenberg SL, Crawford RA. 2006. LSC Teacher Questionnaire Study: A Longitudinal Analysis of Data Collected Between 1997 and 2006. Chapel Hill, NC: Horizon Research, Inc. http://www.pdmathsci.net/reports/heck_rosenberg_crawford_2006a.pdf. Accessed October 2008.

Heckman JJ, LaFontaine PA. 2008. The Declining American High School Graduation Rate: Evidence, Sources, and Consequences. Research Summary. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/reporter/2008number1/heckman.html. Accessed December 2008.

Henke RR, Choy SP, Chen X, Geis S, Alt MN. 1997. America's Teachers: Profile of a Profession, 1993–94. NCES 97-460. Washington, DC: National Center for Education Statistics.

Hill HC, Rowan B, Ball DL. 2005. Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal* 42(2):371–406.

Horn L. 1997. Confronting the Odds: Students at Risk and the Pipeline to Higher Education. NCES 98-094. Washington, DC: National Center for Education Statistics.

Horn L, Kojaku LK. 2001. High School Academic Curriculum and the Persistence Path Through College. NCES 2001-163. Washington, DC: National Center for Education Statistics.

Horn L, Nuñez A-M. 2000. Mapping the Road to College: First-Generation Students' Math Track, Planning Strategies, and Context of Support. NCES 2000-153. Washington, DC: National Center for Education Statistics.

Ingersoll RM. 2001. Teacher turnover and teacher shortages: An organizational analysis. *American Educational Research Journal* 38(3):499–534.

Ingersoll RM. 2003. Out-of-Field Teaching and the Limits of Teacher Policy. Document R-03-5. Seattle, WA: University of Washington, Center for the Study of Teaching and Policy. http://depts.washington.edu/ctpmail/PDFs/LimitsPolicy-RI-09-2003.pdf. Accessed October 2008.

International Society for Technology in Education (ISTE). 2007. National Educational Technology Standards and Performance Indicators for Students. Washington, DC. http://www.iste.org/Content/NavigationMenu/NETS/ForStudents/2007Standards/NETS_for_Students_2007_Standards.pdf. Accessed January 2009.

International Technology Education Association (ITEA). 2007. Washington, DC. Standards for Technological Literacy: Content for the Study of Technology. http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf. Accessed May 2009.

Jencks C, Phillips M. 1998. *The Black-White Test Score Gap.* Washington, DC: Brookings Institution Press.

Johnson E, Cohen J, Chen W-H, Jiang T, Zhang Y. 2005. 2000 NAEP—1999 TIMSS Linking Report. NCES 2005–01. Washington, DC: National Center for Education Statistics.

Johnson EG, Siegendorf A. 1998. Linking the National Assessment of Educational Progress and the Third International Mathematics and Science Study: Eighth-Grade Results. NCES 98-500. Washington, DC: National Center for Education Statistics.

Johnson SM, Berg JH, Donaldson ML. 2005. Who Stays in Teaching and Why? A Review of the Literature on Teacher Retention. Cambridge, MA: Harvard Graduate School of Education. http://assets.aarp.org/www.aarp.org_/articles/NRTA/Harvard_report.pdf. Accessed October 2008.

Kaiser F, O'Heron H. 2005. Myths and Methods on Access and Participation in Higher Education in International Comparison. Enschede, The Netherlands: Center for Higher Education Policy Studies. http://www.minocw.nl/documenten/bgo119.pdf. Accessed January 2009.

Kane TJ, Rockoff JE, Staiger DO. 2006. What Does Certification Tell Us About Teacher Effectiveness? Evidence from New York City. Working Paper 12155. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w12155. Accessed February 2009.

Kerr M. 2008, October 6. Governing Board Awards WestEd Contract to Develop First-Ever Technological Literacy Framework. San Francisco: WestEd. http://www.wested.org/cs/we/view/rs_press/74. Accessed May 2009.

Ketelhut DJ. 2007. The impact of student self-efficacy on scientific inquiry skills: An exploratory investigation in River City, a multi-user virtual environment. *Journal of Science Education Technology* 16(1):99–111. http://www.springerlink.com/content/p006mh0776u28384/fulltext.pdf. Accessed January 2009.

Laird J, Cataldi EF, KewalRamani A, Chapman C. 2008. Dropout and Completion Rates in the United States: 2006. NCES 2008-053. Washington, DC: National Center for Education Statistics.

Laird J, Chen X, Levesque K. 2006. The Postsecondary Educational Experiences of High School Career and Technical Education Concentrators: Selected Results From the NELS:88/2000 Postsecondary Education Transcript Study (PETS) 2000. NCES 2006-309. Washington, DC: National Center for Education Statistics.

Lee J, Grigg WS, Dion GS. 2007. The Nation's Report Card: Mathematics 2007. NCES 2007–494. Washington, DC: National Center for Education Statistics.

Lines PM. 2003. Support for Home-Based Education: Pioneering Partnerships Between Public Schools and Families Who Instruct Their Children at Home. Eugene, Oregon: ERIC Clearinghouse on Assessment & Evaluation.

Lips D, Feinberg E. 2008. Homeschooling: A Growing Option in American Education. No. 2122. Washington, DC: The Heritage Foundation. http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/3d/d6/66.pdf. Accessed February 2009.

Loeb S, Reininger M. 2004. Public Policy and Teacher Labor Markets: What We Know and Why It Matters. East Lansing, MI: The Education Policy Center at Michigan State University. http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/1b/ab/d9.pdf. Accessed October 2008.

Loveless T. 2006. *The 2006 Brown Center Report on American Education: How Well Are American Students Learning?* Washington, DC: Brookings Institution Press.

Loveless T. 2008. *The Misplaced Math Student: Lost in Eighth-Grade Algebra.* Washington, DC: Brookings Institution Press.

Loveless T. 2009. *The 2008 Brown Center Report on American Education: How Well Are American Students Learning?* Washington, DC: Brookings Institution Press.

Magnuson K, Rosenbaum DT, Waldfogel J. 2008. Inequality and black-white achievement trends in the NAEP. In: Magnuson K, Waldfogel J, editors. *Steady Gains and Stalled Progress: Inequality and the Black-White Test Score Gap.* New York: Russell Sage Foundation. p 33–65.

Martin MO, Mullis IVS, Foy P, Olson JF, Erberber E, Preuschoff C, Galia J. 2008. TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

McGrath DJ, Holt EW, Seastrom MM. 2005. Qualifications of Public Secondary School Biology Teachers, 1999–2000. Washington, DC: National Center for Education Statistics.

Miller DC, Sen A, Malley LB, Burns SD. 2009. Comparative Indicators of Education in the United States and Other G-8 Countries: 2009. NCES 2009-039. Washington, DC: National Center for Education Statistics, Institute of Education Science.

Morton BA, Peltola P, Hurwitz MD, Orlofsky GF, Strizek GA. 2008. Education and Certification Qualifications of Departmentalized Public High School-Level Teachers of Core Subjects: Evidence from the 2003–04 Schools and Staffing Survey. Washington, DC: National Center for Education Statistics.

Mullis IVS, Martin MO, Foy P, Olson JF, Preuschoff C, Erberber E, Arora A, Galia J. 2008. TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

National Center for Education Statistics (NCES). 2006a. The Nation's Report Card: Mathematics 2005. NCES 2006-453. Washington, DC.

National Center for Education Statistics (NCES). 2006b. The Nation's Report Card: Science 2005. NCES 2006-466. Washington, DC.

National Center for Education Statistics (NCES). 2007a. A Brief Profile of America's Public Schools. NCES 2007-379. Washington, DC.

National Center for Education Statistics (NCES). 2007b. Mapping 2005 State Proficiency Standards Onto the NAEP Scales. NCES 2007-482. Washington, DC.

National Center for Education Statistics (NCES). 2009a. The Nation's Report Card: Mathematics 2009. NCES 2010-451. Washington, DC.

National Center for Education Statistics (NCES). 2009b. The Condition of Education 2009. NCES 2009-081. Washington, DC.

National Governors Association (NGA). 2005. Graduation Counts. Washington, DC: NGA Center for Best Practices. http://www.nga.org/Files/pdf/0507GRAD.PDF. Accessed November 2008.

National Governors Association (NGA). 2007. Building a Science, Technology, Engineering and Math Agenda. Washington DC. http://www.nga.org/Files/pdf/0702INNOVATIONStem.pdf. Accessed January 2009.

National Governors Association (NGA). 2008. Implementing Graduation Counts: State Progress to Date. Washington, DC: NGA Center for Best Practices. http://www.nga.org/Files/pdf/0807GRADCOUNTS.PDF. Accessed November 2008.

National Mathematics Advisory Panel (NMP). 2008. *Foundations for Success: The Final Report of the National Mathematics Advisory Panel.* Washington, DC: U.S. Department of Education.

National Research Council. 2007. *Taking Science to School: Learning and Teaching Science in Grades K–8.* Washington, DC: The National Academies Press.

National Science Board (NSB). 2006. *Science and Engineering Indicators 2006.* NSB 06-01. Arlington, VA: National Science Foundation.

National Science Board (NSB). 2007. *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System.* NSB 07-114. Arlington, VA: National Science Foundation.

National Science Board (NSB). 2008. *Science and Engineering Indicators 2008.* NSB 08-01. Arlington, VA: National Science Foundation.

Neidorf TS, Binkley M, Gattis K, Nohara D. 2006. Comparing Mathematics Content in the National Assessment of Educational Progress (NAEP), Trends in International Mathematics and Science Study (TIMSS), and Program for International Student Assessment (PISA) 2003 Assessments. NCES 2006-029. Washington, DC: National Center for Education Statistics.

Nelson BC. 2007. Exploring the use of individualized, reflective guidance in an educational multi-user virtual environment. *Journal of Science Education and Technology* 16(1):83–97. http://www.springerlink.com/content/rrx785r86w355268/fulltext.pdf. Accessed January 2009.

Neulight N, Kafai YB, Kao L, Foley B, Galas C. 2007. Children's participation in a virtual epidemic in the science classroom: Making connections to natural infection diseases. *Journal of Science Education and Technology* 16(1):47–58. http://www.springerlink.com/content/e312w7l681h38342/fulltext.pdf. Accessed January 2009.

Nickerson JV, Corter JE, Esche SK, Chassapis C. 2007. A model for evaluating the effectiveness of remote engineering laboratories and simulations in education. *Computers and Education* 49(3) (November):708–25. Elsevier.

Nye B, Konstantopoulos S, Hedges LV. 2004. How large are teacher effects? *Educational Evaluation and Policy Analysis* 26(3):237–57.

Office of Educational Technology. 2004. Toward a New Golden Age in American Education. Washington, DC: U.S. Department of Education. http://www.ed.gov/about/offices/list/os/technology/plan/2004/site/docs_and_pdf/

National_Education_Technology_Plan_2004.pdf. Accessed January 2009.

Organisation for Economic Co-operation and Development (OECD). 2001. *Knowledge and Skills for Life: Forst Results from the OECD Programme for International Student Assessment (PISA) 2000*. Paris, France.

Organization for Economic Co-operation and Development (OECD). 2007. *PISA 2006 Science Competencies for Tomorrow's World. Volume 1—Analysis.* Paris, France.

Organisation for Economic Co-operation and Development (OECD). 2009. *Education at a Glance 2009: OECD Indicators.* Paris, France. http://www.oecd.org/document/24/0,3343,en_2649_39263238_43586328_1_1_1_1,00.html. Accessed October 2009.

Parsad B, Lewis L. 2008. Distance Education at Degree-Granting Postsecondary Institutions: 2006–07. NCES 2009-044. Washington, DC: National Center for Education Statistics.

Pashley PJ, Phillips GW. 1993. Toward World-Class Standards: A Research Study Linking International and National Assessments. Princeton, NJ: Education Testing Service.

Pellegrino JW, Jones LR, Mitchell KJ, editors. 1999. *Grading the Nation's Report Card: Evaluating NAEP and Transforming the Assessment of Educational Progress.* Washington, DC: National Academies Press.

Penuel WR, Fishman BJ, Yamaguchi R, Gallagher LP. 2007. What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal* 44(4):921–58.

Peterson PE, Hess FM. 2008. Few states set world-class standards. *Education Next* 8(3) (Summer):70–73.

Phillips GW. 2007. Expressing International Educational Achievement in Terms of U.S. Performance Standards: Linking NAEP Achievement Levels to TIMSS. Washington, DC: American Institutes for Research.

Picciano AG, Seaman J. 2007. K–12 Online Learning: A Survey of U.S. School District Administrators. Needham, MA: Sloan Consortium. http://www.sloan-c.org/publications/survey/pdf/K-12_Online_Learning.pdf. Accessed January 2009.

Pinkus L. 2006. Who's Counted? Who's Counting? Understanding High School Graduation Rates. Washington, DC: Alliance for Excellent Education.

Podgursky M, Tongrut R. 2006. (Mis-)measuring the relative pay of public school teachers. *Education Finance and Policy* 1(4):425–40.

Porter A, Garet MS, Desimone L, Yoon KS, Birman BF. 2000. Does Professional Development Change Teaching Practice? Results From a Three-Year Study. Doc #2000-04. Washington, DC: U.S. Department of Education. http://www.ed.gov/rschstat/eval/teaching/epdp/report.pdf. Accessed October 2008.

Princiotta D, Flanagan KD, Germino Hausken E. 2006. Fifth Grade: Findings From the Fifth Grade Follow-up of the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99. NCES 2006-038. Washington, DC: National Center for Education Statistics.

Rampey BD, Dion GS, Donahue PL. 2009. NAEP 2008 Trends in Academic Progress. NCES 2009-479. Washington, DC: National Center for Education Statistics, Institute of Education Sciences.

Rice JK. 2003. Teacher Quality: Understanding the Effectiveness of Teacher Attributes. Washington, DC: Economic Policy Institute.

Richardson V, Placier P. 2001. Teacher change. In: Richardson V, editor, *Handbook of Research on Teaching*. 4th ed. New York: Macmillan.

Rockoff JE. 2004. The impact of individual teachers on students' achievement. *American Economic Review* 94(2):247–52.

Rowan B, Correnti R, Miller RJ. 2002. What large-scale, survey research tells us about teacher effects on student achievement: Insights from the "Prospects" study of elementary schools. *Teachers College Record* 104(8):1525–67.

Sadler PM, Tai RH. 2007. The two high-school pillars supporting college science. *Science* 317(5837) (July 27):457–58. AAAS.

Shimkus ES, Banilower ER. 2004. LSC Teacher Interview Study: An Analysis of Data Collected Between 1999 and 2003. Chapel Hill, NC: Horizon Research, Inc. http://www.pdmathsci.net/reports/shimkus_banilower_2004b.pdf. Accessed October 2008.

Sjøberg S. 2007, October. PISA and "real life challenges": Mission impossible? Oslo, Norway: University of Oslo.

Steinkuehler C, Duncan S. 2008. Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology* 17(6):530–43.

Stillwell R, Hoffman L. 2008. Public School Graduates and Dropouts From the Common Core of Data: School Year 2005–06, First Look. NCES 2008-353rev. Washington, DC: National Center for Education Statistics.

Stronge JH, Gareis CR, Little CA. 2006. *Teacher Pay and Teacher Quality: Attracting, Developing, and Retaining the Best Teachers.* Thousand Oaks, California: Corwin Press.

Swanson CB, Chapman D. 2003. Counting High School Graduates when Graduates Count. Washington, DC: The Urban Institute. http://www.urban.org/UploadedPDF/410641_NCLB.pdf. Accessed January 2009.

Trotter A. 2009. Tech literacy confusion. *Education Week* (Digital Directions) (January 21). http://www.edweek.org/dd/articles/2009/01/21/03techlit.h02.html. Accessed February 2009.

Tucker B. 2007. Laboratories of Reform: Virtual High Schools and Innovation in Public Education. Washington, DC: Education Sector. http://www.educationsector.org/usr_doc/Virtual_Schools.pdf. Accessed February 2009.

Tucker B. 2009. Beyond the Bubble: Technology and the Future of Student Assessment. Washington, DC: Education Sector. http://www.educationsector.org/usr_doc/Beyond_the_Bubble.pdf. Accessed February 2009.

Vigdor JL, Ludwig J. 2008. Segregation and the test score gap. In: Magnuson K, Waldfogel J, editors. *Steady Gains and Stalled Progress: Inequality and the Black-White Test Score Gap*. New York: Russell Sage Foundation. p 181–211.

Walston J, Rathburn A. 2008. Eighth Grade: First Findings From the Final Round of the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K). NCES 2008-088. Washington, DC: National Center for Education Statistics.

Watson J, Gemin B, Ryan J. 2008. Keeping Pace with K–12 Online Learning: A Review of State-Level Policy and Practice. Evergreen, CO: Evergreen Consulting Associates. http://www.kpk12.com/downloads/KeepingPace_2008.pdf. Accessed January 2008.

Waxman HC, Lin M-F, Michko GM. 2003. A Meta-Analysis of the Effectiveness of Teaching and Learning with Technology on Student Outcomes. Naperville, IL: Learning Point Associates. http://www.ncrel.org/tech/effects2/waxman.pdf. Accessed January 2009.

Wayne AJ, Youngs P. 2003. Teacher characteristics and student achievement gains: A review. *Review of Educational Research* 73(1):89–122.

Wellman JV. 2007. Apples and Oranges in the Flat World: A Layperson’s Guide to International Comparisons of Postsecondary Education. Washington, DC: American Council on Education.

Wells J, Lewis L. 2006. Internet Access in U.S. Public Schools and Classrooms: 1994–2005. NCES 2007-020. Washington, DC: National Center for Education Statistics.

Wenglinsky H. 2002. How schools matter: The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives* 10(12). http://epaa.asu.edu/epaa/v10n12/. Accessed October 2008.

West J, Denton K, Reaney L. 2000. The Kindergarten Year. NCES 2001-023. Washington, DC: National Center for Education Statistics.

Xu Z, Hannaway J, Taylor C. 2007. Making a Difference? The Effects of Teach For America in High School. Working Paper 17. Washington, DC: National Center for Analysis of Longitudinal Data in Education Research (CALDER). http://www.urban.org/UploadedPDF/411642_Teach_America.pdf. Accessed February 2009.

Xue Y, Meisels SJ. 2004. Early literacy instruction and learning in kindergarten: Evidence from the Early Childhood Longitudinal Study—Kindergarten Class of 1998–99. *American Educational Research Journal* 41:191–229.

Zandberg I, Lewis L. 2008. Technology-Based Distance Education Courses for Public Elementary and Secondary School Students: 2002–03 and 2004–05. 2008-008. Washington, DC: National Center for Education Statistics.

Chapter 2

Higher Education in Science and Engineering

List of Sidebars

List of Tables

List of Figures

Highlights

Undergraduate Education, Enrollment, and Degrees

Enrollment in U.S. higher education is projected to continue rising because of increases in the U.S. college-age population.

- Reflecting changes in the population of 18-year-olds, the number of high school graduates is expected to increase 6% between 2004–05 and 2017–18, a slower rate of growth than between 1992–93 and 2004–05 (25%).
- Postsecondary enrollment rose from 14.5 million in fall 1993 to 18.7 million in fall 2006, and is projected to increase to 20.1 million students in 2017.
- Postsecondary enrollment of all racial/ethnic groups is projected to increase, but the percentage that is white is projected to decrease to 61% in 2017, whereas the percentages that are black and Hispanic are projected to increase.

The number of S&E bachelor's degrees has risen steadily over the past 15 years.

- The number of S&E bachelor's degrees awarded reached a new peak of 485,800 in 2007.
- Most S&E fields (except computer sciences) experienced increases in the number of degrees awarded in 2007. In computer sciences, the number of bachelor's and master's degrees increased sharply from 1998 to 2004 but has decreased since then.
- S&E bachelor's degrees have consistently accounted for roughly one-third of all bachelor's degrees for the past 15 years.

The share of bachelor's degrees awarded to women increased in many major S&E fields from 1993 to 2007.

- Women have earned 58% of all bachelor's degrees since 2002; they have earned about half of all S&E bachelor's degrees since 2000, but major variations persist among fields.
- In 2007, men earned a majority of bachelor's degrees awarded in engineering, computer sciences, and physics (81%, 81%, and 79%, respectively). Women earned half or more of bachelor's degrees in psychology (77%), biological sciences (60%), social sciences (54%), agricultural sciences (50%), and chemistry (50%).
- Among fields with notable increases in the proportion of bachelor's degrees awarded to women are earth, atmospheric, and ocean sciences (from 30% to 41%); agricultural sciences (from 37% to 50%); and chemistry (from 41% to 50%).
- Women's share of bachelor's degrees in computer sciences, mathematics, and engineering has declined in recent years.

The racial/ethnic composition of those earning S&E bachelor's degrees is changing, reflecting both population change and increasing college attendance by members of minority groups.

- For all racial/ethnic groups except white, the total number of bachelor's degrees, the number of S&E bachelor's degrees, and the number of bachelor's degrees in most S&E fields has generally increased since 1995.
- Between 1995 and 2007, the proportion of S&E bachelor's degrees awarded to Asians/Pacific Islanders increased from 8% to 9%; to black students, from 7% to 8%; to Hispanic students, from 6% to 8%; and to American Indian/Alaska Native students, from 0.5% to 0.7%, although the shares to black and American Indian/Alaska Native students have remained fairly flat since 2000. The proportion of S&E degrees awarded to white students declined from 73% to 64%.
- For white students, the total number of bachelor's degrees, the number of S&E bachelor's degrees, and the number of bachelor's degrees in most S&E fields remained fairly flat from 1995 through 2001 as their numbers in the college-age population dropped but rose again through 2007.

Students in the United States on temporary visas earned only a small share (4%) of S&E bachelor's degrees in 2007.

- The number of S&E bachelor's degrees awarded to students on temporary visas increased from about 14,700 in 1995 to 18,800 in 2004 before declining to 17,400 in 2007.
- Students on temporary visas earned larger shares of bachelor's degrees in certain fields in 2007: 9% of those awarded in economics and about 10% of those awarded in electrical and industrial engineering.

Graduate Education, Enrollment, and Degrees

S&E graduate enrollment in the United States continued to rise, reaching a new peak of almost 600,000 in fall 2006.

- Following a long period of growth, graduate enrollment in S&E declined in the latter half of the 1990s but has increased steadily since 1999. First-time full-time enrollment, an indicator of future trends in enrollment, has also increased since the late 1990s.
- Graduate enrollment in computer sciences and engineering has decreased in recent years, although first-time full-time enrollment in these fields increased in 2005 and 2006.

Foreign S&E graduate students in U.S. institutions increased in fall 2006 after 2 years of decline.

- S&E graduate students on temporary visas increased from 22% to 25% of all S&E graduate students from 1993 to 2006.
- The number of first-time full-time S&E graduate students with temporary visas increased in fall 2005 and fall 2006 after declining 18% from 2001 to 2004. The increases (and previous declines) were mainly in computer sciences and engineering.

Master's degrees awarded in S&E fields increased from 86,400 in 1993 to 121,000 in 2006 but declined in 2007.

- Increases occurred in most major science fields, although the number of master's degrees awarded in engineering and computer sciences has dropped since 2004.
- The number and percentage of master's degrees awarded to women in most major S&E fields have increased since 1993.
- The number of S&E master's degrees awarded increased for all racial/ethnic groups from 1995 to 2007, and the percentage awarded to Asians/Pacific Islanders, blacks, Hispanics, and American Indians/Alaska Natives increased during that time period.

The number of S&E doctorates awarded by U.S. academic institutions reached a new peak of almost 41,000 in 2007.

- After rising from the mid-1980s through 1998, the number of S&E doctorates declined through 2002 but has increased in recent years. The largest increases were in engineering and biological/agricultural and medical/other life sciences.
- The recent growth through 2007 occurred among both U.S. citizens/permanent residents and temporary residents.

Foreign students make up a much higher proportion of S&E master's and doctoral degree recipients than of bachelor's degree recipients.

- Foreign students received 24% of S&E master's degrees, 33% of S&E doctoral degrees, and 4% of S&E bachelor's degrees in 2007.
- The number of S&E master's degrees earned by temporary residents rose from 1995 to 2004 and then dropped through 2007.
- The number of S&E doctorates earned by temporary residents rose to a new peak of 13,700 in 2007.

Most foreign recipients of U.S. S&E doctorates plan to stay in the United States after graduation.

- Among 2004–07 graduates, more than three-quarters of foreign S&E doctorate recipients with known plans reported they planned to stay in the United States and about half had accepted firm offers of employment.
- More than 90% of 2004–07 U.S. S&E doctorate recipients from China and 89% of those from India reported plans to stay in the United States, and 59% and 62%, respectively, reported accepting firm offers of employment or postdoctoral research in the United States.
- Between 2000–03 and 2004–07, the percentage reporting definite plans to stay in the United States decreased among U.S. S&E doctorate recipients from all of the top five countries/economies of origin (China, India, South Korea, Taiwan, and Canada). However, for all but Taiwan, increases in the number of doctorate recipients more than offset declines in the percentage staying.

Postdoctoral Education

The number of doctorate recipients with S&E postdoctoral appointments at U.S. universities increased to almost 50,000 in fall 2006.

- More than two-thirds of academic postdoctoral appointments were in biological and medical/other life sciences.
- Temporary visa holders accounted for 57% of S&E postdocs in 2006. They accounted for much of the increase in the number of S&E postdocs, especially in biological and medical sciences.
- The number of U.S. citizen and permanent resident S&E postdocs at these institutions increased more modestly, from approximately 16,700 in 1993 to 21,100 in 2006.
- An increasing share of academic S&E postdocs are funded through federal research grants. In fall 2006, 56% of S&E postdocs at U.S. universities were funded through this mechanism, up from 52% in 1993. Federal fellowships and traineeships funded a declining share of S&E postdocs.

International S&E Higher Education

Students in China earned about 21%, those in the European Union earned about 19%, and those in the United States earned about 11% of the more than 4 million first university degrees awarded in S&E in 2006.

- The number of S&E first university degrees awarded in China, Poland, and Taiwan more than doubled between 1998 and 2006, and those in the United States and many other countries generally increased. Those awarded in Japan decreased in recent years.
- In China, the number of first university degrees awarded in natural sciences and engineering has risen particularly sharply since 2002. In comparison, those awarded in Germany, Japan, United Kingdom, and the United States have remained relatively flat.

- In the United States, S&E degrees are about one-third of bachelor's degrees and have been for a long time. More than half of first degrees were awarded in S&E fields in Japan (63%), China (53%), and Singapore (51%).
- In the United States, about 5% of all bachelor's degrees are in engineering. In Asia about 20% are in engineering, and in China about one-third are in engineering (although the percentage has declined in recent years).

In 2006, the United States awarded the largest number of S&E doctoral degrees of any individual country, followed by China, Russia, Germany, and the United Kingdom.

- The numbers of S&E doctoral degrees awarded in China, Italy, and the United States have risen substantially in recent years. The numbers of S&E doctoral degrees in India, Japan, South Korea, and many European countries have risen more modestly.
- Women earned 40% of S&E doctoral degrees awarded in the United States in 2006, about the same as the percentages earned by women in Australia, Canada, the European Union, and Mexico. The percentage of S&E doctoral degrees earned by women ranged from less than 20% in some countries to 50% or more in others.

International migration of students and highly skilled workers expanded over the past two decades, and countries are increasingly competing for foreign students. In particular, migration of students occurred from developing countries to the more developed countries and from Europe and Asia to the United States.

- Some countries expanded recruitment of foreign students as their own populations of college-age students decreased, both to attract highly skilled workers and increase revenue for colleges and universities.
- The United States remains the destination of the largest number of foreign students worldwide (undergraduate and graduate), although its share of foreign students worldwide decreased from 25% in 2000 to 20% in 2006.
- In addition to the United States, other countries that are among the top destinations for foreign students include the United Kingdom (11%), Germany (9%), and France (8%).

Introduction

Chapter Overview

Higher education performs a number of societal functions, including developing human capital, building the knowledge base (through research and knowledge development), and disseminating, using, and maintaining knowledge (OECD 2008). S&E higher education provides the advanced skills needed for a competitive workforce and, particularly in the case of graduate S&E education, the research capability necessary for innovation. This chapter focuses on the development of human capital by higher education; chapter 5 focuses on S&E research.

Indicators presented in this chapter are discussed in the context of national and global events, including changing demographics, increasing foreign student mobility, and global competition in higher education. After declining in the 1990s, the U.S. college-age population is currently increasing and is projected to increase for the next decade. The composition of the college-age population is also changing, with Asians and Hispanics becoming an increasing share of the population. Recent enrollment and degree trends, to some extent, reflect these changes. Increases in foreign students contributed to most of the growth in overall S&E graduate enrollment in recent years, but after 11 September 2001, the number of foreign students coming to the United States for graduate education dropped. In 2006 the number of foreign S&E graduate students increased (although they have not yet regained earlier levels). Finally, although the United States has historically been a world leader in providing broad access to higher education and in attracting foreign students, many other countries are expanding their own higher education systems, providing expanded educational access to their own population, and attracting growing numbers of foreign students. The effects of these trends, as well as the effects of the recent global financial crisis on domestic and foreign student enrollment in U.S. institutions, remain to be seen.

This chapter does not address the issues of quality of higher education or demand for S&E-educated personnel. Although the quality of higher education and especially the quality of learning outcomes are important, adequate national quantitative measures of quality do not yet exist. This chapter makes no attempt to determine whether current or future trends in degrees are adequate for the expected short- or long-term needs of the labor market. For information on labor market conditions for recent S&E graduates, see chapter 3, "Labor Market Conditions for Recent S&E Graduates," particularly the sidebar "Projected Growth of Employment in S&E Occupations." Chapter 5, "Trends in Academic Employment of Doctoral Scientists and Engineers," contains information on academic employment.

Chapter Organization

This chapter describes characteristics of the U.S. higher education system and trends in higher education worldwide. It begins with characteristics of U.S. higher educational institutions providing S&E education, followed by characteristics of undergraduate education, enrollment, and degrees; graduate education, enrollment, and degrees; and postdoctoral education. Trends are discussed by field and demographic group. The chapter highlights the flow of foreign students into the United States by country and their intentions to remain in this country. The chapter then presents various international higher education indicators, including comparative S&E degree production in several world regions and the growing dependence of all industrialized countries on foreign S&E students.

The data in this chapter come from a variety of federal and nonfederal sources, primarily from surveys conducted by the National Science Foundation's (NSF's) Division of Science Resources Statistics and the National Center for Education Statistics. Most of the data in the chapter are from censuses of the population—for example, all students receiving degrees from U.S. academic institutions—and are not subject to sampling variability. When sample data are used, differences are discussed only if they are statistically significant at the 95% confidence level.

The U.S. Higher Education System

Higher education in S&E is important, because it produces an educated S&E workforce and an informed citizenry. It has also been receiving increased attention as an important component of U.S. economic competitiveness. In his 24 February 2009 address to a joint session of Congress, President Obama called for every American to commit to at least 1 year of postsecondary education. This section discusses the characteristics of U.S. higher education institutions providing S&E education as well as trends in and the characteristics of students and degree recipients.

Institutions Providing S&E Education

The U.S. higher education system consists of a large number of diverse academic institutions that vary in their missions, learning environments, selectivity, religious affiliation, types of students served, types of degrees offered, and whether public or private and for-profit or nonprofit (NCES 2008a). The number of these degree-granting institutions (including branch campuses) has increased from about 3,000 in 1975 to about 4,300 in 2007, with most of the growth in the 1970s and 1980s, and again from 2000 to 2007. The latter growth occurred largely because of growth in the number of for-profit institutions (NCES 2009b). In 2007, U.S. academic institutions awarded more than 2.9 million associate's, bachelor's, master's, and doctoral degrees; 23% of these degrees were in S&E (appendix table 2-1).

Research institutions are the leading producers of S&E degrees at the bachelor's, master's, and doctoral levels. In 2007, research institutions (i.e., doctorate-granting institutions with very high research activity) awarded 70% of S&E doctoral degrees, 40% of master's degrees, and 36% of bachelor's degrees in S&E fields. (See sidebar "Carnegie Classification of Academic Institutions.") Master's colleges and universities awarded another 28% of S&E bachelor's degrees and 25% of S&E master's degrees in 2007. Baccalaureate colleges were the source of relatively few S&E bachelor's degrees (13%) (appendix table 2-1). (See sidebar "Baccalaureate-Origins of S&E Doctorate Recipients.")

Community colleges (also known as 2-year colleges or associate's colleges) are important in preparing students to enter the workforce with certificates or associate's degrees and in preparing students to transition to 4-year colleges or universities (Karp 2008). Thus, they provide the education needed for S&E or S&E-related occupations that require less than a bachelor's degree, and they provide the first 2 years of many students' education before they transfer to an S&E program at a 4-year college or university. Community colleges serve diverse groups of students and offer a more affordable means of participating in postsecondary education. Compared with 4-year colleges, community colleges enroll greater concentrations of low-income, first-generation, minority, immigrant, part-time, older, and academically underprepared students. The more than 1,000 U.S. community colleges enrolled more than 6 million students, or about a third of all postsecondary students in the 2006–07 academic year, more than half of whom were enrolled part time (NCES 2008a).

Community colleges also act as a bridge between high school and college. Dual enrollment programs, which enable high school students to take courses that can earn them college credit, are one way to make this link. In 2002–03, 71% of U.S. public high schools offered dual credit courses, and 57% of U.S. postsecondary institutions had high school students taking courses for college credit (NCES 2005a, b). In 2006, 42 states had dual enrollment policies (WICHE 2006).

Historically, dual enrollment opportunities were offered to high-achieving, academically oriented students. However, dual enrollment programs are increasingly viewed as means to support postsecondary achievement by average-achieving students and students in career and technical education programs. Students enrolled in dual enrollment programs can take college courses on a college campus or courses taught by high school teachers certified as college adjuncts. Courses vary in their eligibility requirements and target populations. Dual enrollment programs are presumed to have many positive outcomes, including early acclimation to postsecondary education, increased high school graduation, decreased need for remediation, and success in postsecondary education. Dual enrollment helps to upgrade career and technical education curricula with high-level academic and technical experiences (Karp et al. 2008).

Carnegie Classification of Academic Institutions

The Carnegie Classification of Institutions of Higher Education is widely used in higher education research to characterize and control for differences in academic institutions. The 2005 version of the Carnegie Foundation for the Advancement of Teaching's basic classification scheme for colleges and universities is more complex than previous versions and includes subcategories, new names, and new criteria for categories. Academic institutions are categorized primarily on the basis of highest degree conferred, level of degree production, and research activity.* In this report, several categories have been aggregated for statistical purposes. The characteristics of those aggregated groups are as follows:

- *Doctorate-granting universities* include institutions that award at least 20 doctoral degrees per year. They include three subgroups based on level of research activity: very high research activity (96 institutions), high research activity (103 institutions), and doctoral/research universities (84 institutions).
- *Master's colleges and universities* include the 663 institutions that award at least 50 master's degrees and fewer than 20 doctoral degrees per year.
- *Baccalaureate colleges* include the 767 institutions for which baccalaureate degrees represent at least 10% of all undergraduate degrees and that award fewer than 50 master's degrees or 20 doctoral degrees per year.
- *Associate's colleges* include the 1,814 institutions in which all degrees are associate's degrees or bachelor's degrees account for less than 10% of all undergraduate degrees.
- *Special-focus institutions* are the 806 institutions in which at least 75% of degrees are concentrated in a single field or a set of related fields.
- *Tribal colleges* are the 32 colleges and universities that are members of the American Indian Higher Education Consortium.

---

* Research activity is based on two indices (aggregate level of research and per capita research activity) derived from a principal components analysis of data on R&D expenditures, S&E research staff, and field of doctoral degree. See http://www.carnegiefoundation.org/classifications/ for more information on the classification system and on the methodology used in defining the categories.

Baccalaureate Origins of S&E Doctorate Recipients

Although baccalaureate colleges produce relatively small numbers of undergraduate S&E degree holders compared with doctorate- and master's-granting institutions, they are important contributors to producing future S&E doctorate recipients (NSF/SRS 2008). When adjusted by the number of bachelor's degrees awarded in all fields, baccalaureate colleges as a group yield more future S&E doctorates per hundred bachelor's degrees awarded than other types of institutions, except research universities. Private institutions, whether research universities or baccalaureate colleges, outperform public institutions in the proportion of their bachelor's degree recipients who go on to receive S&E doctorates. The number of 1997–2006 S&E doctorate recipients per hundred bachelor's degrees awarded in all fields 9 years earlier is higher among private research universities and a subset of baccalaureate schools, the Oberlin 50 liberal arts schools.* The Oberlin 50 colleges have a higher yield in the social and behavioral sciences and about the same yield in the natural sciences but a far lower yield in engineering than the private research universities. In engineering, the research universities, both public and private, yield more future doctorates than either public or private baccalaureate colleges. The yield of future doctorate recipients is only partly related to the range of fields that the various types of institutions offer. Research institutions (both public and private) and the Oberlin 50 schools award more than half of their bachelor's degrees in S&E fields. Baccalaureate and master's institutions (both public and private) award approximately one-third of their bachelor's degrees in S&E fields.

Historically black colleges and universities (HBCUs) are important baccalaureate-origin institutions of black S&E doctorate recipients. In 2006, about one-third of black S&E doctorate recipients received their baccalaureate degrees from HBCUs. When the data were adjusted for the number of bachelor's degrees awarded, HBCUs as a group yielded about as many future S&E doctorates per thousand bachelor's degrees awarded as non-HBCU institutions. The Oberlin 50 colleges and the private research universities yielded the most S&E doctorate recipients per thousand black recipients of bachelor's degrees, but private HBCUs as a group have a yield similar to private baccalaureate colleges and public research universities. Similarly, Hispanic-serving institutions are important baccalaureate-origin institutions of Hispanic S&E doctorate-recipients. Because few tribal colleges or universities award bachelor's degrees in S&E, tribal colleges are not a major source of American Indian S&E doctorate recipients (NSF/SRS 2009d).

---

* The Oberlin 50 institutions are Albion College, Alma College, Amherst College, Antioch University, Barnard College, Bates College, Beloit College, Bowdoin College, Bryn Mawr College, Bucknell University, Carleton College, Colgate University, Colorado College, Davidson College, Denison University, DePauw University, Earlham College, Franklin and Marshall College, Grinnell College, Hamilton College, Hampton University, Harvey Mudd College, Haverford College, College of the Holy Cross, Hope College, Kalamazoo College, Kenyon College, Lafayette College, Macalester College, Manhattan College, Middlebury College, Mount Holyoke College, Oberlin College, Occidental College, Ohio Wesleyan University, Pomona College, Reed College, Smith College, St. Olaf College, Swarthmore College, Trinity College (CT), Union College (NY), Vassar College, Wabash College, Wellesley College, Wesleyan University, Wheaton College (IL), Whitman College, Williams College, and College of Wooster. Two of these institutions (Hampton University and Manhattan College) are now Carnegie master's-granting institutions.

Online and Distance Education

Online education and distance education enable institutions of higher education to reach a wider audience by expanding access to students in remote geographic locations and providing greater flexibility for students who have time constraints. Online education is a relatively new phenomenon and online enrollment has grown substantially over the past 5 years. Institutions believe that higher fuel costs and rising unemployment will drive increased demand for online courses in coming years (Allen and Seaman 2008).

About two-thirds of 2-year and 4-year colleges and universities offer distance education courses (table 2-1). Distance education is prevalent in public 2-year colleges (97%) and public 4-year colleges and universities (88%). A little more than half of private not-for-profit 4-year institutions offered online courses. Public 2-year colleges account for most of the enrollment (4.8 million), followed by public 4-year colleges (3.5 million). Private not-for-profit and private for-profit 4-year institutions both accounted for a little more than 1.8 million enrollments in 2006–07. Most (more than 80%) of the 3.9 million students who took at least one online course in fall 2007 were undergraduates (Allen and Seaman 2008).

Colleges and universities' most prevalent reasons for offering online courses are meeting students' need for flexible schedules (68%); offering courses to those who would not have access because of geographic, family, or work-related reasons (about two thirds); making more courses available (46%); and seeking to increase student enrollment (45%) (NCES 2009b). A smaller percentage of institutions offering programs in engineering (16%) than those offering programs in other major disciplines (psychology; social sciences and history; computer and information sciences; education; health and related sciences; business; and liberal arts and sciences, general studies, humanities) (from 24% to 33%) offered fully online programs in 2007 (Allen and Seaman 2008).

Table 2-1

Postsecondary 2- and 4-year Title IV degree-granting institutions offering distance education courses and enrollments in college-level credit-granting distance education courses, by level of education and institution type: 2006–07

		Institutions offering college-level credit-granting distance education courses (%)			Enrollments in college-level credit-granting distance education courses		
Institution type	Institutions *(n)*	Either level	Undergraduate[a]	Graduate/ first professional[a]	Either level	Undergraduate	Graduate/ first professional
All institutions	4,200	65	66	60	12,153,000	9,803,000	2,349,900
Public 2-year	1,000	97	97	na	4,844,000	4,840,000	3,700
Private for-profit 2-year	500	16	16	na	72,000	72,000	na
Public 4-year	600	88	87	82	3,502,000	2,611,000	890,900
Private not-for-profit 4-year	1,500	53	51	46	1,854,000	1,124,000	730,400
Private for-profit 4-year	300	70	70	S	1,869,000	1,144,000	724,800

na = not applicable, 2-year institutions do not offer graduate degrees, although they sometimes offer individual graduate courses; S = suppressed, reporting standards not met

[a] Based on number of institutions that had undergraduate or graduate/first professional programs in 2006–07.

NOTES: Total includes private not-for-profit 2-year institutions not reported separately. Institutions may offer both undergraduate and graduate/first professional courses. Figures rounded to nearest 100. Detail may not add to total because of rounding. Standard errors for data available in source publication.

SOURCE: National Center for Education Statistics, Distance Education at Degree-Granting Postsecondary Institutions: 2006-07, NCES 2009-044 (2009).

Science and Engineering Indicators 2010

For-Profit Institutions

The rapid growth of for-profit institutions has been seen by some as a competitive threat to public and nonprofit colleges and universities in the United States (Bailey, Badway, and Gumport 2001). Over the past 10 years, the number of for-profit institutions has grown and the number of degrees that they have awarded has more than doubled (NCES 2009a; appendix table 2-2). In 2007, about 2,800 academic institutions in the United States operated on a for-profit basis. More than half of these institutions offer less-than-2-year programs and less than half are degree-granting institutions. Of the degree-granting institutions, close to half award associate's degrees as their highest degree (NCES 2008b).

For-profit academic institutions awarded 2%–3% of S&E degrees at the bachelor's, master's, and doctoral levels and 29% of those at the associate's level in 2007. Computer sciences accounted for 97% of the associate's degrees and 86% of the bachelor's degrees awarded by for-profit institutions in science and engineering fields in 2007 (appendix table 2-3). For-profit institutions award relatively few S&E master's and doctoral degrees; those they do award are mainly in psychology. For-profit institutions are among the top institutions awarding master's and doctoral degrees in psychology. In addition, a for-profit institution, the University of Phoenix Online Campus, awarded more computer sciences bachelor's degrees than any other academic institution in the United States in 2007 (table 2-2).

Cost of Higher Education

Affordability and access to U.S. higher education institutions are perennial concerns (NCPPHE 2008; NSB 2003). In the 2008–09 academic year, average tuition and fees at 4-year colleges rose at a rate greater than inflation. Compared with the previous academic year, average tuition and fees rose 6.4% for in-state students at public 4-year colleges, 5.9% for students in private 4-year colleges, and 4.7% for students at public 2-year colleges, while the Consumer Price Index increased by 5.6% between July 2007 and July 2008 (College Board 2008). Another inflation index, the Higher Education Price Index, which measures the average relative level in the price of a fixed-market basket of goods and services purchased by colleges and universities each year, rose 3.6% in that year (Commonfund Institute 2008). For students at public 4-year colleges, tuition and fee increases over the past decade have been larger than in previous decades and the net price (that is, the published price minus grant aid and tax benefits) has risen since 2003–04 (College Board 2008). In the coming years, greater tuition increases may occur in response to state reductions in higher education funding as a result of the financial downturn that began in 2008.

Table 2-2
Top 10 colleges and universities awarding degrees in computer sciences and psychology, by level of degree: 2007

Degree/academic institution	Degrees (*n*)	Degree/academic institution	Degrees (*n*)
Computer sciences associate's		Computer sciences bachelor's	
All institutions	27,680	All institutions	42,596
ECPI College of Technology	769	University of Phoenix Online Campus	1,993
Full Sail Real World Education	333	American Intercontinental University Online	867
American Intercontinental University Online	300	Strayer University	668
Kaplan University	226	University of Maryland University College	646
Anthem College	222	Pennsylvania State University (main campus)	486
Keiser University (Ft. Lauderdale campus)	214	Colorado Technical University Online	468
ECPI Technical College (Richmond, VA)	209	DeVry University–Illinois	362
Western International University	187	Rochester Institute of Technology	355
Technical Career Institutes	177	University of Maryland Baltimore County	351
Coleman College	162	Full Sail Real World Education	330
Psychology master's		Psychology doctorates	
All institutions	18,594	All institutions	4,696
Webster University	622	Alliant International University (San Diego, CA)	249
Teachers College at Columbia University	365	Capella University	131
Troy University	316	Nova Southeastern University	91
Pepperdine University	313	Carlos Albizu University	85
Chicago School of Professional Psychology	303	Pacific Graduate School of Psychology	67
Prairie View A&M University	279	Argosy University Chicago	59
Nova Southeastern University	258	Chicago School of Professional Psychology	58
National University	246	Argosy University Sarasota	56
Alliant International University (San Diego, CA)	239	Rutgers University New Brunswick	55
Capella University	220	California Institute of Integral Studies	54

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

Undergraduate Education, Enrollment, and Degrees in the United States

Undergraduate education in S&E courses prepares students majoring in S&E for the workforce. It also prepares nonmajors to become knowledgeable citizens with a basic understanding of science and mathematics concepts. This section includes indicators related to enrollment and intentions to major in S&E fields, the need for remediation at the college level, and recent trends in the number of earned degrees in S&E fields.

Curricular Reform

Research on how students learn, as well as concern for the number of young people entering S&E, have driven numerous efforts to improve instructional materials and practices and to assess the effectiveness of curricular reforms (Fortenberry et al. 2007; Lewis and Lewis 2008; Quitadamo et al. 2008). Education innovators in all S&E fields are examining problems in student learning and designing ways to address them through integration of disciplinary knowledge and education research.

Many of these newer methods involve more interaction between students and faculty, improved technology, teamwork, and applications to real-world problems (Brainard 2007). Although research indicates that many of the newer methods are effective in improving student understanding of the scientific process and fundamental concepts, they are not widely adopted. Universities and departments are often unaware of or resistant to new models of instruction, and strong incentives to improve teaching are often lacking (Brainard 2007).

Remedial Education

Remedial education (also known as developmental education) offers below-college-level courses or instruction to students who enter college without skills in reading, writing, or mathematics adequate for college-level courses. In recent years, state university systems have moved remedial education out of 4-year colleges and universities and into community colleges. In the 2003–04 academic year, about 29% of community college students had taken at least one remedial course in their first year of study (NCES 2008a), and nearly 60% of students take at least one remedial course at some point during their college education (Attewell et al. 2006). Mathematics was the most common remedial course taken in 2004 (NCES 2008a). Although more than half of students pass remedial writing and reading courses, less than half pass their remedial mathematics courses (Attewell et al. 2006). (For information on the relationship between achievement in science and mathematics courses and postsecondary remediation rates, see chapter 1, “Relationship of High School Courses Taken to Postsecondary Success.”)

Some have recently begun to question the effectiveness of remedial education (Bailey 2009; Calcagno and Long 2008). Fewer than half of students in all remedial classes complete the required sequence of remedial courses and few of these students go on to college-level courses (Bailey 2009). States and individual colleges and universities lack consensus on the criteria and cutoff points used for assessing college readiness and on the best strategies to address poor skills. Efforts in some colleges are more effective than others. Although some students may make progress, they still may not reach college-level skills and knowledge. Various efforts have attempted to bridge the gaps in expectations between K–12 and higher education expectations for achievement (Cohen et al. 2006), and several states are currently developing initiatives to improve remedial education. Chapter 1, “Transition to Higher Education,” provides more information on the transition from high school to college as well as information specifically on states’ efforts to establish standards for transitioning into higher education.

Undergraduate Enrollment in the United States

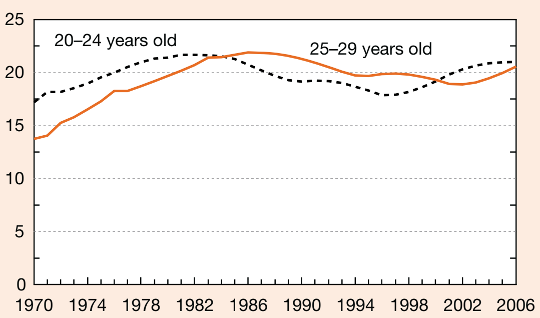
Recent trends in higher education enrollment reflect the expanding U.S. college-age population. This section examines trends in undergraduate enrollment by type of institution, field, and demographic characteristics. For information on enrollment rates of high school seniors, see chapter 1, “Transition to Higher Education.”

Trends in Enrollment and Degrees in Light of Population and Economic Trends and World Events

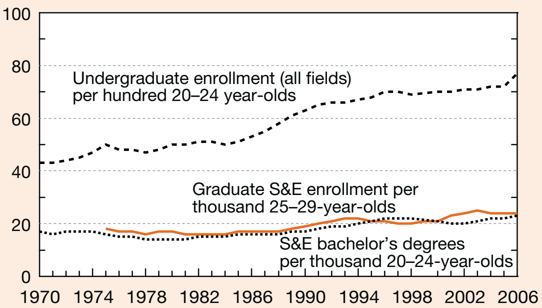
Trends in the college-age population, economic trends, and world events have influenced recent trends in college enrollment and degrees. Population trends and, to a lesser extent, economic factors are also used in projections of future enrollment and degree trends. Undergraduate enrollment, S&E bachelor’s degrees, and graduate S&E enrollment have generally risen over time at a faster rate than population growth, reflecting increases in the percentage of the population participating in higher education. The greatest gains in higher education relative to the population occurred in the 1980s (figure 2-1). The college-age (20–24-year-old) population in the United States declined through the mid-1990s, especially for whites (NSF/SRS 2007). Undergraduate enrollment in all fields and bachelor’s degrees in some fields declined in that period, and graduate S&E enrollment and S&E doctoral degrees declined a few years later. In contrast to population trends, the economy has generally grown faster than higher education enrollment and degrees. That is, enrollment and degrees have generally declined over time

Figure 2-1
Enrollment and degrees per thousand population and per billion dollars GDP: 1970–2006

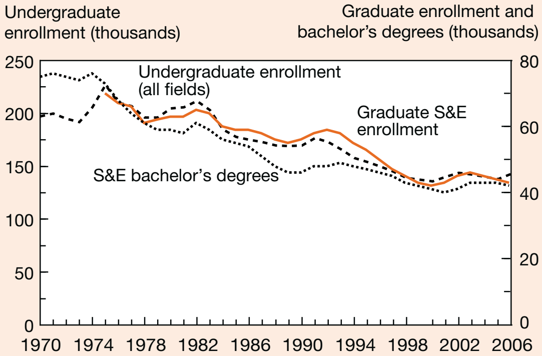
Population ages 20–24 and 25–29 years



Enrollment and degrees



Enrollment and degrees per billion dollars GDP



GDP = gross domestic product

NOTES: Data on graduate enrollment not available before 1975. Data on undergraduate enrollment and bachelor's degrees not available for 1999.

SOURCES: Population: Census Bureau, Current Population Reports, Series P-25, Nos. 1000, 1022, 1045, 1057, 1059, 1092, and 1095, and 2000 through 2008 Population Estimates; and National Center for Education Statistics (NCES), Digest of Education Statistics 2008 (NCES 2009-020), http://www.nces.ed.gov/programs/digest/d08/tables/dt08_015.asp, accessed 19 May 2009; Undergraduate enrollment and S&E bachelor’s degrees: NCES, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation/Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov; Graduate S&E enrollment: NSF/SRS, Survey of Graduate Students and Postdoctorates in Science and Engineering, and WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-12, 2-14, and 4-1.

Science and Engineering Indicators 2010

relative to the U.S. economy as measured by gross domestic product (GDP). This pattern reverses, however, in economic recessions. Upturns in enrollment and degrees relative to GDP occurred during recession periods in 1973–75, 1980–82, 1990–91, and 2001 (figure 2-1). Finally, higher education enrollment and degrees are affected by world events in very specific ways. For example the dot-com bust in the early 2000s was followed by a precipitous decline in enrollment and degrees in computer sciences, and the 9/11 attacks on the United States were followed by a steep drop in international student enrollment through 2004. (See "S&E Bachelor's Degrees" and "Foreign Undergraduate Enrollment.")

Overall Enrollment

Enrollment in U.S. institutions of higher education at all levels rose from 14.5 million students in fall 1993 to 18.5 million in fall 2007 (appendix table 2-4). More than 7 million students (about 38% of all students enrolled in higher education institutions in the United States) were enrolled in associate's colleges in 2007. Research universities (doctorate-granting universities with very high research activity) accounted for 13% and master's-granting universities accounted for 22% of all students enrolled (appendix table 2-4). (See sidebar "Carnegie Classification of Academic Institutions" for definitions of the types of academic institutions.) These trends are expected to continue in the near future.

Projections of High School Graduation and College Enrollment Trends

Because of increases in the population of 18-year-olds (rather than changes in graduation rates), the number of high school graduates is expected to increase through 2017, although at a lower rate than in the recent past. The number of high school graduates is projected to increase 6% between 2004–05 and 2017–18 to 3.3 million graduates. From 1992–93 to 2004–05, the number of high school graduates increased 25% (NCES 2008c). (See chapter 1 for more information on high school graduation rates, course taking, and transition from secondary to postsecondary education.)

Among public schools, the number of high school graduates is projected to increase 8% nationally, but large variations exist among the states, with increases projected in 27 states (mainly in the South and West) and the District of Columbia and decreases projected in 23 states (mainly in the Midwest and Northeast) (NCES 2008c). Arizona, Georgia, Nevada, Texas, and Utah are projected to have the largest percentage increases. Louisiana, Maine, North Dakota, Rhode Island, and Vermont are projected to have the largest percentage decreases in public high school graduates.

Similarly, enrollment in higher education is projected to increase through 2017. These projections are based primarily on population projections but also incorporate information about household income (a measure of ability to pay) and age-specific unemployment rates (a measure of opportunity costs).[1] According to Census Bureau projections, the number of college-age (ages 20–24) individuals is expected to grow from 21.8 million in 2010 to 28.2 million by 2050 (appendix table 2-5). From 2010 to 2050, Asians are projected to increase from 4% to 6% and Hispanics are projected to increase from 18% to 37% of the college-age population, whereas blacks are projected to decrease from 15% to 12% and whites are projected to decrease from 60% to 40% of the college-age population (NCES 2008c).

Largely because of these demographic changes, postsecondary enrollment is expected to increase 13%, to 20.1 million students, in 2017 (NCES 2008c). Increased enrollment in higher education is projected to come mainly from minority groups, particularly Hispanics. Enrollment of all racial/ethnic groups is projected to increase, but the percentage that is white is projected to decrease from 65% in 2006 to 61% in 2017, whereas the percentages that are black and Hispanic are projected to increase from 13% and 11%, respectively, to 14% for both groups. (For further information on assumptions underlying these projections, see "Projection Methodology" in *Projections of Education Statistics to 2017* [NCES 2008c], http://nces.ed.gov/programs/projections/projections2017/app_a.asp, accessed 23 June 2009.)

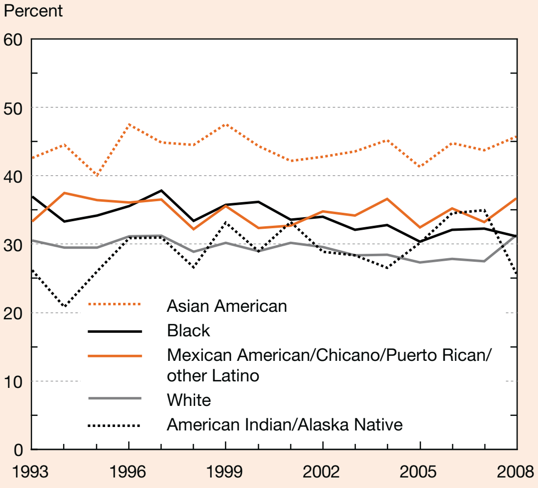
Undergraduate Enrollment in S&E

Freshmen Intentions to Major in S&E. Since 1972, the annual Survey of the American Freshman, National Norms, administered by the Higher Education Research Institute at the University of California at Los Angeles, has asked freshmen at a large number of universities and colleges about their intended majors.[2] The data provided a broadly accurate picture of degree fields several years later.[3] For at least the past two decades, about one-third of all freshmen planned to study S&E. In 2008, about one-third of white, black, Hispanic, and American Indian freshmen and 47% of Asian freshmen reported that they intended to major in S&E (figure 2-2). The proportions planning to major in S&E were higher for men than for women in every racial/ethnic group, with the exception of blacks. In 2007 and 2008, similar percentages of black men and black women planned to major in S&E (appendix table 2-6). For most racial/ethnic groups, about 10%–16% planned to major in social/behavioral sciences, about 6%–10% in engineering, about 8%–10% in biological/agricultural sciences, 1%–2% in computer sciences, 2%–3% in physical sciences,[4] and 1% in mathematics or statistics. Higher proportions of Asian freshmen than of those from other racial/ethnic groups planned to major in biological/agricultural sciences (18%) and engineering (14%). The percentage of all freshmen intending to major in computer sciences has dropped in recent years, whereas the percentage intending to major in biological/agricultural sciences has increased. (See appendix table 2-13 and "S&E Bachelor's Degrees" for trends in bachelor's degrees.) Generally, the percentages earning bachelor's degrees in particular S&E fields are similar to the percentages planning to major in those fields, with the exception of engineering and social/behavioral sciences. The percentage earning bachelor's degrees in engineering is smaller than, and the percentage earning bachelor’s degrees in social/behavioral sciences is larger than, previous years’ percentages planning to major in those fields. (See NSB 2008, pages 2-24 and 2-25, for a discussion of longitudinal data on undergraduate attrition in S&E.)

The demographic composition of students planning S&E majors has become more diverse over time. Women increased from 44% of freshmen planning S&E majors in 1993 to 47% in 2008. White students declined from 79% in 1993 to 69% in 2008. On the other hand, the proportion of Asian students increased from 6% to 12% and the proportion of Hispanic students increased from 4% to 12%. American Indian students were roughly 2% and black students were roughly 11% of freshmen intending to major in S&E in both 1993 and 2008 (appendix table 2-7).

Foreign Undergraduate Enrollment. The number of foreign students enrolled in bachelor’s degree programs in U.S. academic institutions rose 5% in the 2007–08 academic year to approximately 178,000 (IIE 2008). The increase was the second in a row after 4 years of decline, but the number of foreign undergraduates in 2007–08 was still 7% below the peak in 2001–02. Among new foreign undergraduates, enrollment increased 7% in 2007–08, the fourth increase in a row, suggesting that enrollment increases are likely to continue. South Korea (almost 33,000), Japan (almost 21,000), China (16,500), Canada (13,600), and India (13,600) accounted for the largest numbers of foreign undergraduates in the United States in 2007–08. The number of Chinese undergraduates increased 65% over the previous year and the numbers of South Korean and Indian undergraduates increased 17% and 8%, respectively. Among all foreign students (undergraduate and graduate) in 2007–08, the number of those studying the physical and life sciences increased 2%; agricultural sciences, 20%; engineering, 7%; and computer sciences, 4%, compared with the preceding year (IIE 2008). The number of foreign students studying mathematics decreased 9%.

Figure 2-2
Freshmen intending S&E major, by race/ethnicity: 1993–2008



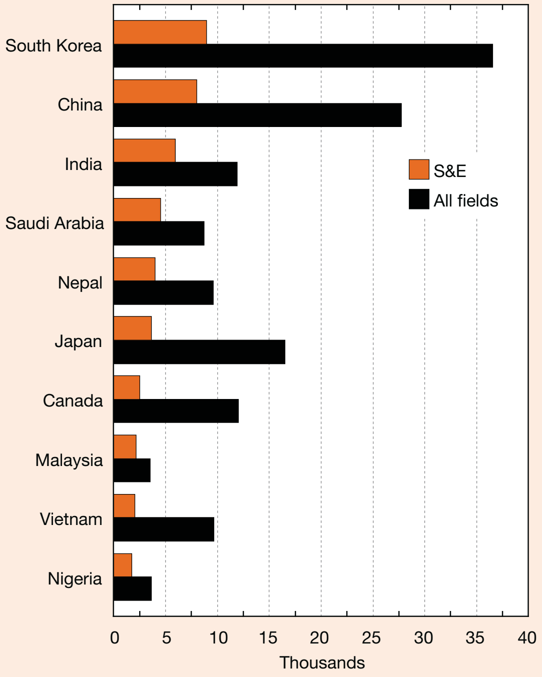
SOURCE: Higher Education Research Institute, University of California at Los Angeles, Survey of the American Freshman: National Norms, special tabulations (2009).

Science and Engineering Indicators 2010

More recent data from the Bureau of Citizenship and Immigration Services show an 11% increase in undergraduate enrollment of foreign students in science and engineering from April 2008 to April 2009, mostly in engineering. South Korea, China, Japan, Canada, and India were among the top countries sending foreign undergraduates in spring 2009 and were also among the top countries sending foreign S&E undergraduates (figure 2-3; appendix table 2-8). Nepal and Saudi Arabia, which accounted for fewer total undergraduates in the United States, were also among the top countries sending foreign undergraduates in S&E fields, sending more than Canada and Japan.

Engineering Enrollment. For the most part, undergraduate enrollment data are not available by field. Students often do not declare majors until their sophomore year; thus,

Figure 2-3
Foreign undergraduate student enrollment in U.S. universities, by top 10 places of origin and field: April 2009



SOURCE: Bureau of Citizenship and Immigration Services, Student and Exchange Visitor Information System database, special tabulations (2009). See appendix table 2-8.

Science and Engineering Indicators 2010

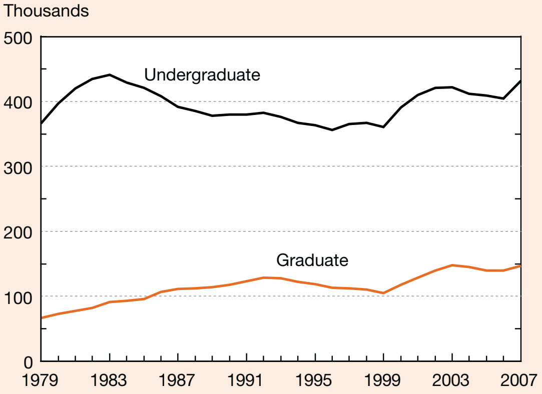
data by field would include a large proportion of missing data. However, because engineering programs generally require students to declare a major in the first year of college, engineering enrollment data can serve as early indicators of both future undergraduate engineering degrees and student interest in engineering careers. The Engineering Workforce Commission administers an annual fall survey that tracks enrollment in undergraduate and graduate engineering programs (EWC 2008).

Undergraduate engineering enrollment declined through most of the 1980s and 1990s, rose from 2000 to 2003, declined slightly through 2006, and rose to 431,900 in 2007 (figure 2-4; appendix table 2-9). The number of undergraduate engineering students in 2007 was the highest it has been since the early 1980s. Full-time freshman enrollment followed a similar pattern, reaching 110,600 in 2007, the highest since 1982. These trends correspond with declines in the college-age population through the mid-1990s, particularly the drop in white 20–24-year-olds, who account for the majority of engineering enrollment (NSF/SRS 2007). Similar trends in undergraduate engineering enrollment are reported by the American Society for Engineering Education (Gibbons 2008).

Undergraduate Degree Awards

The number of degrees awarded by U.S. academic institutions has been increasing over the past two decades both in S&E and non-S&E fields. These trends are expected to continue at least through 2017 (NCES 2008c).

Figure 2-4
Engineering enrollment, by level: 1979–2007



NOTE: Enrollment data include full- and part-time students.

SOURCE: Engineering Workforce Commission, Engineering & Technology Enrollments, various years, American Association of Engineering Societies. See appendix table 2-15.

Science and Engineering Indicators 2010

S&E Associate's Degrees

Community colleges often are an important and relatively inexpensive gateway for students entering higher education. Associate's degrees, largely offered by 2-year programs at community colleges, are the terminal degree for some people, but others continue their education at 4-year colleges or universities and subsequently earn higher degrees.[5] Many who transfer to baccalaureate granting institutions do not earn associate's degrees before transferring. Associate's degrees in S&E and engineering technology accounted for about 11% of all associate's degrees in 2007 (appendix table 2-10).

S&E associate's degrees from all types of academic institutions rose from 23,400 in 1993 to 62,800 in 2003, before declining to 47,500 in 2007. Most of the increase through 2003, and the subsequent decrease, are attributable to computer sciences, which peaked in 2003. Associate's degrees earned in engineering technology (not included in S&E degree totals because of their applied focus) declined from more than 40,000 in the early 1990s to 30,100 in 2007 (appendix table 2-10).

Women earned 62% of all associate's degrees in 2007, up from 59% in 1993. They earned a smaller and decreasing share of associate's degrees in S&E: 39% in 2007, down from 48% in 1993. Most of the decline is attributable to a decrease in women's share of computer sciences degrees, from 51% in 1993 to 26% in 2007 (appendix table 2-10).

Students from underrepresented groups (blacks, Hispanics, and American Indians) earn a higher proportion of associate's degrees than of bachelor's or more advanced degrees.[6] (See "S&E Bachelor's Degrees by Race/Ethnicity" and "Doctoral Degrees by Race/Ethnicity.") In 2007, they earned 27% of S&E associate's degrees, more than one-third of all associate's degrees in social and behavioral sciences, and more than one-quarter of all associate's degrees in biological sciences, computer sciences, and mathematics (appendix table 2-11). Since 1995, the number of S&E associate's degrees earned by these students doubled.

S&E Bachelor's Degrees

The baccalaureate is the most prevalent S&E degree, accounting for more than 70% of all S&E degrees awarded. S&E bachelor's degrees have consistently accounted for roughly one-third of all bachelor's degrees for the past 15 years. The number of S&E bachelor's degrees rose steadily from 366,000 in 1993 to 485,800 in 2007 (appendix table 2-12).

Trends in the number of S&E bachelor's degrees vary widely among fields (figure 2-5). The number of bachelor's degrees earned in social and behavioral sciences plateaued for much of the 1990s, before rising again through 2007. In engineering, mathematics, and physical sciences, the number of bachelor's degrees dropped in the late 1990s, but then rose through 2007. In computer sciences, the number of bachelor's degrees increased sharply from 1998 to 2004, then dropped sharply through 2007. Except for declines from 2000 to 2002, bachelor's degrees in biological sciences have been generally increasing, reaching a new peak in 2007 (appendix table 2-12).

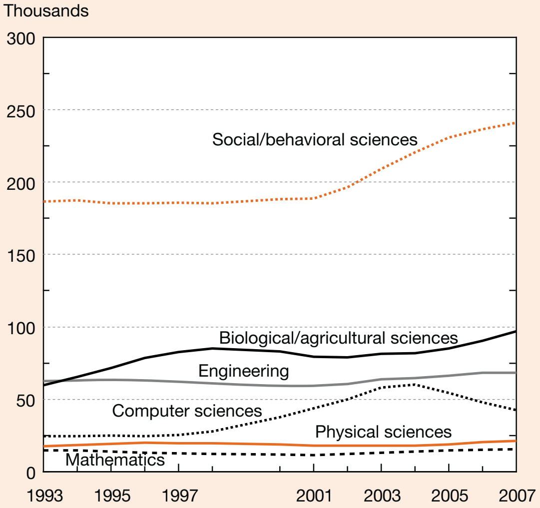
S&E Bachelor's Degrees by Sex. Since 1982, women have outnumbered men in undergraduate education and have earned relatively constant fractions of all bachelor's and S&E bachelor's degrees for several years. Since 2002, women have earned about 58% of all bachelor's degrees; since 2000, they have earned about half of all S&E bachelor's degrees. Within S&E, men and women tend to study different fields. In 2007, men earned a majority of bachelor's degrees awarded in engineering, computer sciences, and physics (81%, 81%, and 79%, respectively). Women earned half or more of bachelor's degrees in psychology (77%), agricultural sciences (50%), biological sciences (60%), chemistry (50%), and social sciences (54%) (appendix table 2-12).

Although gains in recent years have been more modest or nonexistent, the share of bachelor's degrees awarded to women in many major S&E fields has increased (except computer sciences and mathematics) over the past 15 years (figure 2-6). Among fields with notable increases in the proportion of bachelor's degrees awarded to women are earth, atmospheric, and ocean sciences (from 30% to 41%); agricultural sciences (from 37% to 50%); and chemistry (from 41% to 50%) (appendix table 2-12).

The number of bachelor's degrees awarded to women in S&E and in all fields rose from 1993 through 2007. In contrast, the number of bachelor's degrees awarded to men in S&E and in all fields remained fairly flat in the 1990s but increased from 2001 through 2007.[7]

S&E Bachelor's Degrees by Race/Ethnicity. The racial/ethnic composition of S&E bachelor's degree recipients has changed over time, reflecting population changes and increasing college attendance by members of minority groups.[8] Between 1995 and 2007, the proportion of S&E degrees awarded to white students declined from 73% to 64% (appendix table 2-13). The proportion awarded to Asians/Pacific Islanders increased from 8% to 9%; to black students, from 7% to 8%; to Hispanic students, from 6% to 8%; and to American Indian/Alaska Native students, from 0.5% to 0.7%, although the shares to black and American Indian/Alaska Native students have remained fairly flat since 2000 (figure 2-7). The number of S&E bachelor's degrees earned by white students decreased in the 1990s as their numbers in the college-age population dropped but then rose again through 2007. The number of S&E bachelor's degrees earned by students of unknown race/ethnicity also increased (appendix table 2-13). (See sidebar "Increase in Student Nonreporting of Race/Ethnicity" in *Science and Engineering Indicators 2008* [NSB 2008].)

Figure 2-5
S&E bachelor's degrees, by field: 1993–2007

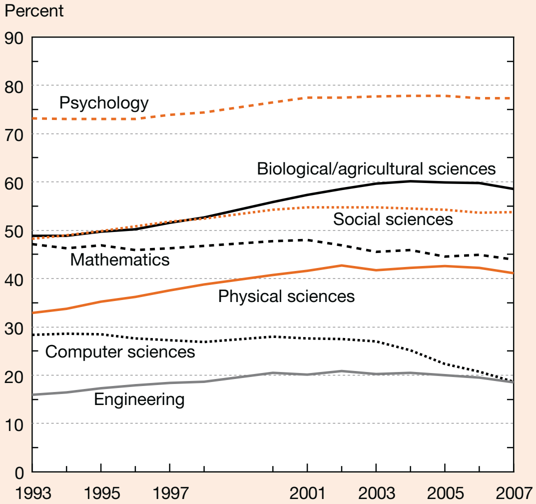


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-12.

Science and Engineering Indicators 2010

Figure 2-6
Female share of S&E bachelor's degrees, by field: 1993–2007



NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

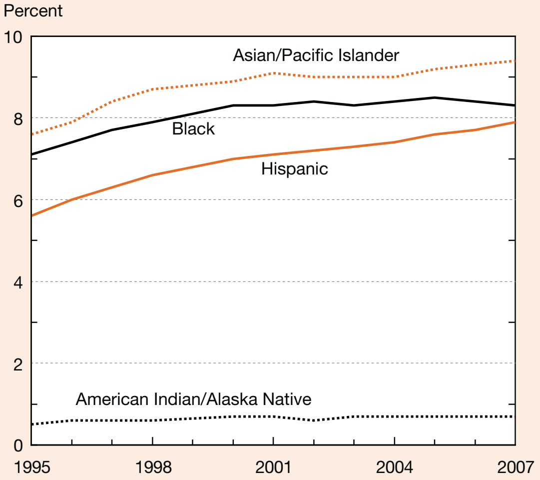
SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-12.

Science and Engineering Indicators 2010

Despite considerable progress over the past couple of decades for underrepresented minority groups earning bachelor's degrees in any field, the gap in educational attainment between young minorities and whites continues to be wide. The percentage of the population ages 25–29 with bachelor's or higher degrees was 20% for blacks, 12% for Hispanics, and 36% for whites in 2007, up from 12%, 9%, and 25%, respectively, in 1987 (NCES 2008a). Differences in completion of bachelor's degrees in S&E by race/ethnicity reflect differences in high school completion rates, college enrollment rates, and college persistence and attainment rates. In general, blacks and Hispanics are less likely than whites and Asians/Pacific Islanders to graduate from high school, to enroll in college, and to graduate from college. (For information on immediate post-high school college enrollment rates, see chapter 1, "Transition to Higher Education.") Among those who do enroll in or graduate from college, blacks, Hispanics, and American Indians/Alaska Natives are about as likely as whites to choose S&E fields; Asians/Pacific Islanders are more likely than members of other racial/ethnic groups to choose these fields. For Asians/Pacific Islanders, almost half of all bachelor's degrees received are in S&E, compared with about one-third of all bachelor's degrees earned by each of the other racial/ethnic groups (appendix table 2-13).

The contrast in field distribution among whites, blacks, Hispanics, and American Indians/Alaska Natives on the one hand and Asians/Pacific Islanders on the other is apparent within S&E fields as well. White, black, Hispanic, and American Indian/Alaska Native S&E baccalaureate recipients share a similar distribution across broad S&E fields. In 2007, between 9% and 11% of all baccalaureate recipients in each of these racial/ethnic groups earned their degrees in the natural sciences,[9] 2% to 4% in engineering, and 15% to 18% in the social and behavioral sciences. Asian/Pacific Islander baccalaureate recipients earned 19% of their bachelor's degrees in natural sciences and 9% in engineering (appendix table 2-13).

Figure 2-7
Minority share of S&E bachelor's degrees, by race/ethnicity: 1995–2007



NOTES: Data not available for 1999. Data by detailed field and race/ethnicity not available before 1995.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-13.

Science and Engineering Indicators 2010

For all racial/ethnic groups (except white), the total number of bachelor's degrees, the number of S&E bachelor's degrees, and the number of bachelor's degrees in most S&E fields (except computer sciences) has generally increased since 1995. For white students, the total number of bachelor's degrees, the number of S&E bachelor's degrees, and the number of bachelor's degrees in most S&E fields remained fairly flat from 1995 through 2001 but have increased since then (appendix table 2-13).

Bachelor's Degrees by Citizenship. Since 1995, students on temporary visas in the United States have consistently earned a small share (4%) of S&E degrees at the bachelor's level. These students earned 9% of bachelor's degrees awarded in economics in 2007 and about 10% of degrees awarded in electrical and industrial engineering. The number of S&E bachelor's degrees awarded to students on temporary visas increased from about 14,700 in 1995 to about 18,800 in 2004 before declining to 17,400 in 2007 (appendix table 2-13).

Graduate Education, Enrollment, and Degrees in the United States

Graduate S&E educational institutions are a major source of both the highly skilled workers of the future and the research needed for a knowledge-based economy. This section includes indicators related to graduate enrollment, financial support for graduate education, recent trends in the number of earned degrees in S&E fields, and participation by women, minorities, and foreign students in graduate education in U.S. academic institutions.

Graduate Enrollment in S&E

S&E graduate enrollment in the United States reached a new peak of 597,600 in fall 2006. Following a long period of growth that began in the 1970s (NSB 2008), graduate enrollment in S&E declined in the latter half of the 1990s, then increased steadily through 2006 (appendix table 2-14). Growth occurred through 2006 in most major science and engineering fields except agricultural sciences (which remained fairly flat) and computer sciences (which has been declining for several years). In engineering, enrollment dropped in recent years but rose in 2006. According to more recent data from the Engineering Workforce Commission and the American Society for Engineering Education (Gibbons 2008), graduate engineering enrollment continued to rise in 2007. Moreover, the number of full-time engineering students reached a new peak in 2007 of 104,900 (figure 2-4; appendix table 2-15).

The number of full-time students enrolled for the first time in S&E graduate departments offers a good indicator of developing trends. The number of first-time full-time S&E graduate students also reached a new peak (116,500) in 2006. It declined in the mid-1990s in all major S&E fields but increased in most fields through 2006 (appendix table 2-16). Growth was greatest in biological sciences, medical/other life sciences, and social and behavioral sciences. After declines in recent years, first-time full-time graduate enrollment in engineering and computer sciences increased in 2005 and 2006.

Enrollment by Sex

The increase in S&E graduate enrollment occurred across all major U.S. citizen and permanent resident demographic groups. The number of women enrolled in S&E graduate programs has increased steadily since 1993. In contrast, the number of men enrolled in S&E graduate programs declined from 1993 through the end of that decade before increasing through 2003 and remaining more or less at that level through 2006 (appendix table 2-14).

Women's rising percentages in S&E fields also continued. Women made up 42% of S&E graduate students in 1993 and 50% in 2006, although large variations among fields persist. In 2006, women constituted the majority of graduate students in psychology (76%), medical/other life sciences (78%), biological sciences (56%), and social sciences (54%). They constituted close to half of graduate students in earth, atmospheric, and ocean sciences (47%) and agricultural sciences (48%) and more than one-third of graduate students in mathematics (37%), chemistry (40%), and astronomy (34%). Their percentages in computer sciences (25%), engineering (23%), and physics (20%) were low in 2006, although higher than in 1993 (23%, 15%, and 14%, respectively) (appendix table 2-14).

Enrollment by Race/Ethnicity

The proportion of underrepresented minority (black, Hispanic, and American Indian/Alaska Native) students in graduate S&E programs increased from about 8% in 1993 to about 11% in 2006.[10] Increases occurred in all major science fields and in engineering during that period (appendix table 2-17). In 2006, blacks, Hispanics, and American Indians/Alaska Natives as a group made up 6%–7% of graduate enrollment in many S&E fields (engineering; mathematics; physical sciences; earth, atmospheric, and ocean sciences; and computer sciences), 8%–10% of graduate enrollment in agricultural and biological sciences, 15% in medical/other life sciences, 17% in social sciences, and 19% in psychology. Asians/Pacific Islanders accounted for about 6% of S&E graduate enrollment in 2006, up from 5% in 1993.

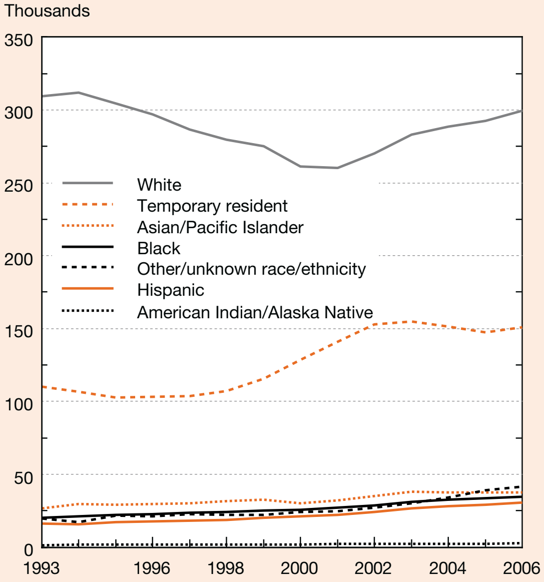
The number of white S&E graduate students decreased from 1994 to 2001 and then increased through 2006, whereas the numbers of Asian, black, Hispanic, and American Indian/Alaska Native students increased almost every year from 1993 through 2006 (figure 2-8). The rise in the numbers of black, Hispanic, and American Indian/Alaska Native graduate students occurred in most S&E fields. The number of Asian students increased in most science fields but decreased in engineering and in computer sciences in the past 3 or 4 years (appendix table 2-17).

Foreign Student Enrollment

Foreign graduate student enrollment in S&E grew from 110,300 in 1993 to 155,000 in 2003, declined for 2 years, and increased slightly in 2006 to 151,000. Foreign students increased from 22% to 25% of all S&E graduate students from 1993 to 2006 (appendix table 2-17). The concentration of foreign enrollment was highest in engineering (45%), computer sciences (44%), physical sciences (40%), mathematics (36%), and economics (52%).[11]

First-time full-time enrollment of foreign S&E graduate students increased in fall 2005 and fall 2006 after declining 18% from 2001 through 2004. The numbers still remain slightly below those of 2001 (appendix table 2-18). Declines and subsequent increases were concentrated mainly in engineering and computer sciences, fields heavily favored by

Figure 2-8
S&E graduate enrollment, by citizenship and race/ethnicity: 1993–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-17.

Science and Engineering Indicators 2010

foreign students. Foreign students' share of first-time full-time S&E graduate enrollment dropped from 35% in fall 2000 to 30% in fall 2006, with most of the decrease in computer sciences (from 71% to 62%) and engineering (from 61% to 55%) (appendix table 2-18).

According to data collected by the Institute of International Education (IIE 2009), the overall number of foreign graduate students in all fields increased 5% from academic year 2006–07 to 2007–08, with almost all of the increase occurring among master's degree students. The number of foreign doctoral students increased 0.9% to approximately 109,000, and the number of foreign master's students increased 9% to approximately 133,700. The number of new foreign graduate students rose 8%. India, China, South Korea, Taiwan, and Canada are the top places of origin for foreign graduate students. More than half of all foreign graduate students are studying S&E.

More recent data from the Bureau of Citizenship and Immigration Services show a continuing increase in foreign graduate students from April 2008 to April 2009, with foreign enrollment in S&E fields growing 8% (appendix table 2-19). As in the recent past, most of the growth was in computer sciences (up 13%) and engineering (up 11%). Two countries—India, with 56,680 foreign S&E graduate students, and China, with 36,890—accounted for more than half of the foreign S&E graduates in the United States in April 2009. South Korea, Taiwan, and Turkey also sent large numbers of S&E graduate students, although South Korea and Taiwan sent far larger numbers of graduate students in non-S&E fields (primarily business and humanities).

Financial Support for S&E Graduate Education

More than one-third of all S&E graduate students are self-supporting; that is, they rely primarily on loans, their own funds, or family funds for financial support. The other approximately two-thirds receive primary financial support from a variety of sources, including the federal government, university sources, employers, nonprofit organizations, and foreign governments.

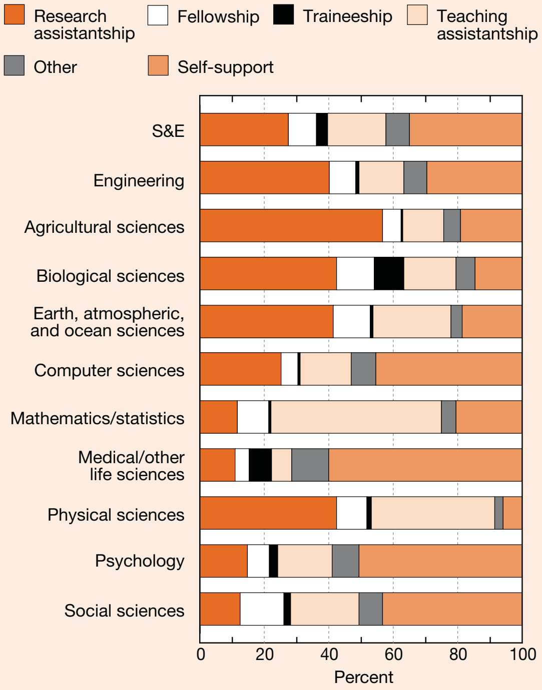
Support mechanisms include research assistantships (RAs), teaching assistantships (TAs), fellowships, and traineeships. Sources of funding include federal agency support, nonfederal support, and self-support. Nonfederal support includes state funds, particularly in the large public university systems; these funds are affected by the condition of overall state budgets. Most graduate students, especially those who pursue doctoral degrees, are supported by more than one source or mechanism during their time in graduate school, and some receive support from several different sources and mechanisms in any given academic year.

Other than self-support, RAs are the most prevalent primary mechanism of financial support for S&E graduate students. In 2006, a little more than one-fourth of full-time S&E graduate students were supported primarily by RAs, 18% were primarily supported through TAs, and 12% relied primarily on fellowships or traineeships (appendix table 2-20).

Primary mechanisms of support differ widely by S&E field of study (appendix table 2-21). For example, in fall 2006 full-time students in physical sciences were financially supported mainly through RAs (42%) and TAs (38%) (figure 2-9). RAs also were important in agricultural sciences (57%); biological sciences (42%); earth, atmospheric, and ocean sciences (41%); and engineering (40%). In mathematics, more than half (53%) of full-time students were supported primarily through TAs and another 21% were self-supported. Full-time students in the social and behavioral sciences were mainly self-supporting (46%) or received TAs (20%), and students in medical/other life sciences were mainly self-supporting (60%).

The federal government served as the primary source of financial support for one-fifth of full-time S&E graduate students in 2006 (appendix table 2-22). The federal government plays a substantial role in supporting S&E graduate students through some mechanisms and in some fields, and a smaller role in others. For example, in 2006 the federal government

Figure 2-9
Full-time S&E graduate students, by field and mechanism of primary support: 2006



NOTE: Self-support includes any loans (including federal) and support from personal or family financial contributions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-21.

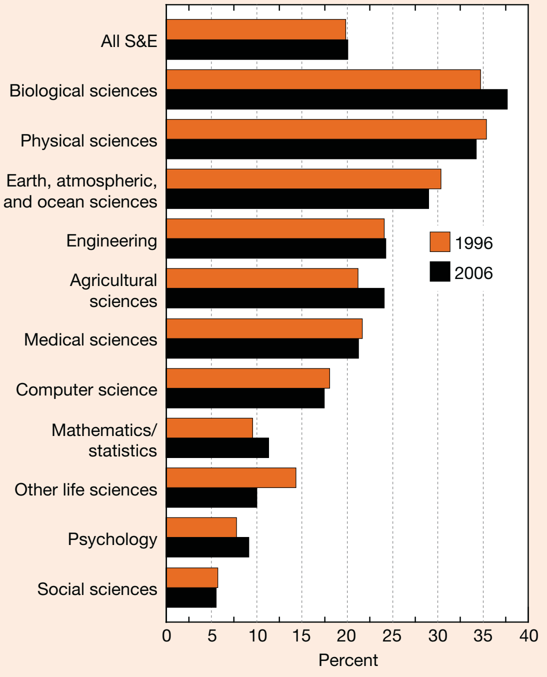
Science and Engineering Indicators 2010

funded 67% of S&E graduate students on traineeships, 50% of those with RAs, and 23% of those with fellowships. Federal financial support for graduate education reaches relatively more students in the biological sciences; the physical sciences; the earth, atmospheric, and ocean sciences; and engineering. Relatively fewer students in computer sciences, mathematics, other life sciences, psychology, and social sciences receive federal support (figure 2-10). Appendix table 2-22 provides detailed information by field and mechanism. (For information on federal academic R&D funding by discipline, see chapter 5, "Expenditures by Field and Funding Source.")

Most federal financial support for graduate education is in the form of RAs funded through grants to universities for academic research. RAs are the primary mechanism of support for 69% of federally supported full-time S&E graduate students, up from 66% in 1993. Fellowships and traineeships are the means of funding for 21% of the federally funded full-time S&E graduate students. The share of federally supported S&E graduate students receiving traineeships declined from 15% in 1993 to 12% in 2006, and the share receiving fellowships declined from 11% to 10%. For students supported through nonfederal sources in 2006, TAs were the most prominent mechanism (39%), followed by RAs (30%) (appendix table 2-20).

Figure 2-10

Full-time S&E graduate students with primary support from federal government, by field: 1996 and 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-22.

Science and Engineering Indicators 2010

The National Institutes of Health (NIH) and NSF support most of the full-time S&E graduate students whose primary support comes from the federal government. In 2006, they supported about 27,600 and 20,300 students, respectively. Trends in federal agency support of graduate students show considerable increases from 1993 to 2006 in the proportion of students funded (NIH, from 27% to 33%; NSF, from 20% to 24%). Support from the U.S. Department of Defense declined from 14% to 11% of federally supported graduate students (appendix table 2-23).

For doctoral degree students, notable differences exist in primary support mechanisms by type of doctorate-granting institution. In 2007, the primary support mechanism for S&E doctorate recipients from research universities (i.e., doctorate-granting institutions with very high research activity, which receive the most federal funding) was RAs. For those from medical schools, which are heavily funded by NIH, the primary support mechanism was fellowships or traineeships, and for those from doctoral/research universities, which receive less federal funding, the primary support mechanism was personal funds (table 2-3). These differences by type of institution hold for all S&E fields (NSF/SRS 2000). As noted earlier in this chapter, about 70% of S&E doctorate recipients received their doctorate from research universities with very high research activity.

Notable differences also exist for doctoral degree students in primary support mechanisms by sex, race/ethnicity, and citizenship. Among U.S. citizens and permanent residents in 2007, men were more likely than women to be supported by RAs (29% compared with 21%) and women were more likely than men to support themselves from personal sources (21% compared with 13%). Also, among U.S. citizens and permanent residents, whites and Asians were more likely than other racial/ethnic groups to receive primary support from RAs (26% and 32%, respectively), whereas underrepresented minorities depended more on fellowships or traineeships (35%). The primary source of support for doctoral degree students with temporary visas was an RA (54%) (appendix table 2-24).

White and Asian men, as well as foreign doctoral degree students, are more likely than white and Asian women and underrepresented minority doctoral degree students of both sexes to receive doctorates in engineering and physical sciences, fields largely supported by RAs. Women and underrepresented minorities are more likely than other groups to receive doctorates in social sciences and psychology, fields in which self-support is prevalent. Differences in type of support by sex, race/ethnicity, or citizenship remain, however, even accounting for doctorate field (NSF/SRS 2000). Although remaining differences in self-support are small (2–3 percentage points) in some fields, differences between men and women in self-support remain substantial (13–25 percentage points) in computer and health sciences, and differences between underrepresented minorities and whites in RA support remain substantial (15–31 percentage points) in agricultural sciences; computer sciences; earth, atmospheric, and ocean sciences; physical sciences; and engineering.

At the time of doctoral degree conferral, 44% of S&E doctorate recipients have debt related to their undergraduate or graduate education. More than one-fourth have some undergraduate debt and about one-third owe money directly related to graduate education. In 2007, 27% of S&E doctorate recipients reported having undergraduate debt and 30% reported having graduate debt. For some, debt levels were high, especially for graduate debt: 0.3% reported more than $70,000 of undergraduate debt and 4% reported more than $70,000 of graduate debt (appendix table 2-25).

Levels of debt vary widely by doctorate fields. In 2007, high levels of graduate debt were most common among doctorate recipients in psychology, social sciences, and medical/other health sciences. Psychology doctorate recipients were most likely to report having graduate debt and also high levels of debt.[12] In 2007, 16% of psychology doctoral degree recipients reported graduate debt of more than $70,000. Doctorate recipients in engineering; biological sciences; computer sciences; earth, atmospheric, and ocean sciences; mathematics; and physical sciences were least likely to report graduate debt. A higher percentage of doctorate recipients in non-S&E fields than those in S&E fields reported graduate debt.

Interdisciplinary Education

The scientific community increasingly views interdisciplinary research as critical to innovation and scientific advance and as a means to respond to emerging complex problems (COSEPUP 1995, 2004; NSF/DGE 2009). Over the past decade, academic institutions and federal funding agencies have made efforts to promote interdisciplinary education and research. Although new programs and efforts have arisen, academic institutions and funding agencies remain for the most part organized around disciplines; thus, university structures, evaluation and promotion practices, and funding opportunities often do not facilitate interdisciplinary research (NSF/DGE 2009). Measurement of interdisciplinary enrollment and degree attainment also remains a challenge, as students often are assigned to only one department or program to avoid duplication in records, and schools are asked to report the enrollment or degree in only one department or program. As interdisciplinary degree programs become established and award degrees, measurement becomes easier. For example, the number of doctoral degrees increased in interdisciplinary fields such as neuroscience (from 117 in 1982 to 737 in 2006), materials science (from 147 in 1982 to 582 in 2006), and bioengineering (from 59 in 1982 to 525 in 2006) (NSF/SRS 1993, 2009c). For information based on students' own reports of their research, see the sidebar "Interdisciplinary Dissertation Research."

S&E Master's Degrees

In some fields, such as engineering and geology, a master's degree is often the terminal degree for students. In other fields, master's degrees are a step toward doctoral degrees, and in certain others, master's degrees are awarded when students fail to advance to the doctoral level. Professional master's degree programs, which stress interdisciplinary

Table 2-3

Primary support mechanisms for S&E doctorate recipients, by Carnegie classification of doctorate-granting institution: 2007

(Percent distribution)

Mechanism	All institutions	Research universities (very high research activity)	Research universities (high research activity)	Doctoral/research universities	Medical schools and medical centers	Other/not classified
Doctorate recipients *(n)*	33,826	24,860	6,045	1,118	1,110	693
All mechanisms	100.0	100.0	100.0	100.0	100.0	100.0
Fellowship or traineeship	19.4	20.8	13.2	11.3	32.3	15.6
Grant	6.2	6.4	3.9	3.0	16.8	5.5
Teaching assistantship	14.5	14.6	18.6	7.8	1.7	5.9
Research assistantship	33.9	37.8	27.1	10.3	22.1	10.4
Other assistantship	0.6	0.4	1.2	0.8	0.4	0.6
Personal	10.4	6.6	17.9	36.2	15.6	30.7
Other	3.6	2.9	5.9	4.8	3.1	7.9
Unknown	11.5	10.5	12.2	25.8	8.0	23.4

NOTES: Personal support mechanisms include personal savings, other personal earnings, other family earnings or savings, and loans. Traineeships include internships and residency. Other support mechanisms include employer reimbursement or assistance, foreign support, and other sources. Percents may not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

training, are a relatively new direction in graduate education. (See sidebar "Professional Science Master's Degrees.")

Master's degrees in S&E fields increased from 86,400 in 1993 to 121,000 in 2006 before dropping slightly in 2007 (appendix table 2-26). Increases occurred in most major science fields. Master's degrees in engineering and computer sciences have dropped since 2004 (figure 2-11).

Master's Degrees by Sex

The number of S&E master's degrees earned by women rose from about 31,000 in 1993 to about 54,900 in 2007 (figure 2-12). The number of master's degrees earned by men grew more slowly, from about 55,500 in 1993 to about 65,400 in 2007, with most of the growth between 2002 and 2004. The number of S&E master's degrees earned by men declined between 2005 and 2007. As a result, the percentage of women earning master's degrees rose steadily during that time period. In 1993, women earned 36% of all S&E master's degrees; by 2007, they earned 46% (appendix table 2-26).

Interdisciplinary Dissertation Research

One indicator of interdisciplinary research is the number of doctorate recipients reporting two or more dissertation fields. A recent analysis from the Survey of Earned Doctorates shows that during the period 2004–07, the share of doctorate recipients reporting more than one dissertation research field fluctuated between 28% and 30% (NSF/SRS 2009a).

The report found that interdisciplinary research at the dissertation research level occurred mostly within the same knowledge domain, whether science (80.2%), engineering (58.5%), or non-science and engineering (non-S&E, 69.3%). Respondents who reported a primary dissertation field in the sciences most frequently reported a secondary research field within the same broad field in the sciences. However, this varied considerably by field of primary dissertation research, from the biological sciences (81.2%) to computer sciences (11.2%). About half of the doctorate recipients who reported a primary dissertation research field in the earth, atmospheric, and ocean sciences; the physical sciences; psychology; or the social sciences reported a secondary dissertation research field within the same broad field. The biological sciences were also the most frequent secondary dissertation research field across all the other sciences except the social sciences.

About 29% of mathematics and 11% of computer sciences doctorate holders listed a secondary field within the same respective major field. Dissertations in which the primary research field was computer sciences most frequently had engineering (24.9%) or a non-S&E field (20.1%) as the secondary dissertation research field. Dissertations with mathematics as the primary research field most often had biological sciences (24.6%) or engineering (11.7%) as the secondary field.

Professional Science Master's Degrees

Partially in response to the call for more realistic programs to serve the nation's S&E needs and students' professional goals, a number of universities have developed Professional Science Master's (PSM) programs (CGS 2008d; Colwell 2009; NAS 2008; NPSMA 2009). These programs are designed to prepare people to work primarily in nonacademic sectors as laboratory administrators or project directors in, for example, large government or industrial laboratories or in small startup companies. They serve people who need advanced technical training (beyond the bachelor's degree) within an S&E field combined with knowledge of and skills in business fundamentals, management, team building, and communication. Prospective students include people already working as S&E professionals and others who feel the "strictly research" approach does not appeal to them. The American Recovery and Reinvestment Act of 2009 (Public Law 111-5) includes funds specifically for support of such programs.*

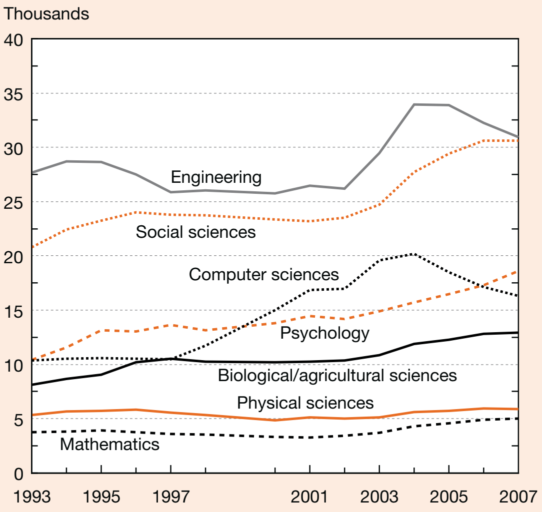
Starting from a handful of PSM programs in 1997, there are now more than 125 such programs in more than 60 institutions in 25 states and the District of Columbia in disciplines such as mathematics, physics, biological sciences, computational science, forensics, chemistry, and geographical information systems. Most PSM programs are interdisciplinary in nature. About 2,500 students are enrolled annually, and these numbers are increasing. Student enrollment is highest in the biological sciences and biotechnology disciplines. More than 2,100 PSM students have graduated thus far, and 65% of these graduates have found employment in industry or government (NPSMA 2009). Many PSM programs were initiated with startup funds from the Sloan Foundation and the Council of Graduate Schools with the intent that they become self-supporting as their value to industry and their students' professional aspirations become apparent. Also of note are the growing number of such programs abroad, as other nations see the value of preparing an S&E-trained managerial workforce, and the growing interest in them of professional societies and journals (CGS 2008a; Teitelbaum and Cox 2007).

---

* See the Joint Explanatory Statement–Division A of the American Recovery and Reinvestment Act of 2009, http://www.rules.house.gov/bills_details.aspx?NewsID=4149, accessed 12 June 2009.

Women's share of S&E master's degrees varies by field. In 2007, women earned a majority of master's degrees in psychology (79%), biological sciences (60%), social sciences (56%), and agricultural sciences (55%). Women earned a small share of master's degrees in engineering, although their share in 2007 (23%) was higher than their share in 1993 (15%) (appendix table 2-26). The number of master's degrees awarded to women in most major S&E fields increased through 2005 but has flattened or declined since then.

Figure 2-11
S&E master's degrees, by field: 1993–2007

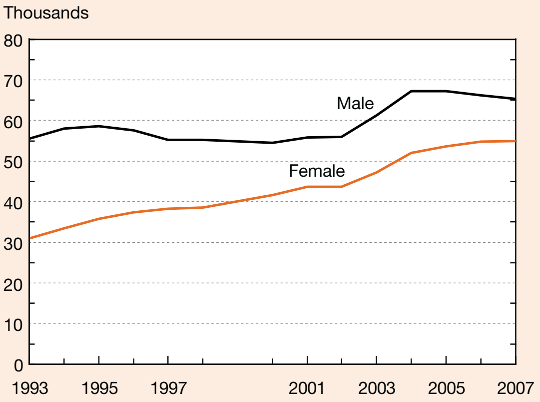


NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data not available for 1999.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-26.

Science and Engineering Indicators 2010

Figure 2-12
S&E master's degrees, by sex: 1993–2007



NOTE: Data not available for 1999.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-26.

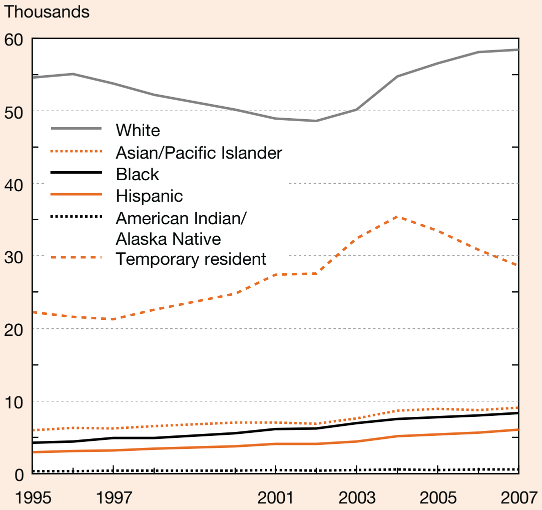
Science and Engineering Indicators 2010

Master's Degrees by Race/Ethnicity

The number of S&E master's degrees awarded to U.S. citizens and permanent residents increased for all racial/ethnic groups between 1995 and 2007, although degrees to white students dropped from 1997 to 2002 before increasing again (figure 2-13; appendix table 2-27).[13]

The proportion of master's degrees in S&E fields earned by U.S. citizen and permanent resident racial and ethnic minorities increased over the past two decades. Asians/Pacific Islanders accounted for 8% of S&E master's degrees in 2007, up from 6% in 1995. Blacks, Hispanics, and American Indians/Alaska Natives also registered gains during this period (from 4% to 7% for blacks, from 3% to 5% for Hispanics, and from 0.3% to 0.5% for American Indians/Alaska Natives). The percentage of S&E master's degrees earned by white students fell from 58% in 1995 to 49% in 2007 as the percentage of degrees earned by minorities and temporary residents increased (appendix table 2-27).

Figure 2-13
S&E master's degrees, by race/ethnicity and citizenship: 1995–2007



NOTES: Race/ethnicity includes U.S. citizens and permanent residents. Data not available for 1999.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-27.

Science and Engineering Indicators 2010

Master's Degrees by Citizenship

Foreign students make up a much higher proportion of S&E master's degree recipients than of bachelor's or associate's degree recipients. In 2007, foreign students earned 24% of S&E master's degrees. Their degrees are heavily concentrated in computer sciences and engineering, where they earned 39% and 38%, respectively, of all master's degrees awarded in 2007 (appendix table 2-27). Within engineering, students on temporary visas earned half of the master's degrees in electrical engineering.

S&E master's degrees awarded to students on temporary visas rose from approximately 22,200 in 1995 to about 35,500 in 2004, then declined to 28,700 in 2007. Most of the decline in recent years is accounted for by declines in computer sciences and engineering.

S&E Doctoral Degrees

Doctoral education in the United States prepares a new generation of faculty and researchers in academia, as well as a high-skilled workforce for other sectors of the economy. It also generates new knowledge important for the society as a whole and for U.S. competitiveness in a global knowledge-based economy.

After rising from the mid-1980s through 1998, the number of S&E doctorates conferred annually by U.S. universities declined through 2002 but increased in recent years, reaching a new peak of almost 41,000 in 2007 (NSB 2008; appendix table 2-28). The recent growth through 2007 occurred among both U.S. citizens/permanent residents and temporary residents. The largest increases were in engineering, biological/agricultural sciences, and medical/other life sciences (figure 2-14).

Time to Doctoral Degree Completion

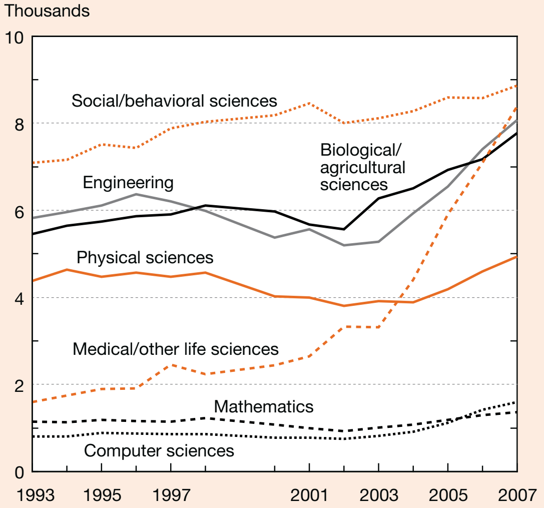
The time required to earn a doctoral degree and the success rates of those entering doctoral programs are concerns for those pursuing a degree, the universities awarding the degree, and the agencies and organizations funding graduate study (NORC 2007). (See sidebar "Doctoral Completion and Attrition.") Time to degree (as measured by time from graduate school entry to doctorate receipt) increased through the mid-1990s but since then has decreased for S&E fields as a whole and for each field (appendix table 2-29). The physical sciences, mathematics, biological sciences, and engineering had the shortest time to degree, while the social sciences and medical/other life sciences had the longest. In 2007, the median time to doctorate receipt was 6.4 years in physical sciences, 6.9 years in mathematics and biological sciences, 7.0 years in engineering, 8.9 years in social sciences, and 9.7 years in medical/other life sciences. From 1995 to 2007, time to degree shortened in each of these fields. In science and engineering as a whole, median time to degree decreased from 8.0 to 7.2 years during this period.

Time to degree for doctorate recipients decreased in each of the Carnegie types of academic institutions awarding doctoral degrees from 1993 to 2007. (See sidebar "Carnegie Classification of Academic Institutions.") The majority of S&E doctorates are earned at research universities (i.e., doctorate-granting institutions with very high research activity). Time to degree is shortest at these universities: 7.0 years for 2007, down from 7.8 in 1993. Doctorate recipients at medical schools also finish quickly (7.1 years in 2007). Time to degree is longer at research universities with high research activity (7.9 years) and longest at doctoral/research universities (9.0 years) (table 2-4).

Doctoral Degrees by Sex

Among U.S. citizens and permanent residents, the proportion of S&E doctoral degrees earned by women has risen considerably since 1993, reaching a record high of 55% in 2007 (appendix table 2-28). During this period, women made gains in most major fields, but considerable differences by field continue. In 2007, women earned half or more of doctorates in non-S&E fields, in social/behavioral sciences, and in medical/other life sciences, but they earned considerably less than half of doctorates in physical sciences (31%), mathematics/computer sciences (26%), and engineering (23%) (appendix table 2-28). Although the percentages of degrees earned by women in physical sciences and engineer-

Figure 2-14
S&E doctoral degrees earned in U.S. universities, by field: 1993–2007



NOTES: Data not available for 1999. Physical sciences include earth, atmospheric, and ocean sciences. Data in this figure differ from doctoral degree data in other tables and figures in this report that are based on NSF Survey of Earned Doctorates and that refer to research doctorates only. Greatest differences are in psychology and medical/other life sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

ing are low, they are substantially higher than in 1993 (23% and 13%, respectively).

The increase in the proportion of S&E doctoral degrees earned by women resulted from both an increase in the number of women and a decrease in the number of men earning these degrees. The number of U.S. citizen and permanent resident women earning doctorates in S&E increased from 6,800 in 1993 to 15,000 in 2007 (appendix table 2-28). Meanwhile, the number of S&E doctorates earned by U.S. citizen or permanent resident men increased from 10,900 in 1993 to 12,300 in 2007. The increase in the number of S&E doctorates earned by women occurred in most major S&E fields. For example, the number of engineering doctorates earned by U.S. citizen and permanent resident women increased from approximately 300 in 1993 to 700 in 2007; biological sciences doctorates, from 1,300 to 2,300; physical sciences doctorates, from 600 to 700; and social/behavioral sciences doctorates, from 3,300 to 4,700. A decrease in the number of doctorates earned by men after the mid-1990s and through about 2002 to 2004 occurred in non-S&E fields as well as in engineering and in most science fields (except for biological sciences and medical/other life sciences). In recent years, the number of doctorates earned by U.S. citizen and permanent resident men increased in biological sciences; earth, atmospheric, and ocean sciences; computer sciences; physical sciences; mathematics; and engineering.

Doctoral Completion and Attrition

An ongoing study by the Council of Graduate Schools (CGS 2008c) collected data on doctoral completion and attrition of doctoral students from the 1992–93 academic year to the 2003–04 academic year from about 30 academic institutions for 5 broad fields: engineering, mathematics and physical sciences, the life sciences, the social sciences, and the humanities. The study, which focused on 10-year completion and attrition rates, revealed that 57% of doctoral students complete their degrees within 10 years (and some are likely to complete after that). Completion rates varied by field, with higher percentages of students in engineering and the life sciences and lower percentages of students in mathematics and the physical sciences, social sciences, and humanities completing within 10 years. Ten-year completion rates varied by subdisciplines within the broader disciplines (e.g., within engineering, 10-year completion rates were higher for civil engineering and lower for electrical engineering) and also differed between men and women and among racial and ethnic groups. Ten-year completion rates were higher for men than for women in most fields (except the social sciences and humanities) and were higher for whites than for all other racial/ethnic groups (CGS 2008b).

Exit surveys of doctorate completers conducted as part of the study found that financial support, mentoring/advising, and family (nonfinancial) support headed the factors reported as influencing doctorate completion, with more than half of the respondents reporting each of these as factors in their ability to complete their doctoral programs. The relative prevalence of these factors varied by field, although differences by broad field of study may reflect differences in the demographics of students in the fields (CGS 2009).

The study found that most students who leave doctoral programs leave within the first 4 years. Attrition rates have improved over time, with rates of attrition lower for later cohorts than for earlier cohorts of students. Attrition was highest in mathematics and the physical sciences (CGS 2008a).

Doctoral Degrees by Race/Ethnicity

The number and proportion of doctoral degrees in S&E fields earned by U.S. citizen and permanent resident underrepresented minorities has also increased since 1995. Blacks earned 1,287, Hispanics earned 1,301, and American Indians/Alaska Natives earned 128 S&E doctorates in 2007, together accounting for 7% of all S&E doctoral degrees earned that year, up from 4% in 1995 (appendix table 2-30). Their share of S&E doctoral degrees earned by U.S. citizens and permanent residents rose from 6% to 10% in the same period. Gains by all groups contributed to this rise, although the number of S&E degrees earned by blacks and Hispanics rose considerably more than the number earned by American Indians/Alaska Natives (figure 2-15). Asian/Pacific Islander U.S. citizens and permanent residents earned 6% of all S&E doctorates in 2007, down from 7% in 1995. The number of S&E doctorates earned by white U.S. citizens and permanent residents declined from the mid-1990s to 2002, with most of the decrease among white men. The number of S&E doctoral degrees earned by white U.S. citizen and permanent resident men declined in the late 1990s through 2003, then gradually increased (figure 2-16). The number of degrees earned by white U.S. citizen and permanent resident women dropped briefly in 1996 and has increased since then. As the number of S&E doctorates awarded to minorities and temporary residents increased, the proportion of S&E doctoral degrees earned by white U.S. citizens and permanent residents decreased from 54% in 1995 to 49% in 2007 (appendix table 2-30).

Foreign S&E Doctorate Recipients

Temporary residents earned approximately 13,700 S&E doctorates in 2007, up from 8,700 in 1995. Foreign students on temporary visas earn a larger proportion of doctoral degrees than master's, bachelor's, or associate's degrees (appendix tables 2-11, 2-13, 2-27, and 2-30). The temporary resident share of S&E doctorates rose from 31% in 1995 to 33% in 2007. Foreign students earn considerable shares of doctoral degrees in some fields. In 2007, foreign students

Table 2-4

Median number of years from S&E doctorate recipients' entry to graduate school to receipt of doctorate, by Carnegie classification of doctorate-granting institution: 1993–2007

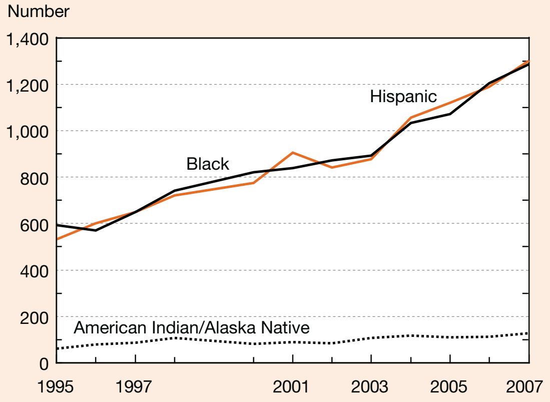
Year of doctorate	All institutions	Research universities (very high research activity)	Research universities (high research activity)	Doctoral/ research universities	Medical schools and medical centers	Other/ not classified
1993..........	7.9	7.8	8.4	10.0	7.9	8.5
1994..........	8.0	7.8	8.6	9.9	8.0	8.6
1995..........	8.0	7.8	8.6	10.2	7.9	8.9
1996..........	7.9	7.7	8.7	9.7	8.0	8.8
1997..........	7.7	7.5	8.6	10.0	7.9	8.4
1998..........	7.6	7.4	8.3	9.8	7.2	8.3
1999..........	7.6	7.4	8.3	9.2	7.0	7.8
2000..........	7.7	7.5	8.3	9.2	7.2	8.3
2001..........	7.6	7.4	8.3	9.9	7.3	8.0
2002..........	7.7	7.5	8.4	10.0	7.1	8.4
2003..........	7.7	7.5	8.3	10.0	7.1	9.0
2004..........	7.3	7.1	8.0	9.3	7.0	7.8
2005..........	7.4	7.3	8.0	9.6	7.1	8.4
2006..........	7.3	7.1	8.0	8.7	7.0	8.0
2007..........	7.2	7.0	7.9	9.0	7.1	8.0

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 2-15

S&E doctoral degrees earned by U.S. citizen and permanent resident underrepresented minorities, by race/ethnicity: 1995–2007



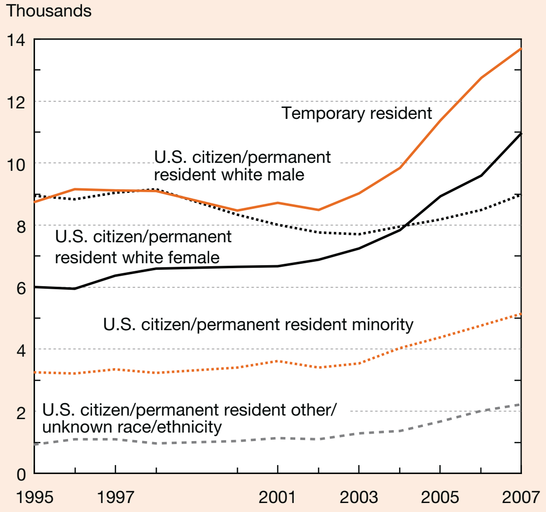
NOTES: Data not available for 1999. Detailed field not collected by citizenship or race/ethnicity prior to 1995. Data in this figure differ from doctoral degree data in other tables and figures in this report that are based on NSF Survey of Earned Doctorates and that refer to research doctorates only. Greatest differences are in psychology and medical/other life sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

Figure 2-16

S&E doctoral degrees, by sex, race/ethnicity, and citizenship: 1995–2007



NOTES: Data not available for 1999. Detailed field not collected by citizenship or race/ethnicity prior to 1995. Minority includes Asian/ Pacific Islander, black, Hispanic, and American Indian/Alaska Native. Data in this figure differ from doctoral degree data in other tables or figures in this report that are based on NSF Survey of Earned Doctorates and that refer to research doctorates only. Greatest differences are in psychology and medical/other life sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

on temporary visas earned half or more of doctoral degrees awarded in engineering, physics, mathematics, computer sciences, and economics. They earned considerably lower proportions of doctoral degrees in other S&E fields, for example, 30% in biological sciences, 8% in medical/other life sciences, and 5% in psychology (appendix table 2-30).

Countries/Economies of Origin

The top 10 foreign countries/economies of origin of foreign S&E doctorate recipients together accounted for 66% of all foreign recipients of U.S. S&E doctoral degrees from 1987 to 2007 (table 2-5). All but 3 of those top 10 countries are located in Asia. The major Asian countries/economies sending doctoral degree students to the United States have been, in descending order, China, India, South Korea, and Taiwan.

Table 2-5

Foreign recipients of U.S. S&E doctorates, by country/economy of origin: 1987–2007

Country/economy	Number	Percent
All foreign recipients	206,256	100.0
Top 10 total	136,120	66.0
China	50,220	24.3
India	21,354	10.4
South Korea	20,549	10.0
Taiwan	18,523	9.0
Canada	6,676	3.2
Turkey	4,575	2.2
Thailand	3,707	1.8
Germany	3,567	1.7
Japan	3,536	1.7
Mexico	3,413	1.7
All others	70,136	34.0

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

Asia. From 1987 to 2007, students from four Asian countries/economies (China, India, South Korea, and Taiwan) earned more than half of U.S. S&E doctoral degrees awarded to foreign students (110,600 of 206,300), almost four times more than students from Europe (27,900). Most of these degrees were awarded in engineering, biological sciences, and physical sciences (table 2-6).

Students from China earned the largest number of U.S. S&E doctorates awarded to foreign students during the 1987–2007 period (50,200), followed by those from India (21,400), South Korea (20,500), and Taiwan (18,500) (table 2-6). The numbers of S&E doctorates earned by students from China and India dropped in the late 1990s but have been increasing since then (figure 2-17). Over the 20-year period, the number of S&E doctorates earned by Chinese nationals increased more than tenfold[14] and the number of S&E doctorates earned by students from India more than trebled. The number of S&E doctoral degrees earned by South Korean students also dipped in the late 1990s and then rose, but the number of students did not rise as dramatically as those from China and India. In 1987, students from Taiwan earned more U.S. S&E doctoral degrees than students from China, India, or South Korea. However, as universities in Taiwan increased their capacity for advanced S&E education in the 1990s, the number of students from Taiwan earning S&E doctorates from U.S. universities declined.

Europe. European students earned far fewer U.S. S&E doctorates than Asian students between 1987 and 2007, and they tended to focus less on engineering than did their Asian counterparts (table 2-7). Western European countries whose

Table 2-6

Asian recipients of U.S. S&E doctorates, by field and country/economy of origin: 1987–2007

Field	Asia	China	India	South Korea	Taiwan
All fields	168,627	53,665	24,386	26,402	22,577
S&E	143,927	50,220	21,354	20,549	18,523
Engineering	53,621	16,183	9,419	7,965	8,332
Science	90,306	34,037	11,935	12,584	10,191
Agricultural sciences	5,746	1,562	534	807	727
Biological sciences	23,637	11,532	3,240	2,386	2,701
Computer sciences	7,186	2,166	1,791	849	959
Earth, atmospheric, and ocean sciences	2,947	1,461	230	367	319
Mathematics	6,888	3,184	641	921	700
Medical/other life sciences	4,621	992	888	492	819
Physical sciences	21,162	10,181	2,606	2,561	2,038
Psychology	2,198	350	265	369	308
Social sciences	15,921	2,609	1,740	3,832	1,620
Non-S&E	24,700	3,445	3,032	5,853	4,054

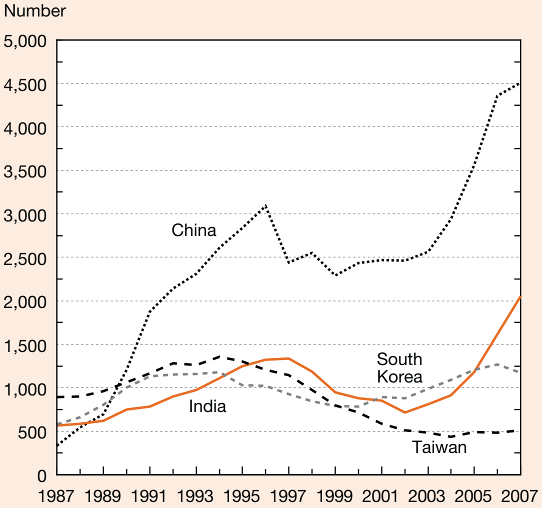
NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

students earned the largest number of U.S. S&E doctorates from 1987 to 2007 were Germany, the United Kingdom, Greece, Italy, and France, in that order. From 1987 to 1993, Greece was the primary European country of origin; thereafter, its numbers of doctoral degree recipients declined. The numbers of U.S. S&E doctorate recipients from Italy and France generally increased over the past two decades. The number of U.S. S&E doctorate recipients from the United Kingdom fluctuated mainly between 100 and 150 over the period, and the number of doctorate recipients from Germany declined since 2000 (figure 2-18).

Figure 2-17
U.S. S&E doctoral degree recipients, by selected Asian country/economy of origin: 1987–2007



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

The number of Central and Eastern European students earning S&E doctorates at U.S. universities increased from 55 in 1987 to more than 800 in 2007 (about the same number as those from Western Europe) (figure 2-19). A higher proportion of Central and Eastern European U.S. doctorate recipients (88%) than of Western European doctorate recipients (73%) earned their doctorates in S&E fields, particularly in mathematics and physical sciences (table 2-7).

North America. The Canadian and Mexican shares of U.S. S&E doctoral degrees were small compared with those from Asia and Europe. The number of U.S. S&E degrees earned by students from Canada increased from about 200 in 1987 to more than 400 in 2007. The number of doctoral degree recipients from Mexico increased from 99 in 1987 to 187 in 2007 (figure 2-20). A higher proportion of Mexican than of Canadian U.S. doctoral degree recipients earned doctorates in science and engineering fields: 85% of Mexican and 64% of Canadian doctoral degree students in U.S. universities earned S&E doctorates (table 2-7). In particular, higher percentages of Mexican than of Canadian U.S. doctoral degrees were in engineering and agricultural sciences.

Table 2-7
European and North American recipients of U.S. S&E doctorates, by field and region/country of origin: 1987–2007

	Europe[a]				North America		
Field	All countries	Western	Scandinavia	Central/ Eastern	All countries	Canada	Mexico
All fields	36,073	23,527	2,083	10,463	14,443	10,363	4,028
S&E	27,937	17,168	1,586	9,183	10,111	6,676	3,413
Engineering	5,563	3,588	286	1,689	1,725	933	792
Science	22,374	13,580	1,300	7,494	8,386	5,743	2,621
Agricultural sciences	802	590	61	151	832	264	568
Biological sciences	4,121	2,580	237	1,304	1,951	1,378	565
Computer sciences	1,423	815	74	534	299	211	87
Earth, atmospheric, and ocean sciences	1,053	720	83	250	369	229	138
Mathematics	2,820	1,284	107	1,429	498	313	184
Medical/other life sciences	630	488	71	71	603	508	93
Physical sciences	5,708	2,902	221	2,585	1,106	823	281
Psychology	1,047	803	103	141	912	822	85
Social sciences	4,770	3,398	343	1,029	1,816	1,195	620
Non-S&E	8,136	6,359	497	1,280	4,332	3,687	615

[a] See figure 2-19 notes for countries included in Western Europe, Scandinavia, and Central/Eastern Europe.

NOTE: Foreign doctorate recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

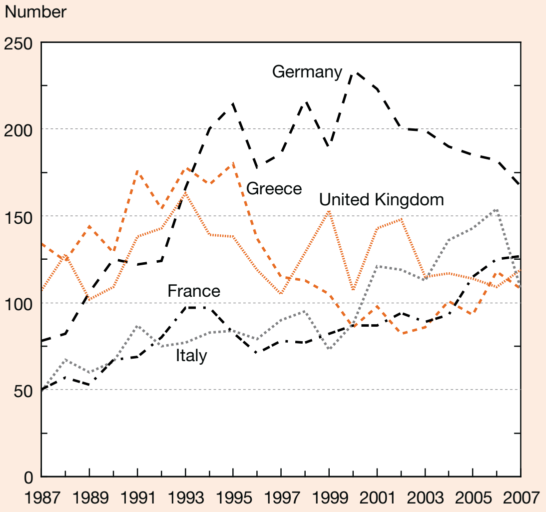
Science and Engineering Indicators 2010

Stay Rates

Most foreign U.S. doctorate recipients plan to stay in the United States after graduation, and although the percentage of recipients staying is dropping, the number of recipients staying is increasing (figure 2-21). This section examines data on foreign S&E doctorate recipients' plans for staying in the United States at the time of doctorate receipt. Chapter 3 provides data based on examination of Social Security records on the percentage of foreign students with U.S. S&E doctorates who remain in the U.S. labor force up to 5 years after graduation.

At the time of doctorate receipt, more than three-quarters of foreign recipients of U.S. S&E doctorates plan to stay in the United States and about half have either accepted an offer of postdoctoral study or employment or are continuing employment in the United States (appendix table 2-31). Until the early 1990s, about half of foreign students who earned S&E degrees at U.S. universities reported that they planned to stay in the United States after graduation, and about one-third said they had firm offers for postdoctoral study or employment (NSB 1998). In the 1990s, however, these percentages increased substantially. For example, in the period 1996–99, 71% of foreign S&E doctoral degree recipients reported plans to remain in the United States after receiving their degree and 45% already had firm offers for postdoctoral study or employment. In the 2004–07 period, 77% of foreign doctoral recipients in S&E fields with known plans intended to stay in the United States and 51% had firm offers to do so (appendix table 2-31). Higher percentages of foreign doctorate recipients in physical sciences, biological and agricultural sciences, and mathematics/computer

Figure 2-18
U.S. S&E doctoral degree recipients, by selected Western European country: 1987–2007

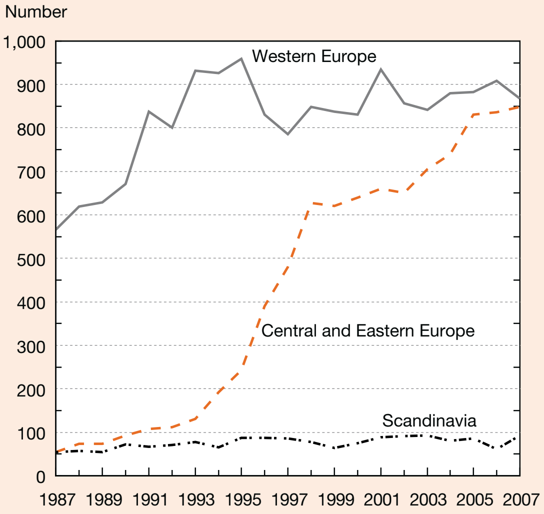


NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 2-19
U.S. S&E doctoral degree recipients from Europe, by region: 1987–2007

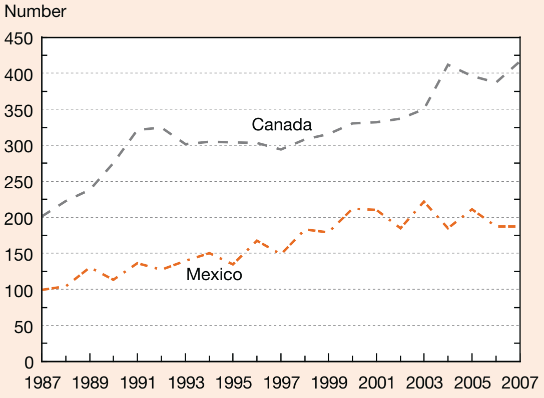


NOTES: Degree recipients include permanent and temporary residents. Western Europe includes Andorra, Austria, Belgium, France, Germany, Greece, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Portugal, San Marino, Spain, Switzerland, and United Kingdom. Central and Eastern Europe includes Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, Serbia-Montenegro, Slovakia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, and Yugoslavia. Scandinavia includes Denmark, Finland, Iceland, Norway, and Sweden.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 2-20
U.S. S&E doctoral degree recipients from Canada and Mexico: 1987–2007



NOTE: Degree recipients include permanent and temporary residents.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

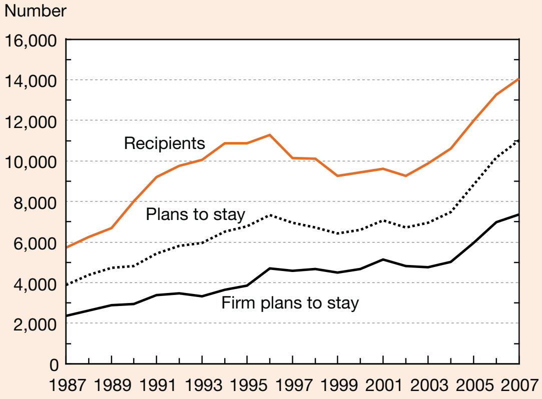
Science and Engineering Indicators 2010

sciences, and lower percentages of foreign doctorate recipients in social/behavioral and health sciences reported definite plans to stay.

Stay rates vary by place of origin. In the period 2004–07, more than 90% of U.S. S&E doctoral recipients from China and 89% of those from India reported plans to stay in the United States, and more than half reported accepting firm offers for employment or postdoctoral research in the United States (appendix table 2-31). Doctorate recipients from Japan, South Korea, and Taiwan were less likely than those from China and India to stay in the United States (figure 2-22). Among U.S. S&E doctoral degree recipients from Europe, a relatively high percentage from the United Kingdom planned to stay, whereas smaller percentages from Greece and Spain (compared with other Western European countries) planned to stay after graduation. In North America, the percentage of 2004–07 doctoral degree students who had definite plans to stay in the United States was higher for Canada than for Mexico (appendix table 2-31).

Between 2000–03 and 2004–07, the percentage of U.S. S&E doctoral degree recipients from all of the top five countries/economies of origin (China, India, South Korea, Taiwan, and Canada) reporting definite plans to stay in the United States declined. However, for all but Taiwan, increases in the numbers of doctorate recipients more than offset declines in the percentage staying. Thus, the numbers of U.S. S&E doctoral degree recipients from Canada, China, India, and South Korea who had definite plans to stay in the United States were larger in the 2004–07 period than in the 2000–03 period (appendix table 2-31).

Figure 2-21
Plans of foreign recipients of U.S. S&E doctorates to stay in United States: 1987–2007

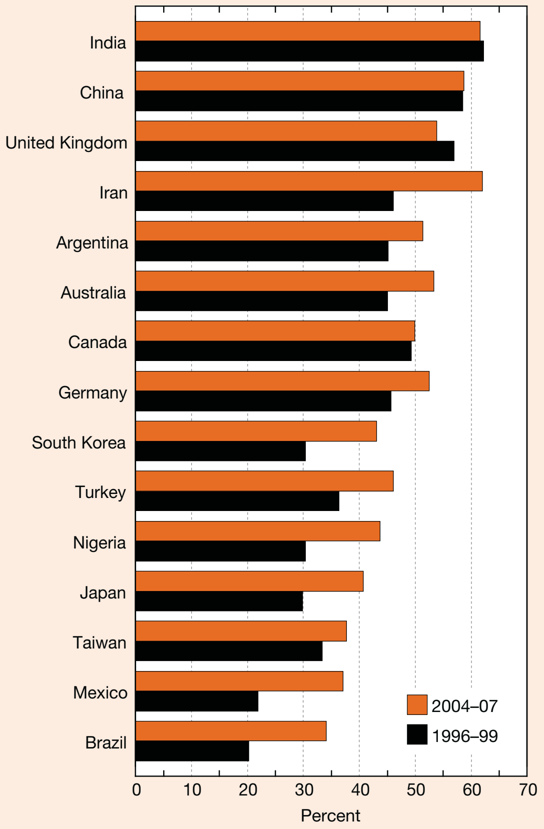


NOTES: Degree recipients include permanent and temporary residents. See appendix table 2-31 for plans to stay by field of study and place of origin in 4-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 2-22
Short-term stay rates of foreign recipients of U.S. S&E doctorates, by place of origin: 1996–99 and 2004–07



NOTES: Degree recipients include permanent and temporary residents. Short-term stay rates are those with firm commitments of postaward or postdoctoral employment. Longer-term stay rates may differ. See appendix table 2-31 for plans to stay by field of study and place of origin in 4-year increments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2009).

Science and Engineering Indicators 2010

Postdoctoral Education

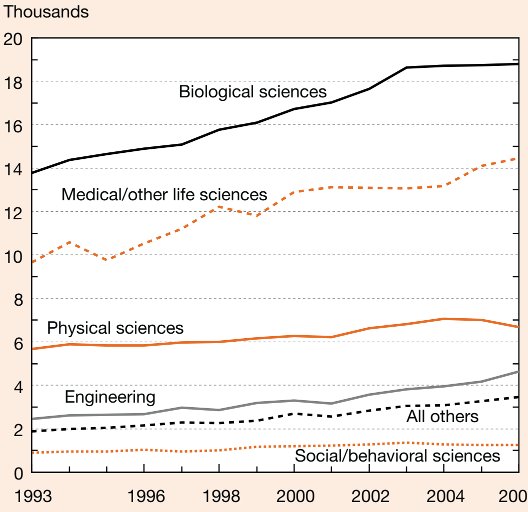
Typically, postdoctoral fellows ("postdocs") have temporary appointments involving full-time research or scholarship, the purpose of which is to further their education and training. The titles associated with these positions and the conditions of employment vary widely. The status of postdoctoral fellows within the academic hierarchy is not well defined and varies among institutions, although it is generally accepted that the postdoctoral experience represents the last step of a person's training for becoming an independent investigator and faculty member (COSEPUP 2000). Postdoctoral fellows also are important contributors to academic research. They bring a new set of techniques and perspectives to the laboratory that broadens research teams' experience and can make them more competitive for additional research funding. Chapter 3 provides more detail on postdoctoral employment, including reasons for and length of postdoc appointments, salaries and subsequent employment. Chapter 5 provides more detail on postdocs in the academic R&D setting.

Since 1993, the number of S&E postdocs at U.S. universities increased from 34,300 to 49,300 in fall 2006 (appendix table 2-32). Most of the growth was in biological and medical/other life sciences, accounting for more than two-thirds of S&E postdocs (figure 2-23).[15]

Noncitizens account for much of the increase in the number of S&E postdocs, especially in biological sciences and medical sciences (figure 2-24). The number of S&E postdocs with temporary visas at U.S. universities increased from approximately 17,600 in 1993 to 28,200 in 2006. The number of U.S. citizen and permanent resident S&E postdocs at these institutions increased more modestly, from approximately 16,700 in 1993 to 21,100 in 2006 (appendix table 2-32). Temporary visa holders accounted for 57% of S&E postdocs in 2006.

An increasing share of academic S&E postdocs are funded through federal research grants. In fall 2006, 56% of S&E postdocs at U.S. universities were funded through this mechanism, up from 52% in 1993. Federal fellowships and traineeships funded a declining share of S&E postdocs: 13% in 2006, down from 17% in 1993. In 2006, 31% of S&E postdocs were funded through nonfederal sources (table 2-8).

Figure 2-23
Postdoctoral students at U.S. universities, by field: 1993–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-32.

Science and Engineering Indicators 2010

International S&E Higher Education

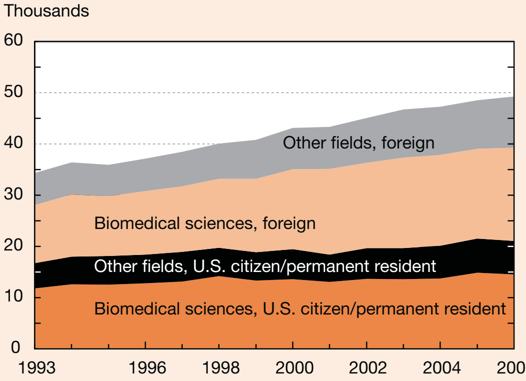
In the 1990s, many countries expanded their higher education systems and access to higher education. At the same time, flows of students worldwide increased. More recently, a number of countries adopted policies to encourage the return of students who studied abroad, to attract foreign students, or both. (For information on worldwide trends affecting doctoral education, see sidebar "Globalization and Doctoral Education.")

Higher Education Expenditures

Increasingly, governments around the world have come to regard movement toward a knowledge-based economy as key to economic progress. Realizing that this requires a well-trained workforce, they have invested in upgrading and expanding their higher education systems and broadening participation. In most instances, government spending underwrites these developments. One indicator of the importance of higher education is the percentage of resources devoted to higher education, as measured by expenditures on tertiary education (education beyond high school) as a percentage of gross domestic product (GDP). The United States, Canada, and Korea spend the highest percentage of GDP on higher education (appendix table 2-33).

An indicator of the growing importance of higher education is the change in expenditures for higher education over time. Expenditures for tertiary education rose more in the United States than in other Organisation for Economic Co-operation and Development (OECD) countries between

Figure 2-24
Postdoctoral students at U.S. universities, by field and citizenship status: 1993–2006



NOTES: Biomedical sciences include biological sciences and medical sciences. Other fields include engineering; agricultural sciences; earth, atmospheric, and ocean sciences; mathematics; computer sciences; other life sciences; physical sciences; psychology; and social sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-32.

Science and Engineering Indicators 2010

1995 and 2000, but less in the United States than in other OECD countries between 2000 and 2005. From 1995 to 2000, educational expenditures in the United States increased faster than the OECD average and faster than almost all of the other OECD countries (except Greece, Ireland, and Poland). From 2000 to 2005, educational expenditures in the United States increased more slowly than the OECD average but at a similar or faster rate than many countries. (In 2006, expenditures per student in the U.S. were double the OECD average [OECD 2008].) Several countries, the Czech Republic, Greece, Iceland, Poland, Portugal, the Slovak Republic, and the United Kingdom, far exceeded the OECD average increase in expenditures from 2000 to 2005 (appendix table 2-33). Examination of higher education funding over time is complicated by many things, including changes in measurement, prevalence of public versus private institutions (private institutions are much more prevalent in the United States than in other countries), types and levels of government funding included, and types and levels of education included.

Table 2-8

Source of funding of S&E postdoctoral students: 1993–2006

(Percent distribution)

Source	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
All sources	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Federal fellowships	8.5	8.7	8.8	8.9	9.0	10.2	9.4	9.1	8.3	8.7	7.8	7.9	7.8	7.5
Federal traineeships	8.5	8.1	7.6	7.4	7.2	7.3	6.6	6.0	5.7	5.9	5.7	5.4	5.8	5.5
Federal research grants	52.1	51.3	51.9	52.0	51.7	51.2	53.2	54.5	54.7	55.9	56.1	57.9	56.6	55.6
Nonfederal sources	30.9	31.9	31.6	31.6	32.1	31.3	30.7	30.3	31.3	29.4	30.4	28.8	29.8	31.4

NOTE: Percents may not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, Integrated Science and Engineering Resources Data System (WebCASPAR) database, http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

Globalization and Doctoral Education

With increasing student flows and increasing transnational university partnerships and agreements, doctoral education is becoming more global in nature. In addition, doctoral education in many countries around the world is being shaped by common forces in common ways. Globalization of the economy, shifts to a knowledge-based economy, and various policy efforts are transforming doctoral education around the world. Nerad and Heggelund (2008) identified several key interrelated dimensions of these global trends in doctoral education:

- Across countries, doctoral education is increasingly seen as a commodity with a measurable economic value.
- The market economy is demanding skills in addition to technical skills, that is, skills such as communication, leadership, and team work, which are increasingly being incorporated into graduate curricula. Private institutions and for-profit institutions are arising where only public institutions used to prevail, and tuition is being charged in countries in which education used to be free.
- Research has shifted from individual curiosity-driven research to team research on marketable projects, and research has become more collaborative and interdisciplinary.
- Developing countries are losing their doctoral students to more developed countries through “brain drain.”
- Doctoral education around the world is increasingly conducted in English, and scholarly papers are written in English.
- Doctoral education is becoming more standardized in terms of common definitions of degrees, common curricular elements, interdisciplinary training, ethics training, relationship between bachelor’s degrees and doctorates, and length of time.
- Universities are developing and applying quality assurance standards and assessment techniques to compete more effectively in the global marketplace, and new accreditation agencies are being developed.
- The Bologna Accords in Europe are moving toward harmonization of doctoral education in terms of supervision, length of study, mobility across borders, and collaboration.

The nature of the individual university’s responses to these changes and the extent to which universities and countries embrace or resist them vary.

Educational Attainment

Higher education in the United States expanded greatly after World War II, and for several decades the United States led the world in its population's educational attainment. In the 1990s, many countries in Europe and Asia also began to expand their higher education systems. The United States continues to be among those countries with the highest percentage of the population ages 25–64 with a bachelor's degree or higher, but several other countries have surpassed the United States in the percentage of the younger (ages 25–34) population with a bachelor's degree or higher (figure 2-25; appendix table 2-34).[16]

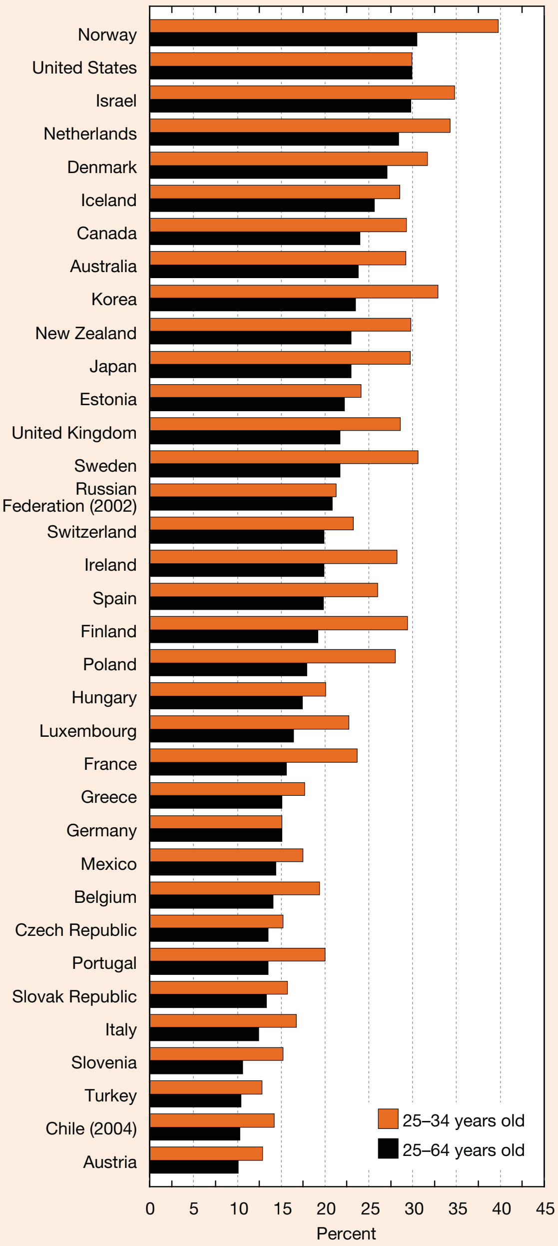
First University Degrees in S&E Fields

More than 12 million students worldwide earned first university degrees[17] in 2006, with more than 4 million of these in S&E fields (appendix table 2-35). These worldwide totals include only countries for which relatively recent data are available (primarily countries in Asia, Europe, and the Americas) and therefore are likely an underestimation. Asian universities accounted for 1.8 million of the world's S&E first university degrees in 2006, almost 900,000 of these in engineering. Students across Europe (including Eastern Europe and Russia) earned more than 1 million S&E degrees and students in North and Central America more than 600,000 in 2006.

In the United States, S&E degrees are about one-third of U.S. bachelor's degrees and have been for a long time. In several countries/economies around the world, the proportion of first university degrees in S&E fields, especially engineering, is higher. More than half of first university degrees were in S&E fields in Japan (63%), China (53%), and Singapore (51%). China has traditionally awarded a large proportion of its first university degrees in engineering, although the percentage has declined in recent years (appendix table 2-36). In the United States, about 5% of all bachelor's degrees are in engineering. However, in Asia, about 20% are in engineering, and in China about one-third are in engineering (appendix table 2-35). About 12% of all bachelor's degrees in the United States and worldwide are in natural sciences (physical, biological, computer, and agricultural sciences, and mathematics). See the sidebar "International Changes in the Ratio of Natural Science and Engineering Degrees to the College-Age Population."

The number of S&E first university degrees awarded in China, Poland, and Taiwan more than doubled between 1998 and 2006, and those in the United States and many other countries generally increased. Those awarded in Japan decreased in recent years (appendix table 2-36). Natural sciences and engineering (NS&E) degrees account for most of the increase in S&E first university degrees in China. The number of NS&E first university degrees in China rose sharply from 2002 to 2006 and more than trebled between 1998 and 2006 (figure 2-26). In comparison, those awarded in Germany, Japan, South Korea, the United Kingdom, and

Figure 2-25
Attainment of tertiary-type A and advanced research programs, by country and age group: 2006



NOTES: Tertiary-type A programs (International Standard Classification of Education [ISCED] 5A) are largely theory based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although typically last ≥4 years. In United States, correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification, e.g., doctorate. See appendix table 2-34.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2008 (2008).

Science and Engineering Indicators 2010

the United States remained relatively flat. (For information on reforms affecting degree awards in Europe, see sidebar “Changes in European Higher Education Since the Bologna Process.”)

International Changes in the Ratio of Natural Science and Engineering Degrees to the College-Age Population

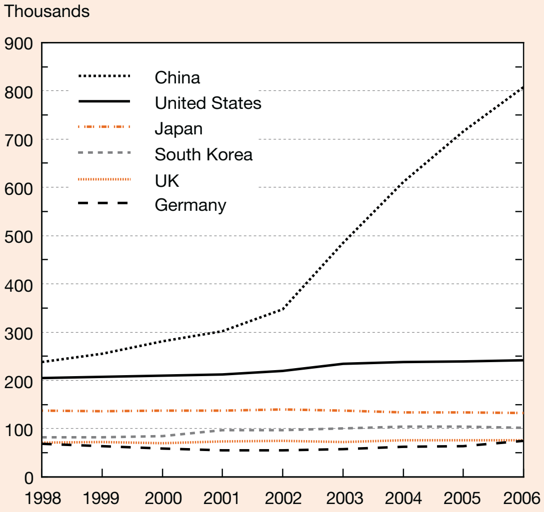
The ratio of natural sciences and engineering (NS&E) degrees to the college-age population is one measure of the technical skill level of those entering the workforce. Over time, the United States has fallen from one of the top countries in terms of its ratio of NS&E degrees to the college-age population to near the bottom of the 23 countries for which data are available. The ratios of first university degrees in NS&E to the college-age population increased substantially in recent decades in these 23 countries. In 1975, only Japan had a higher ratio than the United States of NS&E degrees per hundred 20–24-year-olds (the college-age population). By 1990, a few other countries/economies had surpassed the U.S. ratio, and by 2005 nearly all had done so. A recent NSF report (NSF/SRS 2009b) examined the relative influence on this ratio of increased university degree completion relative to the college-age population and NS&E degrees as an increasing share of all degrees. This study examined increases in the ratio of NS&E first university degrees to the college-age population in the United States and 22 other countries/economies for two periods: 1975–90 and 1990–2005.

The study found that the rising ratio of NS&E degrees to the college-age population in the locations compared with the United States can primarily be attributed to increased university degree completion, not to an increased emphasis on NS&E education; however, the relative importance of these components varies substantially by location. In both the 1975–90 and the 1990–2005 periods, the university degree completion component was either the only component or the larger component for the majority of countries/economies for which such data were available. That is not to say that increased emphasis on NS&E was not an important factor in some countries. The NS&E share component was either the only component or the larger component for five countries in the 1975–90 period but for no countries in the 1990–2005 period. In another eight countries in which the university degree completion component was larger, the NS&E share component and/or the interaction component was substantial in one or the other period.

S&E First University Degrees by Sex

Women earned half or more of first university degrees in S&E in many countries around the world in 2006, including Algeria, Argentina, Canada, Greece, Portugal, Saudi Arabia, the United States, and a number of smaller countries. Several countries in Europe are not far behind, with more than 40% of first university S&E degrees earned by women. In many Asian and African countries, women generally earn about one-third or less of the first university degrees awarded in S&E fields (appendix table 2-37). In Canada, Japan, the United States, and many smaller countries, more than half of the S&E first university degrees earned by women are in the social and behavioral sciences. In South Korea, 45% of the S&E first university degrees earned by women are in engineering; in Europe, more than 20% are in engineering. In the United Kingdom and the United States, 6% of S&E first university degrees earned by women are in engineering.

Figure 2-26
First university natural sciences and engineering degrees, by selected countries: 1998–2006



UK = United Kingdom

NOTES: Natural sciences include physical, biological, earth, atmospheric, ocean, and agricultural sciences; computer sciences; and mathematics. Data for United States not available for 1999.

SOURCES: China—National Bureau of Statistics of China, China Statistical Yearbook, annual series (Beijing) various years; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea and Germany—Organisation for Economic Co-operation and Development, OECD Stat Extracts, http://stats.oecd.org/WBOS/index.aspx/; United Kingdom—Higher Education Statistics Agency; and United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-36.

Science and Engineering Indicators 2010

Global Comparison of S&E Doctoral Degrees

Almost 174,000 S&E doctoral degrees were earned worldwide in 2006. The United States awarded the largest number of S&E doctoral degrees of any country (about 30,000),[18] followed by China (about 23,000), Russia (almost 20,000), and Germany and the United Kingdom (about 10,000 each) (appendix table 2-38). More than 52,000 S&E doctoral degrees were earned in the European Union.

Changes in European Higher Education Since the Bologna Process

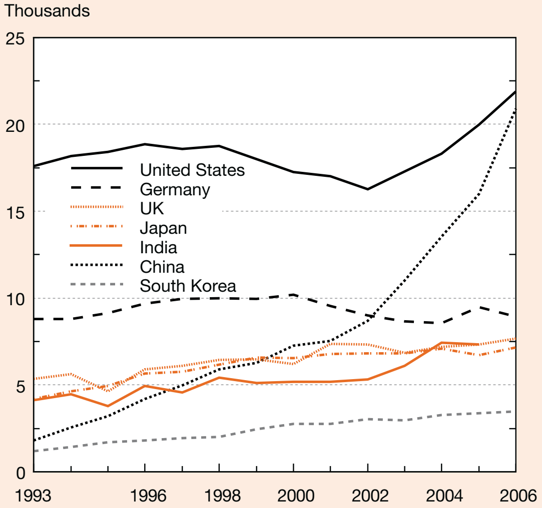
In 1999, 29 European countries, through the Bologna Declaration, initiated a system of reforms in higher education in Europe. The goal of the Bologna Process is to harmonize certain aspects of higher education within participating countries by the year 2010 so that degrees are comparable, credits are transferable, and students, teachers, and researchers can move freely from institution to institution across national borders. Its aim is to replace the varied degree programs in existence, which typically have taken 5 or more years to complete, with a standard 3-year bachelor's degree and a 2-year master's degree and with a standardized credit system. Implementation of these reforms has implications for graduate admissions to U.S. academic institutions: Will U.S. academic institutions see these 3-year bachelor's degrees as equivalent to U.S. 4-year bachelor's degrees? (IIE 2009). The Bologna Process is also stimulating discussion about reform of the U.S. higher education system (Adelman 2008).

By 2008, higher education reform in Europe had been extended to more than 45 countries, but it is still in process in many countries and in many fields, and the impact is still uncertain. Many countries have established regulations for reform, but implementation of changes is ongoing, particularly in some disciplines. In many European countries, law and medicine have not moved to the 2-cycle (bachelor's and master's) structure. One of the major difficulties countries are experiencing in the shift to the 2-cycle structure, particularly in law and medicine, is with the bachelor-level degree's relevance to the labor market (Huisman, Witte, and File 2006). In a few countries, the impact of the change on degree trends is already apparent. In 2001, Italy introduced a 3-year bachelor's degree in accordance with the Bologna guidelines, and the number of students completing an undergraduate degree has since increased, particularly from 2004 on (appendix table 2-36). In Germany, implementation was later, but evidence of the change is apparent in the number of first university degrees in 2006.

Women earned 40% of S&E doctoral degrees awarded in the United States in 2006, about the same as the percentage earned by women in Australia, Canada, the European Union, and Mexico. They earned more than half of S&E doctoral degrees in Portugal and less than one-quarter of S&E doctoral degrees in the Netherlands, Poland, South Korea, and Taiwan (appendix table 2-39).

The number of S&E doctoral degrees awarded in China, Italy, and the United States has risen steeply in recent years (appendix tables 2-40 and 2-41). The United States awarded the largest number of natural sciences and engineering doctoral degrees, but China (as of 2006) was rapidly catching up (figure 2-27) and may have since surpassed the United States. In the United States, as well as in France, Germany, Italy, Spain, Switzerland, and the United Kingdom, the largest numbers of S&E doctoral degrees are in the physical and biological sciences. The number of doctoral degrees in those

Figure 2-27
Natural sciences and engineering doctoral degrees, by selected country: 1993–2006



UK = United Kingdom

NOTES: Natural sciences and engineering include physical, biological, earth, atmospheric, ocean, and agricultural sciences; computer sciences; mathematics; and engineering. Data for United States not available for 1999.

SOURCES: China—National Bureau of Statistics of China; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, OECD. Stat Extracts, http://stats.oecd.org/WBOS/index.aspx/; United Kingdom—Higher Education Statistics Agency; and Germany—Federal Statistical Office, Prüfungen an Hochschulen, and Organisation for Economic Co-operation and Development, OECD. Stat Extracts, http://stats.oecd.org/WBOS/index.aspx/; and United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov. See appendix tables 2-40 and 2-41.

Science and Engineering Indicators 2010

fields stagnated or declined in many of these countries from the late 1990s through 2006, although the number of these degrees in Italy, Switzerland, and the United States increased in recent years. The number of S&E doctoral degrees in Germany has declined slightly since 2000 (appendix table 2-40).

In Asia, China was the largest producer of S&E doctoral degrees. The number of S&E doctorates awarded in China rose from about 1,900 in 1993 to almost 23,000 in 2006 (appendix table 2-41). Recently, the Chinese State Council Academic Degrees Committee announced that China would begin to limit admissions growth in doctoral programs and would focus more on quality of graduates (Mooney 2008). The number of S&E doctorates awarded in India, Japan, South Korea, and Taiwan also rose from 1993 to 2006, but at a lower rate. In China, Japan, South Korea, and Taiwan, more than half of S&E doctorates were awarded in engineering. In India, most doctorates were awarded in the physical and biological sciences (appendix table 2-41).

Global Student Mobility

International migration of students and highly skilled workers expanded in the past two decades, and countries are increasingly competing for foreign students. In particular, students migrated from developing countries to the more developed countries, and from Europe and Asia to the United States. Some migrate temporarily for education, whereas others remain permanently. Some factors influencing the decision to migrate are economic opportunities, research opportunities, research funding, and climate for innovation in the country of destination (OECD 2004). In recent years, many countries, particularly Australia, Canada, the United Kingdom, and the United States, have expanded their provision of transnational education, that is, programs for foreign students in their home countries (NSB 2008). The rise in transnational education, however, has not had much impact on foreign student flows (De Wit 2008). The influence of the worldwide economic and monetary crises beginning in 2008 on international flows of students in the future is uncertain.

Some countries expanded recruitment of foreign students as their own populations of college-age students decreased, both to attract highly skilled workers and increase revenue for colleges and universities (OECD 2008). The population of individuals ages 20–24 (a proxy for the college-age population) decreased in China, Europe, Japan, and the United States in the 1990s and is projected to continue decreasing in China, Europe (mainly Eastern Europe), Japan, and South Korea (appendix table 2-42). The U.S. population of 20–24-year-olds is projected to increase.

The U.S. share of foreign students worldwide declined in recent years, although the United States remains the destination of the largest number of foreign students worldwide (both undergraduate and graduate) of all OECD countries (figure 2-28). In 2006, the United States received 20% of foreign students worldwide, down from 25% in 2000

Figure 2-28
Foreign students enrolled in tertiary education, by country: 2006

NOTES: Data for Canada are for 2005 and exclude private institutions and tertiary-type B programs, e.g., associate's. Data for Austria exclude tertiary-type B programs, e.g., associate's. Data for Netherlands and Germany exclude advanced research programs, e.g., doctorate. Data for Ireland are based on country of prior education and exclude part-time students. Data for United Kingdom, United States, and Australia based on country of residence. Data for Belgium exclude social advancement education. Data for Russia exclude private institutions and advanced research programs, i.e., doctorate.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2008 (2008).

Science and Engineering Indicators 2010

(OECD 2008). Other countries that are among the top destinations for foreign students include the United Kingdom (11%), Germany (9%), and France (8%).

Although Australia has a higher percentage of higher education students (undergraduate and graduate) who are foreign (18%) than the United States (3%), it has a lower share (6%) of foreign students worldwide. Other countries with relatively high percentages of higher education students who are foreign include New Zealand (16%), Switzerland and the United Kingdom (14%), and Austria (12%). A number of countries, including Belgium, Canada, New Zealand, Switzerland, the United Kingdom, and the United States, have relatively high percentages (more than 20%) of doctoral students who are foreign (OECD 2008).

The United Kingdom has been actively expanding its position in international education, both by recruiting foreign students to study in the country and expanding its provision of transnational education (British Council 2007). Foreign student enrollment in the United Kingdom is increasing, especially at the graduate level, with increasing flows of students from China and India (appendix table 2-43). In just 5 years, from 2001 to 2006, foreign students increased from 35% to 45% of all graduate students studying S&E in the United Kingdom. Foreign students now account for more than half of graduate students in mathematics/computer sciences and engineering. Students from China and India accounted for most of the increase, but the number of graduate students from France, Germany, Ireland, Malaysia, Nigeria, Pakistan, and the United States also increased. The number of foreign undergraduate students also increased, but not as dramatically. Foreign undergraduates accounted for 10% of S&E enrollment in the United Kingdom in 2001 and 11% in 2006.

Japan has increased its enrollment of foreign students in recent years and in 2008 announced plans to triple foreign enrollment in 12 years (McNeil 2008). Almost 60,000 foreign students were enrolled in S&E programs in Japanese universities in 2008, up from 42,000 in 2001. Foreign S&E student enrollment in Japan is concentrated at the undergraduate level, accounting for 68% of all foreign S&E students. Foreign undergraduates account for 3% of undergraduate and 14% of graduate S&E students in Japan. Most of the foreign students were from Asian countries. China, Indonesia, Malaysia, Myanmar, Nepal, South Korea, Thailand, and Vietnam were among the top 10 countries of origin for both undergraduates and graduate students. Chinese students accounted for more than half of foreign undergraduate (68%) and graduate (54%) S&E students in Japan in 2008 (appendix table 2-44).

Foreign students are an increasing share of enrollment in Canadian universities. Foreign S&E students accounted for about 6% of undergraduate and 20% of graduate S&E enrollment in Canada in 2006, up from 3% and 17% in 1996, although the foreign shares in 2006 were down slightly from recent years (NSB 2008). In 2005–06, at both the undergraduate and graduate levels, the highest percentages of foreign S&E students were in mathematics/computer sciences and engineering. Asian countries/economies were the top places of origin of foreign S&E graduate and undergraduate students in Canada. China alone accounted for 18% of foreign S&E graduate and undergraduate students in Canada. The United States was also among the top countries of origin of foreign students, accounting for 6% of foreign S&E graduate students and 12% of foreign S&E undergraduate students in Canada (appendix table 2-45).

Although foreign students are a large share of U.S. higher education, U.S. students are a relatively small share of foreign students worldwide. About 49,000 U.S. students (in all fields) were reported as foreign students by OECD and OECD partner countries in 2006, far fewer than the numbers of foreign students from China, France, Germany, India, Japan, or South Korea. The main destinations of U.S. students were the United Kingdom (14,800), Canada (9,500), Germany (3,300), Australia (2,900), France (2,800), Ireland (2,100), and New Zealand (2,100)—mainly English speaking countries (OECD 2008).

Approximately 242,000 U.S. students from U.S. universities enrolled in study-abroad programs in the 2006–07 academic year, up 8.5% from 2005–06 (IIE 2008). A little more than one-third were in programs lasting one semester, and more than half were in short-term programs (2–8 weeks). About 5% were graduate students; the rest were undergraduates, primarily juniors or seniors. About one-third were studying in S&E fields: 21% in social sciences, 7% in physical or life sciences, 3% in engineering, 2% in math or computer sciences, and 1% in agricultural sciences.

Conclusion

S&E higher education in the United States is attracting growing numbers of students. The number of bachelor's and doctoral degrees awarded in all fields and in S&E fields continues to rise, having reached new peaks in 2007. Graduate enrollment in S&E fields is also increasing. Most of the growth in undergraduate S&E education occurred in science fields. In engineering, bachelor's degrees increased since 2001 but have not yet attained the levels of the 1980s. Computer sciences degrees dropped precipitously in recent years. In doctoral degrees, growth occurred in both science and engineering fields.

Foreign graduate student enrollment in S&E increased in 2006 after declines in 2004 and 2005. The number of entering foreign students dropped after 11 September 2001 but partially rebounded in 2005 and 2006. Students on temporary visas earned 33% of S&E doctorates in the United States in 2007 and half or more of doctoral degrees awarded in engineering, physics, mathematics, computer sciences, and economics. A large fraction of these students stay in the United States: more than three-quarters of foreign doctoral degree recipients in 2007 planned to stay in the United States after graduation.

Globalization of higher education continues to expand. Although the United States continues to attract the largest number and fraction of foreign students worldwide, its share of foreign students has decreased in recent years. Universities in several other countries (e.g., Canada, Japan, and the United Kingdom) have expanded their enrollment of foreign S&E students.

Notes

1. Based on previous projections, NCES has estimated that the mean absolute percentage error for bachelor's degrees projected 9 years out was 8.0 (NCES 2008c).

2. These data are from sample surveys and are subject to sampling error. Information on estimated standard errors can be found in appendix E of the annual report "The American Freshman: National Norms for Fall 2008" published by The Cooperative Institutional Research Program of the Higher Education Research Institute, University of California–Los Angeles (http://www.gseis.ucla.edu/heri/pr-display.php?prQry=28, accessed 23 June 2009). Data reported here are significant at the .05 level.

3. The number of S&E degrees awarded to a particular freshmen cohort is lower than the number of students reporting such intentions and reflects losses of students from S&E, gains of students from non-S&E fields after their freshman year, and general attrition from bachelor's degree programs.

4. The physical sciences include earth, atmospheric, and ocean sciences.

5. About 17% of 2001 and 2002 S&E bachelor's degree recipients had previously earned an associate's degree (NSF/SRS 2006).

6. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

7. For longer trends in degrees, see the NSF report series "Science and Engineering Degrees," http://www.nsf.gov/statistics/degrees/, accessed 12 June 2009. For more detail on enrollment and degrees by sex and by race/ethnicity, see *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009* (NSF/SRS 2009d).

8. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

9. The natural sciences include agricultural; biological; computer; earth, atmospheric, and ocean; and physical sciences and mathematics.

10. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

11. See *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009* (NSF/SRS 2009d) for more detail on enrollment of foreign students by sex.

12. Clinical psychology programs and programs that emphasize professional practice (professional schools and Psy.D. programs) are associated with higher debt, but even in the more research-focused subfields of psychology, lower percentages of doctorate recipients were debt free and higher percentages had high levels of debt than those in other S&E fields. For information on debt levels of clinical versus nonclinical psychology doctorates in 1993–96, see "Psychology Doctorate Recipients: How Much Financial Debt at Graduation?" (NSF 00-321) at http://www.nsf.gov/statistics/issuebrf/sib00321.htm (accessed 12 June 2009).

13. Data for racial/ethnic groups are for U.S. citizens and permanent residents only.

14. The number of S&E doctoral degrees earned by students in Chinese universities continued to increase throughout this period, from 1,894 in 1993 to 22,953 in 2006.

15. For more information about the distribution of postdoc positions according to sex, see *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009* (NSF/SRS 2009d).

16. These data are based on national labor force surveys and are subject to sampling error; therefore, small differences between countries may not be meaningful. The standard error for the U.S. percentage of 25–64-year-olds with a bachelor's or higher degree is roughly 0.1, and the standard error for the U.S. percentage of 25–34-year-olds with a bachelor's or higher degree is roughly 0.4.

17. A first university degree refers to the completion of a terminal undergraduate degree program. These degrees are classified as level 5A in the International Standard Classification of Education, although individual countries use different names for the first terminal degree (e.g., *laureata* in Italy, *diplome* in Germany, *maîtrise* in France, bachelor's degree in the United States and Asian countries).

18. In international comparisons, S&E fields do not include medical or health fields.

Glossary

Baccalaureate-origin institution: The college or university from which an S&E doctorate recipient earned a bachelor's degree.

Distance education: Formal education process in which the student and instructor are not in the same place.

First university degree: A terminal undergraduate degree program; these degrees are classified as level 5A in the International Standard Classification of Education, although individual countries use different names for the first terminal degree (e.g., *laureata* in Italy, *diplome* in Germany, *maîtrise* in France, and *bachelor's degree* in the United States and in Asian countries).

Internationally mobile students: Those individuals who are not citizens of the country in which they study.

Net price: The published price of an undergraduate college education minus the average grant aid and tax benefits that students receive.

Online education: A type of distance education where the medium of instruction is computer technology via the Internet.

Stay rate: The proportion of students on temporary visas who have plans to stay in the United States immediately after degree conferral.

Tertiary type A programs: Higher education programs that are largely theory based and designed to provide sufficient qualifications for entry to advanced research programs and to professions with high skill requirements, such as medicine, dentistry, or architecture, and have a minimum duration of 3 years, although they typically last 4 or more years. These correspond to bachelor's or master's degrees in the United States.

Tertiary type B programs: Higher education programs that focus on practical, technical, or occupational skills for direct entry into the labor market and have a minimum duration of 2 years. These correspond to associate's degrees in the United States.

Underrepresented minority: Blacks, Hispanics, and American Indians/Alaska Natives are considered to be underrepresented minorities in S&E.

References

Adelman C. 2008. The Bologna Club: What U.S. higher education can learn from a decade of European reconstruction. Washington, DC: Institute for Higher Education Policy. http://www.ihep.org/assets/files/TheBolognaClub.pdf. Accessed 21 May 2009.

Allen I, Seaman J. 2008. *Staying the Course: Online Education in the United States, 2008.* Needham, MA: The Sloan Consortium.

Attewell P, Lavin D, Domina T, Levey T. 2006. New evidence on college remediation. *Journal of Higher Education* 77(5):886–924.

Bailey T. 2009. Rethinking developmental education in community college. CCRC Brief. New York: Community College Research Center, Teachers College, Columbia University. http://ccrc.tc.columbia.edu/Publication.asp?UID=672. Accessed 3 March 2009.

Bailey T, Badway N, Gumport P. 2001. For-profit higher education and community colleges. Stanford, CA: National Center for Postsecondary Improvement. http://www.stanford.edu/group/ncpi/documents/pdfs/forprofitandcc.pdf. Accessed 12 May 2009.

Brainard J. 2007. America's science test: The tough road to better science teaching. *Chronicle of Higher Education* 53(48):A16.

British Council. 2007. The Prime Minister's Initiative for International Education. http://www.britishcouncil.org/eumd-pmi.htm. Accessed 11 February 2009.

Calcagno J, Long B. 2008. The impact of postsecondary remediation using a regression discontinuity approach: Addressing endogenous sorting and noncompliance. NBER Working Paper 14194. Cambridge, MA: National Bureau of Economic Research. http://www.nber.org/papers/w14194. Accessed 9 June 2009.

Cohen M, Lengenfelter P, Meredith T, Ward D. 2006. A coordinated effort to prepare students for college. *Chronicle of Higher Education* 53(17):B20.

College Board. 2008. *Trends in College Pricing: 2008.* New York.

Colwell R. 2009. Graduate education: Professional science master's programs merit wider support. *Science* 323(5922):1676–77.

Committee on Science, Engineering, and Public Policy (COSEPUP). 1995. *Reshaping the Graduate Education of Scientists and Engineers.* Washington, DC: National Academies Press. http://www.nap.edu/openbook.php?record_id=4935. Accessed 22 June 2009.

Committee on Science, Engineering, and Public Policy (COSEPUP). 2000. *Enhancing the Postdoctoral Experience for Scientists and Engineers.* Washington, DC: National Academies Press. http://books.nap.edu/catalog.php?record_id=9831#toc. Accessed 1 June 2007.

Committee on Science, Engineering, and Public Policy (COSEPUP). 2004. *Facilitating Interdisciplinary Research.* Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=11153. Accessed 22 June 2009.

Commonfund Institute. 2008. 2008 HEPI update. http://www.commonfund.org/Templates/Generic/RESOURCE_REQUEST/target.pdf?RES_GUID=B878F541-69A2-488A-B649-A575FB597EBB. Accessed 18 February 2009.

Council of Graduate Schools (CGS) 2008a. *Global Perspectives on Graduate Education: Proceedings of the Strategic Leaders Global Summit on Graduate Education.* Washington, DC.

Council of Graduate Schools (CGS). 2008b. *Ph.D. Completion and Attrition: Analysis of Baseline Demographic Data from the Ph.D. Completion Project.* Washington, DC.

Council of Graduate Schools (CGS). 2008c. *Ph.D. Completion and Attrition: Analysis of Baseline Program Data from the Ph.D. Completion Project.* Washington, DC.

Council of Graduate Schools (CGS). 2008d. *The Professional Science Master's Degree: Results of a Pilot Survey of Programs*. Washington, DC.

Council of Graduate Schools (CGS). 2009. *Ph.D. Completion and Attrition: Findings from Exit Surveys of Ph.D. Completers.* Washington, DC.

De Wit H. 2008. *The Dynamics of International Student Circulation in a Global Context.* Rotterdam: Sense Publishers.

Engineering Workforce Commission (EWC). 2008. Engineering & technology enrollments, fall 2007. Washington, DC: American Association of Engineering Societies.

Fortenberry JF, Sullivan P, Jordan N, Knight DW. 2007. Engineering education research aids instruction. *Science* 317(5842):1175–76.

Gibbons MT. 2008. Engineering by the numbers. Washington, DC: American Society for Engineering Education. http://www.asee.org/publications/profiles/upload/2007ProfileEng.pdf. Accessed 10 April 2009.

Huisman J, Witte J, File JM, editors. 2006. The extent and impact of higher education curricular reform across Europe. Center for Higher Education Policy Studies. http://www.utwente.nl/cheps/publications/Publications%202006/extent1.pdf. Accessed 2 February 2009.

Institute of International Education (IIE). 2008. Open doors 2008: A report on international education exchange. http://opendoors.iienetwork.org/?p=131531. Accessed 11 February 2009.

Institute of International Education (IIE). 2009. Three-year Bologna-compliant degrees: Responses from U.S. graduate schools. http://www.iie.org/Content/NavigationMenu/Research_and_Evaluation/Briefing_Papers/SurveyBolognaProcessBriefingPaper2009.pdf. Accessed 21 May 2009.

Karp M. 2008. Towards a community college research agenda: Summary of the National Community College Symposium. Washington, DC, June 19, 2008. http://www.ed.gov/about/offices/list/ovae/pi/cclo/cc-sympsm-smmry10-29-08-final.pdf. Accessed 3 March 2009.

Karp M, Calcagno JC, Hughes KL, Jeong DW, and Bailey T. 2008. Dual enrollment students in Florida and New York City: Postsecondary outcomes. Community College Research Center Brief, Number 37, February 2008. http://ccrc.tc.columbia.edu/Publication.asp?UID=578. Accessed 3 September 2009.

Lewis SE, Lewis JE. 2008. Seeking effectiveness and equity in a large college chemistry course: An HLM investigation of peer-led guided inquiry. *Journal of Research in Science Teaching* 45(7):794–811.

McNeil D. 2008. Japan announces plan to enroll more foreign students. *Chronicle of Higher Education News Blog,* 28 July 2008. http://chronicle.com/news/article/4899/japan-announces-plan-to-enroll-more-foreign-students?utm_source=at&utm_medium=en. Accessed 12 February 2009.

Mooney P. 2008. China to limit enrollments in doctoral programs. *Chronicle of Higher Education*. http://chronicle.com/article/China-Limits-Growth-of-Univ/11420/. Accessed 17 September 2009.

National Academy of Sciences (NAS). 2008. *Science Professionals: Master's Education for a Competitive World*. Washington, DC. http://www.nap.edu/catalog/12064.html. Accessed 24 February 2009.

National Center for Education Statistics (NCES). 2005a. *Dual Credit and Exam-Based Courses in U.S. Public High Schools: 2002–03.* NCES 2005-009. Washington, DC.

National Center for Education Statistics (NCES). 2005b. *Dual Enrollment of High School Students at Postsecondary Institutions: 2002–03*. NCES 2005-008. Washington, DC.

National Center for Education Statistics (NCES). 2008a. *The Condition of Education: 2008.* NCES 2008-031. Washington, DC.

National Center for Education Statistics (NCES). 2008b. *Postsecondary Institutions in the United States: Fall 2007, Degrees and Other Awards Conferred: 2006–07, and 12-Month Enrollment: 2006–07.* NCES 2008-159. Washington, DC.

National Center for Education Statistics (NCES). 2008c. *Projections of Education Statistics to 2017.* NCES 2008-078. Washington, DC.

National Center for Education Statistics (NCES). 2009a. *Digest of Education Statistics: 2008.* NCES 2009-020. Washington, DC.

National Center for Education Statistics (NCES). 2009b. *Distance Education at Degree-Granting Postsecondary Institutions: 2006–07.* NCES 2009-044. Washington, DC.

National Center for Public Policy and Higher Education (NCPPHE). 2008. Measuring up 2008: The national report card on higher education. San Jose, CA. http://measuringup2008.highereducation.org/print/NCPPHEMUNationalRpt.pdf. Accessed 25 February 2009.

National Opinion Research Center (NORC). 2007. Doctorate recipients from United States universities: Summary report 2006. Chicago, IL. http://www.norc.org/SED.htm. Accessed 24 June 2009.

National Professional Science Master's Association (NPSMA). 2009. PSM degree program enrollee & graduate report. http://www.npsma.org/assetlibrary/eg_data_report_final.pdf. Accessed 16 March 2009.

National Science Board (NSB). 1998. *Science and Engineering Indicators 1998.* NSB 98-1. Arlington, VA.

National Science Board (NSB). 2003. *The Science and Engineering Workforce: Realizing America's Potential.* NSB 03-69. Arlington, VA.

National Science Board (NSB). 2008. *Science and Engineering Indicators 2008.* Two volumes. Arlington, VA (volume 1, NSB 08-01; volume 2, NSB 08-01A).

National Science Foundation, Division of Graduate Education (NSF/DGE). 2009. Impact of transformative interdisciplinary research and graduate education on academic institutions. May 2008 Workshop Report. NSF 09-33. Carol Van Hartesveldt and Judith Giordan. Arlington, VA. http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf0933. Accessed 21 September 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 1993. Science and engineering doctorates: 1960–91. NSF 93-301. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2000. Modes of financial support in the graduate education of science and engineering doctorate recipients. NSF 00-319, Mark Morgan, Joan Burrelli, and Alan Rapoport. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2006. Characteristics of recent science and engineering graduates: 2003. NSF 06-329. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2007. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2007.* NSF 07-315. Arlington, VA. http://www.nsf.gov/statistics/wmpd/pdf/nsf07315.pdf. Accessed 17 June 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2008. Baccalaureate origins of S&E doctorate recipients. NSF 08-311, Joan Burrelli, Alan Rapoport, and Rolf Lehming. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009a. Interdisciplinary dissertation research. Forthcoming.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009b. Reasons for international changes in the ratio of natural science and engineering degrees to the college-age population. NSF 09-308, Joan Burrelli and Alan Rapoport. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009c. Science and engineering doctorate awards: 2006. NSF 09-311. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009d. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009.* NSF 09-305. Arlington, VA. http://www.nsf.gov/statistics/wmpd/start.htm. Accessed 16 April 2009.

Nerad M, Heggelund M, editors. 2008. *Toward a Global PhD: Forces & Forms in Doctoral Education Worldwide.* Seattle: University of Washington Press.

Organisation for Economic Co-operation and Development (OECD). 2004. *Education at a Glance: 2004.* Paris.

Organisation for Economic Co-operation and Development (OECD). 2008. *Education at a Glance: 2008.* Paris.

Quitadamo IJ, Faiola CL, Johnson JE, Kurtz MJ. 2008. Community-based inquiry improves critical thinking in general education biology. *CBE Life Sciences Education* 7(3):327–37. http://www.lifescied.org/cgi/content/abstract/7/3/327. Accessed 24 February 2009.

Teitelbaum MS, Cox VT. 2007. A degree of professionalism. *Nature* 445(7126):458.

Western Interstate Commission for Higher Education (WICHE). 2006. Accelerated learning options: Moving the needle on access and success: A study of state and institutional policies and practices. Boulder, CO. http://wiche.edu/pub/12758. Accessed 17 September 2009.

Chapter 3
Science and Engineering Labor Force

List of Sidebars

List of Tables

List of Figures

Highlights

The S&E workforce has shown sustained growth for over half a century, and growth is projected to continue into the future.

- The number of workers in S&E occupations grew from about 182,000 in 1950 to 5.5 million in 2007. This represents an average annual growth rate of 6.2%, nearly 4 times the 1.6% growth rate for the total workforce older than age 18 during this period.
- More recently, from 2004 to 2007, S&E workforce growth averaged 3.2% but was still twice as high as that of the total U.S. workforce.
- The sustained U.S. S&E workforce growth rests largely on three factors: increased S&E degree production, immigration of scientists and engineers, and few retirements because of the relative youth of the S&E workforce compared to the total U.S. workforce.

Scientists and engineers can be categorized in many ways, including by occupation and by degree field.

- Defined by occupation, the U.S. S&E workforce totaled between 4.3 million and 5.8 million people in 2006.
- Individuals with an S&E bachelor's degree or higher (16.6 million) or whose highest degree was in S&E (12.4 million) substantially outnumbered those working in S&E occupations.
- The majority of those with an S&E degree but working in non-S&E occupations report that their jobs are related to their degree.

R&D is an important activity for the S&E workforce.

- The majority of S&E degree holders who report R&D as a major work activity have bachelor's degrees as their highest degree (53%); only 12% have doctorates.
- Engineering degree holders comprise more than one-third (36%) of the total R&D workforce; those with degrees in computer sciences and mathematics constitute another 17%.
- Well above half of doctorate holders in most S&E fields report participating in R&D; the exception is those with social science doctorates.
- Among all scientists and engineers named on patent applications from fall 1998 to fall 2003, 41% held a bachelor's degree, 31% a master's degree, and 24% a doctorate.

Scientists and engineers work for all types of employers.

- For-profit firms employed 47% of all individuals whose highest degree is in S&E but only 28% of S&E doctorate holders.
- Academic institutions employed about 42% of individuals with S&E doctorates, including those in postdocs or other temporary positions.
- About 17% of employed workers whose highest degree was in S&E (1.7 million workers) reported they were self-employed in 2006, with two-thirds in incorporated businesses.

S&E occupations are found throughout industry.

- Industries with above-average proportions of S&E jobs tend to pay higher average salaries to both their S&E and non-S&E workers.
- Small firms are important employers of those with science or engineering degrees. Firms with fewer than 100 persons employ 36% of them.

Aging and retirement patterns are likely to alter the composition of the S&E labor force.

- Absent changes in degree production, immigration, and retirement patterns, the number of S&E-trained persons in the workforce will continue to grow, but at a slowing rate, as more S&E workers reach traditional retirement age (26% were older than age 50 in 2006).
- Across all S&E degree levels, by age 61 about half of S&E workers are no longer working full time; for doctorate holders, half no longer work full time by age 66.
- A much larger proportion of doctorate holders than those with bachelor's and master's degrees are near retirement age.

Women remain underrepresented in the S&E workforce, although to a lesser degree than in the past.

- Women constituted two-fifths (40%) of those with S&E degrees in 2006, but their proportion is smaller in most S&E occupations.
- As more women than men have entered the S&E workforce over the decades, their proportion in S&E occupations rose from 12% in 1980 to 27% in 2007.
- Women in the S&E workforce are on average younger than men, suggesting that larger proportions of men than of women may retire in the near future, thus changing these sex ratios.

The proportion of blacks and Hispanics in the S&E labor force is lower than their proportion in the general population; the reverse is true for Asians/Pacific Islanders.

- The proportions of blacks and Hispanics in S&E occupations have continued to grow over time. However, these groups remain underrepresented relative to their proportions in the total population.
- Blacks, Hispanics, and other underrepresented minorities together constitute 24% of the U.S. population, 13% of college graduates, and 10% of the college-degreed in S&E occupations.
- The proportion of blacks in nonacademic S&E occupations was 3% in 1980 and 5% in 2007; that of Hispanics was 2% and 4%, respectively.

- At the doctoral level, blacks, Hispanics, and American Indians/Alaska Natives combined represented just over 4% of employment in nonacademic S&E occupations in 1990 and 6% in 2007.
- Asian/Pacific Islanders constitute 5% of the U.S. population, 7% of college graduates, and 14% of those in S&E occupations; most of them (82%) are foreign born.

Workers with S&E degrees or occupations tend to earn more than other comparable workers.

- Half of the workers in S&E occupations earned $70,600 or more in 2007, more than double the median earnings ($31,400) of the total U.S. workforce.
- Workers with S&E degrees, regardless of their occupations, earn more than workers with comparable-level degrees in other fields.

Especially at lower education levels, people whose work is associated with S&E are less often exposed to unemployment.

- Unemployment rates for those in S&E occupations tend to be lower than those for all college-degreed individuals and much lower than those of persons with less than a bachelor's degree.
- Unemployment data through September 2009 illustrate the advantages occurring to those whose jobs involve S&E: 9.7% unemployment for all workers, 7.6% for S&E technicians and computer programmers, 5.4% for all bachelor's degree holders, and 5.5% for those in S&E occupations.
- For the 12 months beginning in September 2008, unemployment rates rose sharply for all workers, moving from 6.1% to 9.7%. Substantial increases occurred for technicians and programmers (4.9 percentage points) and workers in S&E occupations (3.3 percentage points), which exceeded those for all bachelor degree holders (2.3 percentage points).
- The unemployment rates for S&E doctorate holders are generally much lower than for those at other degree levels.

Postdoc positions are increasingly common, but their frequency is different in different disciplines.

- The total number of postdocs in the United States is unknown. About half of the known postdocs in 2005 are in the biological and other life sciences.
- The incidence of individuals taking S&E postdoc positions during their careers has risen, from about 31% of those with a pre-1972 doctorate to 46% of those receiving their doctorate in 2002–05.
- A majority of doctorate holders in the life or physical sciences now have a postdoc position as part of their career path; so do 30% or more of doctorate holders in mathematics and computer sciences, social sciences, and engineering.

The importance of foreign-born scientists and engineers to the S&E enterprise in the United States continues to grow.

- Twenty-five percent of all college-educated workers in S&E occupations in 2003 were foreign born, as were 40% of doctorate holders in S&E occupations.
- More than 40% of all university-educated foreign-born workers had their highest degree from a foreign institution, up from about half that percentage before the 1980s.
- From 2003 to 2007, the shares of the foreign born among master's degree and doctorate holders rose 2 percentage points each.
- About half of all foreign-born scientists and engineers are from Asia, including: 16% from India; 11% from China; 4% to 6% each from the Philippines, South Korea, and Taiwan.
- More than a third of U.S.-resident doctorate holders come from China (22%) and India (14%).

The number of most types of temporary work visas issued to high-skilled workers has continued to increase from their post-9/11 lows.

- More temporary visas are issued than are used.
- H-1B temporary work visas are restricted to 65,000 annually, with 20,000 exemptions for students earning U.S. master's degrees or doctorates and further exemptions for U.S. academic and research institutions in their own hiring.
- Over two-thirds of H-1B visas were issued for S&E occupations, with a large portion of the remainder for closely related work.
- More than half of all H-1B visa recipients were from India; Asian citizens made up three-quarters of all H-1B visa recipients.

Most foreign doctoral students choose to remain in the United States after earning their degree.

- The 5-year stay rate for foreign doctoral students showed a small decline: 62% of 2002 doctorate recipients were in the country in 2007, down from 65% for the class of 2000 but remaining near its record high.
- Overall declines in stay rates reflect lower rates for doctorate recipients from some countries (e.g., Taiwan, Japan, and India), whereas stay rates for students from other countries (e.g., the United Kingdom and Germany) increased.
- Tentative evidence suggests that foreign students who receive their doctorates from highly rated departments may have long-term (5-year) stay rates that are below the rates for those who receive their doctorates from less highly reputed departments.

The capability to work in science and technology has increased throughout the world.

- There are no comprehensive measures of the global S&E labor force, but fragmentary data suggest that the U.S. world share is continuing to decline.
- Data on the number of researchers compiled by the Organisation for Economic Cooperation and Development (OECD) show moderate average growth from 1995 to 2007 for established scientific nations and regions, in contrast to rapid growth in selected developing regions.
- Over about a decade, the estimated number of U.S. researchers rose by 40% to about 1.4 million in 2007, that of the European Union to 1.4 million, and Japan's to about 710,000.
- The number of researchers in China rose to an estimated 1.4 million, comparable to the estimates for the EU-27 and the United States.

R&D employment of multinational companies (MNCs) has been increasing.

- In 2004 U.S.-based MNCs employed about 854,000 research and development (R&D) workers globally, 16% of them overseas in majority-owned subsidiaries, compared with about 727,000 researchers in 1994 (14% of them overseas).
- From 1994 to 2004, R&D employment of foreign-based MNCs in the United States rose from about 90,000 to 129,000.

Introduction

Chapter Overview

Like most developed economies, the United States increasingly depends on a technically skilled workforce, including scientists and engineers. Workers for whom knowledge and skill in S&E are central to their jobs have an effect on the economy and the wider society that is disproportionate to their numbers: they contribute to research and development, increased knowledge, technological innovation, and economic growth. Moreover, the knowledge and skills associated with science and engineering have diffused across occupations and become more important in jobs that are not traditionally associated with S&E.

Chapter Organization

This chapter has five major sections. The first describes different measures of the U.S. S&E workforce by occupation, education, and technical expertise needed on the job. It also presents a discussion of the size and growth of the S&E workforce.

The second section examines employment patterns. This includes discussion of the types of jobs that S&E degree holders have, where they work, and what they do on the job.

S&E labor force demographics are the subject of the third section. Topics include the age distribution and retirement patterns of the S&E labor force, trends in the participation of women and underrepresented racial/ethnic minorities, and the continuing importance of foreign-born, and often foreign-educated, scientists and engineers.

The fourth section presents measures of recent S&E labor market conditions. It includes measures of earnings and unemployment, indicators which are applicable to all segments of the labor market. In addition, it reports data on the proportion of S&E-trained workers who are involuntarily working outside of their field. Because highly educated S&E workers often prefer, but cannot always find, work that uses knowledge and skills related to their education, variations in this measure can be a valuable indicator of labor market conditions for these workers. For recent S&E doctoral recipients, data on academic employment and postdoc appointments are also presented.

High-quality data on the global S&E labor force are quite sparse. The available data are presented in the final section. It includes data on the growth in S&E human capital across most of the globe and on the increasing importance of international movements of highly skilled workers to developed nations and elsewhere. This section also includes a more detailed discussion of the globalization of the U.S. S&E workforce, about which there are relatively more complete data.

Scope of the S&E Workforce

Measures of the S&E Workforce

The terms *scientist* and *engineer* can include very different sets of workers. This section presents three types of measures that can be used to estimate the size and describe the characteristics of the U.S. S&E labor force.[1] Different categories of measures are better adapted for addressing some questions than others, and not all general population and workforce surveys include questions in each category.

Occupation

U.S. federal occupation data classify workers by the activities or tasks they primarily perform in their jobs. The Bureau of Labor Statistics' (BLS's) Occupational Employment Statistics (OES) survey collects data that rely on employers to classify their workers using standard occupational definitions. Census Bureau and National Science Foundation (NSF) occupational data in this chapter come from surveys in which individuals supplied information about job titles and/or work activities. This information enables jobs to be coded into standard occupational categories.

Although there is no standard definition of an S&E occupation, NSF has developed a widely used set of occupational categories that it calls *S&E occupations.* These occupations are generally associated with a bachelor's level of knowledge and education in S&E fields. A second set of occupations, *S&E-related occupations,* also require some S&E knowledge or training, but not necessarily as a required credential or at the bachelor's degree level. Examples of such occupations are S&E technicians or managers of the S&E enterprise who may supervise people working in S&E occupations. Other occupations, although classified as *non-S&E,* may include individuals who use their S&E technical expertise in their work. Examples include salespeople who sell specialized research equipment to chemists and biologists and technical writers who edit scientific publications. The NSF occupational classification of S&E, S&E-related, and non-S&E occupations appears in table 3-1.

Other general terms, including science, technology, engineering, or mathematics (STEM), science and technology (S&T), and science, engineering, and technology (SET), are often used to designate the part of the labor force that works with S&E. These terms are broadly equivalent and have no standard meaning.

In this chapter, the narrow classification of S&E occupations is sometimes expanded to include S&E technicians, computer programmers, S&E managers, and a small number of non-health S&E-related occupations such as actuary and architect. This broader grouping is referred to here as STEM occupations.

Education

The pool of S&E workers could also be identified in terms of educational credentials. Individuals who possess an S&E degree, whose highest degree is in S&E, or whose most recent degree is in S&E may be qualified to hold jobs that require S&E knowledge and skills and may choose to seek such jobs if they do not currently hold them. However, a focus on people with relevant educational credentials includes individuals who do not hold jobs that are generally identified with S&E and are not likely to seek them in the future.

Table 3-1
Classification of degree field and occupation

Classification	Degree field	Occupation	Classification of occupation	
			STEM (X)	S&T (X)
S&E	Computer and mathematical sciences	Computer and mathematical scientists	X	X
	Biological, agricultural, and environmental life sciences	Biological, agricultural and environmental life scientists	X	X
	Physical sciences	Physical scientists	X	X
	Social sciences	Social scientists	X	X
	Engineering	Engineers	X	X
		S&E postsecondary teachers	X	X
S&E-related	Health fields	Health-related occupations		
	Science and math teacher education	S&E managers	X	
	Technology and technical fields	S&E precollege teachers		
	Architecture	S&E technicians and technologists	X	X
	Actuarial science	Architects		
		Actuaries		
		S&E-related postsecondary teachers		
Non-S&E	Management and administration	Non-S&E managers		
	Education (except science and math teacher education)	Management-related occupations		
		Non-S&E precollege teachers		
	Social services and related fields	Non-S&E postsecondary teachers		
	Sales and marketing	Social services occupations		
	Arts and humanities	Sales and marketing occupations		
	Other fields	Arts and humanities occupations		
		Other occupations		

S&T = science and technology; STEM = science, technology, engineering, and mathematics

NOTES: Designations STEM and S&T refer to occupation only. For a more detailed classification of occupations and degrees by S&E, S&E-related, and non-S&E, see National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov/docs/occ03maj.html and http://sestat.nsf.gov/docs/ed03maj.html.

Science and Engineering Indicators 2010

Workers with degrees in S&E may not have maintained current knowledge of the fields in which they were trained, may lack interest in working in jobs that require skills associated with S&E education, or may have advanced in their careers to a point where other skills have become more important.

S&E Technical Expertise

The S&E workforce may also be defined by the expertise required to perform a job or the extent to which job requirements are related to formal training in S&E. Many people, including some outside S&E occupations or without S&E degrees, report that their jobs require at least a bachelor's degree level of technical expertise in engineering, computer sciences, mathematics, the natural sciences, or social sciences (S&E technical expertise). Unlike defining the S&E workforce by occupational groupings or educational credentials, defining it by the use of technical knowledge, skills, or expertise involves assessing the content and characteristics of individual jobs. However, it also involves asking survey respondents to make a complex judgment about their jobs and apply a criterion that they are likely to interpret differently.[2]

Size of the S&E Workforce

Defined by occupation, the U.S. S&E workforce totaled between 4.3 million and 5.8 million people in 2006 (table 3-2). Those in S&E occupations who also had bachelor's degrees were estimated at between 4.3 million (Census Bureau 2007) and 5.0 million (NSF, Division of Science Resources Statistics [SRS], Scientists and Engineers Statistical Data System [SESTAT]).[3] SESTAT's 2006 estimates for individuals with an S&E degree at the bachelor's level or higher (16.6 million) or whose highest degree was in S&E (12.4 million) were substantially higher than the number of current workers in S&E occupations. Many of those whose highest degree is in S&E reported that their job, although not in an occupation classified as S&E, was closely or somewhat related to their highest degree (1.95 million closely related and 2.02 million somewhat related). Counting these people, along with those in S&E occupations, as part of the S&E workforce increases by 80% the size of the estimate by occupation alone.

The 2003 SESTAT surveys provide the most recent estimate for a different subjective assessment of S&E

Table 3-2
Measures and counts of S&E workforce: 2003 and 2006

Measure	Education coverage	Data source	Number
Occupation			
Employment in S&E occupations	All	2006 BLS OES	4,962,000
Employment in S&E occupations	Bachelor's and above	2006 NSF/SRS SESTAT	5,024,000
Employment in S&E occupations	Bachelor's and above	2006 Census Bureau ACS	4,262,000
Employment in S&E occupations	All	2006 Census Bureau ACS	5,771,000
Education			
At least one degree in S&E field	Bachelor's and above	2006 NSF/SRS SESTAT	16,602,000
Highest degree in S&E field	Bachelor's and above	2006 NSF/SRS SESTAT	12,436,000
Employed and job closely related to highest degree	Bachelor's and above	2006 NSF/SRS SESTAT	4,540,000
Job is in S&E	Bachelor's and above	2006 NSF/SRS SESTAT	2,590,000
Job is something other than S&E	Bachelor's and above	2006 NSF/SRS SESTAT	1,950,000
Employed and job somewhat related to highest degree	Bachelor's and above	2006 NSF/SRS SESTAT	3,045,000
Job is in S&E	Bachelor's and above	2006 NSF/SRS SESTAT	1,026,000
Job is something other than S&E	Bachelor's and above	2006 NSF/SRS SESTAT	2,019,000
Employment requires bachelor's level S&E technical expertise in —			
One or more S&E fields	Bachelor's and above	2003 NSF/SRS SESTAT and NSCG	12,855,000
Engineering, computer science, math, or natural sciences	Bachelor's and above	2003 NSF/SRS SESTAT and NSCG	9,215,000
Social sciences	Bachelor's and above	2003 NSF/SRS SESTAT and NSCG	5,335,000

ACS = American Community Survey; BLS = Bureau of Labor Statistics; OES = Occupational and Employment Statistics; NSF/SRS = National Science Foundation, Division of Science Resources Statistics; SESTAT = Scientists and Engineers Statistical Data System; NSCG = National Survey of College Graduates

SOURCES: BLS, 2006 OES Survey; Census Bureau, 2006 ACS; and NSF/SRS, 2006 SESTAT integrated file and special analytic file comprising 2003 SESTAT integrated file and 2003 NSCG.

Science and Engineering Indicators 2010

work—whether jobs require technical expertise at the bachelor's degree level or higher in S&E fields. According to these surveys, 12.9 million bachelor's degree holders reported that their jobs required at least this level of expertise in one or more S&E fields. This contrasts with 2003 SESTAT estimates of 4.8 million in S&E occupations and 11.9 million whose highest degree is in an S&E field.

Growth of the S&E Workforce

However defined, the S&E workforce has for decades grown faster than the total workforce. Defined by occupation, growth in the S&E workforce can be examined over nearly 6 decades using Census Bureau data. (For a discussion of longer periods, see the sidebar "Scientists Since Babylon.") The number of workers in S&E occupations grew from about 182,000 in 1950 to 5.5 million in 2007. This represents an average annual growth rate of 6.2%, nearly 4 times the 1.6% growth rate for the total workforce older than age 18 during this period. The somewhat broader category of S&T occupations grew from 205,000 to 6.5 million (figure 3-1).

In each decade, the growth rate of S&E occupations exceeded that of the total workforce (figure 3-2). During the 1960s, 1980s, and 1990s, the difference in growth rates was very large (about 3 times the rate for the total labor force). It was smallest during the slower growth period of the 1970s and between 2000 and 2007. S&E occupational employment has grown from 2.6% of the workforce in 1983 to 4.3% of all employment in 2007 (figure 3-3).

Recent OES employment estimates for workers in S&E occupations indicate that the S&E workforce is continuing to grow faster than the total workforce (see table 3A in sidebar "Scientists Since Babylon"). The OES estimate was 5.6 million in May 2007, up 9.9% from the May 2004 total of 5.1 million. This implies an average annual growth rate of 3.2%, about double the 1.6% average annual increase in employment in all occupations. During the same period, the broader STEM aggregate (including technicians, S&E managers, etc.) reached 7.6 million in May 2007 but grew at an average annual rate of 2.2%—slower than S&E occupations because of employment declines for both technicians/programmers and S&E managers. OES projections are that S&E occupations will continue to grow at a faster rate than the total workforce. (See sidebar, "Projected Growth of Employment in S&E Occupations.")

Between 1980 and 2000, although the number of S&E degree holders in the workforce grew more than the number of people working in S&E occupations, degree production in all broad categories of S&E fields rose at a slower pace than employment in S&E jobs (figure 3-4; see chapter 2 for a

Scientists Since Babylon

In the early 1960s, a prominent historian of science, Derek J. de Solla Price, examined the growth of science and the number of scientists over very long periods in history and summarized his findings in a book entitled *Science Since Babylon* (1961). Using a number of empirical measures (most over at least 300 years), Price found that science, and the number of scientists, tended to double about every 15 years, with measures of higher quality science and scientists tending to grow slower (doubling every 20 years) and measures of lower quality science and scientists tending to grow faster (every 10 years).

According to Price (1961), one implication of this long-term exponential growth is that "80 to 90% of all the scientists that ever lived are alive today." This insight follows from the likelihood that most of the scientists from the past 45 years (a period of three doublings) would still be alive. Price was interested in many implications of these growth patterns, but in particular, he was interested in the idea that this growth could not continue indefinitely and the number of scientists would reach "saturation." Price was concerned in 1961 that saturation had already begun.

How different are the growth rates in the number of scientists and engineers in recent periods from what Price estimated for past centuries? Table 3-A shows growth rates for some measurements of the S&E labor force in the United States and elsewhere in the world for a period of available data. Of these measures, the number of S&E doctorate holders in the United States labor force showed the lowest average annual growth of 2.4% (doubling in 31 years if this growth rate were to continue). The number of doctorate holders employed in S&E occupations in the United States showed a faster average annual growth of 3.8% (doubling in 20 years if continued). There are no global counts of individuals in S&E, but counts of "researchers" in member countries of the Organisation for Economic Co-operation and Development (OECD) grew at an average annual rate of 3.3% (doubling in 23 years if continued). Data on the population of scientists and engineers in most developing countries are very limited, but OECD data for researchers in China show a 10.8% average annual growth rate (doubling in 8 years if continued). All these numbers are broadly consistent with a continuation of growth in S&E labor exceeding the rate of growth in the general labor force.

Table 3-A
Growth rates for selected S&E labor force measurements

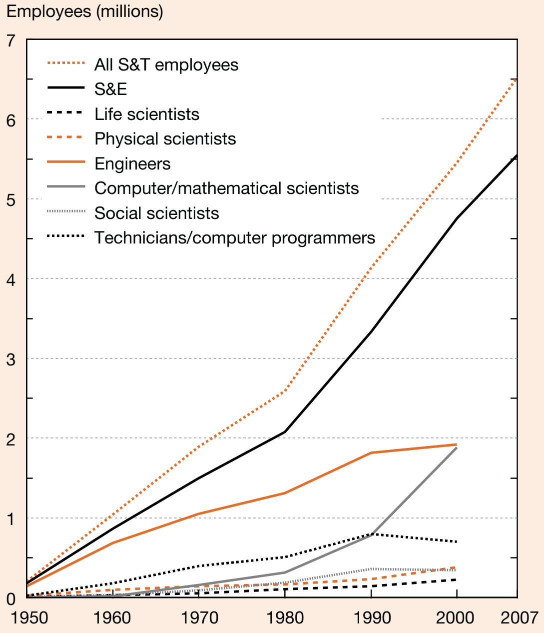
Measurement	Source	Years	First year	Last year	Average annual growth rate (%)
Researchers in OECD countries	OECD	1995–2005	2,815,000	3,880,000	3.3
College graduates in the U.S. in S&E occupations (except postsecondary teachers)	U.S. Census	1990–2005	200,000	390,000	4.6
Doctorate holders in the U.S. in S&E occupations (except postsecondary teachers)	U.S. Census	1990–2005	2,362,000	4,111,000	3.8
Workers with highest degree in S&E who report job related to degree	NSF/SRS SESTAT	1993–2006	5,342,000	7,585,000	2.7
S&E doctorate holders in U.S.	NSF/SRS SESTAT	1993–2006	590,000	803,000	2.4
S&E bachelor's degree and above holders in U.S.	NSF/SRS SESTAT	1993–2006	11,022,000	16,602,000	3.2
Engineers in Japan	Statistical Yearbook Japan	1980-2000	686,662	1,687,795	4.6
Researchers in China	OECD	2000–07	695,000	1,423,400	10.8

NSF/SRS = National Science Foundation, Division of Science Resources Statistics; OECD = Organisation for Economic Co-operation and Development; SESTAT = Scientists and Engineers Statistical Data System

SOURCES: NSF/SRS, SESTAT database, 1993 and 2003, http://sestat.nsf.gov; Census Bureau, Public Use Microdata Sample, 1990; American Community Survey, 2005; and OECD, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

Figure 3-1
Employment in S&T occupations: 1950–2007



S&T = science and technology

NOTE: Data include bachelor's degrees or higher in science occupations, some college and above in engineering occupations, and any education level for technicians and computer programmers. No estimates available below level of S&E and S&T from the 2007 American Community Survey.

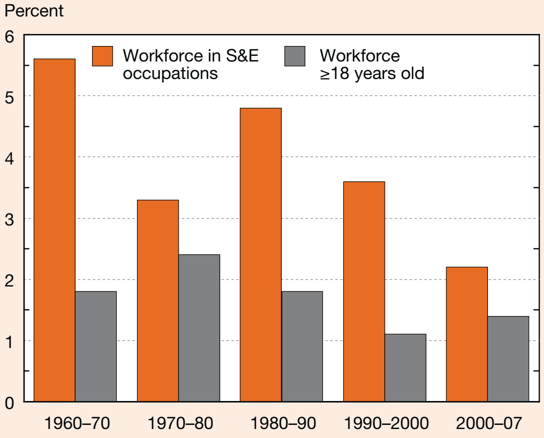
SOURCE: Lowell BL, Regets M, A half-century snapshot of the STEM workforce, 1950 to 2000, Commission on Professionals in Science and Technology, STEM Workforce Data Project: White Paper No. 1 (2006); and Census Bureau, American Community Survey (2007).

Science and Engineering Indicators 2010

fuller discussion of S&E degrees). During this period, S&E employment grew from 2.1 million to 4.8 million (4.2% average annual growth), while total S&E degree production increased from 526,000 to 676,000 (1.5% average annual growth). Except for mathematics, computer sciences, and the social sciences, the growth rate for advanced degrees was higher than for bachelor's degrees.

This growth in the S&E labor force was largely made possible by the following three factors: (1) increases in U.S. S&E degrees earned by both native and foreign-born students who entered the labor force, (2) temporary and permanent migration to the United States of those with foreign S&E education, and (3) the relatively small proportion of scientists and engineers leaving the S&E labor force because they had reached retirement age. Many have expressed concerns about the effects of changes in any or all of these factors on the future of the U.S. S&E labor force (see NSB 2003).

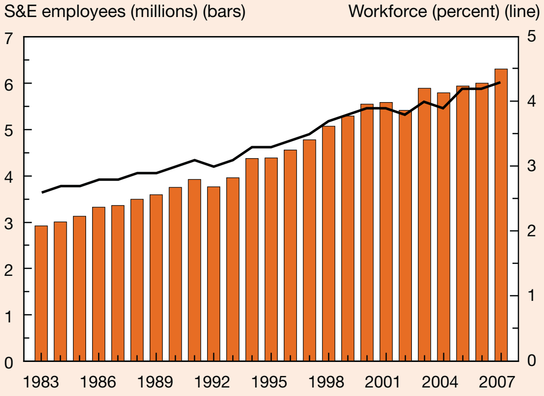
Figure 3-2
Average annual growth rates of total workforce and workforce in S&E occupations: 1960–2007



SOURCE: University of Michigan, Integrated Public Use Microdata Series, 1960–2000 Decennial Census files and 2007 American Community Survey, http://usa.ipums.org/usa/, special tabulations.

Science and Engineering Indicators 2010

Figure 3-3
U.S. workforce in S&E occupations: 1983–2007



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations from Bureau of Labor Statistics, Current Population Survey Monthly Outgoing Rotation files (1983–2007).

Science and Engineering Indicators 2010

Employment Patterns

This section describes the distribution of members of the S&E labor force in the economy. In view of the disjunction between S&E occupations and S&E degrees, this discussion begins with an analysis of data on the educational characteristics of those in S&E occupations and the occupations of workers with S&E degrees. It then describes the institutional sectors in which members of the S&E labor force are employed and provides industry breakdowns within the

Projected Growth of Employment in S&E Occupations

Projections of employment growth are notoriously difficult to make, and the present economic environment makes them even more uncertain. Conceivably, the worldwide economic crisis will produce long-term changes in employment patterns and trends. The reader is cautioned that the assumptions underlying projections such as these, which rely on past empirical relationships, may no longer be valid.

The most recent BLS occupational projections, for the period 2006–16, suggest that total employment in occupations that NSF classifies as S&E will increase at more than double the overall growth rate for all occupations (figure 3-A). These projections involve only the demand for strictly defined S&E occupations and do not include the wider range of jobs in which S&E degree holders often use their training.

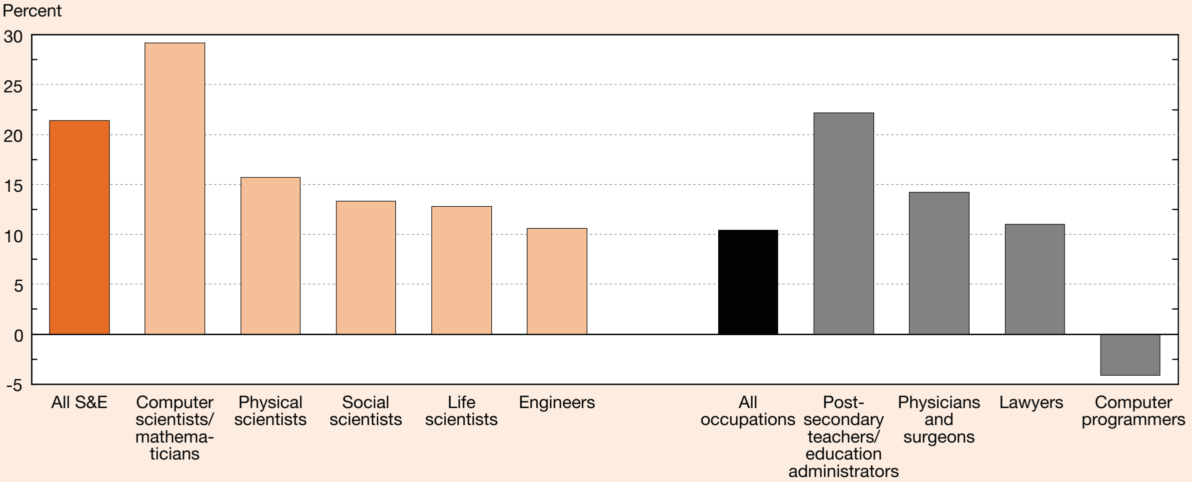
S&E occupations are projected to grow by 21.4% between 2006 and 2016, while employment in all occupations is projected to grow 10.4% over the same period (table 3-B, appendix table 3-2).[4] Yet, there are challenges to making projections about the S&E workforce. Many corporate and government spending decisions on R&D are difficult or impossible to anticipate. In addition, R&D money increasingly crosses borders in search of the best place to have particular research performed. (The United States may be a net recipient of these R&D funds; see the discussion in chapter 4.) Finally, it may be difficult to anticipate new products and industries that may be created via the innovation processes that are most closely associated with scientists and engineers.

Approximately 64% of BLS's projected increase in S&E jobs is in computer and mathematical scientist occupations (table 3-B). Apart from these occupations, the growth rates projected for physical scientists, life scientists, and social scientists are above those for all occupations. Engineering occupations, with projected growth of 10.6%, are growing at about the same rate as all jobs.

Table 3-B also shows occupations that either contain significant numbers of S&E trained people or represent other career paths for those pursuing graduate training. Among these, postsecondary teacher or administrator, which includes all fields of instruction, is projected to grow faster than computer and mathematical occupations, from 1.8 million to 2.3 million workers over the decade between 2006 and 2016—an increase of 31.4%. In contrast, BLS projects computer programmers to increase by only 2.0%.

BLS also projects that job openings in NSF-identified S&E occupations over the 2006–16 period will represent a greater proportion of current employment than all other occupations—43.9% versus 33.7% (figure 3-B). Job openings include both growth in total employment and openings caused by attrition.

Figure 3-A
Bureau of Labor Statistics projections of increase in employment for S&E and selected other occupations: 2006–16



BLS = Bureau of Labor Statistics

SOURCE: BLS, Office of Occupational Statistics and Employment Projections. See appendix table 3-1.

Science and Engineering Indicators 2010

Table 3-B

Bureau of Labor Statistics projections of employment and job openings in S&E occupations: 2006–16

(Thousands)

Occupation	BLS National Employment Matrix 2006 estimate	BLS projected 2016 employment	Job openings from growth and net replacements, 2006–16	10-year growth in total employment (%)	10-year job openings as percent of 2006 employment
All occupations	150,620	166,220	50,732	10.4	33.7
All S&E	5,187	6,296	2,280	21.4	43.9
Computer/mathematical scientists	2,859	3,694	1,466	29.2	51.3
Life scientists	258	292	103	12.8	40.0
Physical scientists	267	309	109	15.7	41.0
Social scientists/related occupations	291	330	96	13.3	32.9
Engineers	1,512	1,671	505	10.6	33.4
S&E-related occupations					
S&E managers	513	616	200	20.1	39.0
S&E technicians	874	986	303	12.8	34.7
Computer programmers	455	464	117	2.0	25.6
Physicians and surgeons	633	723	204	14.2	32.3
Health technologists and technicians	2,612	3,094	1,074	18.5	41.1
Selected other occupations					
Postsecondary teachers/administrators	1,760	2,312	953	31.4	54.1
Lawyers	761	844	228	11.0	29.9

BLS = Bureau of Labor Statistics

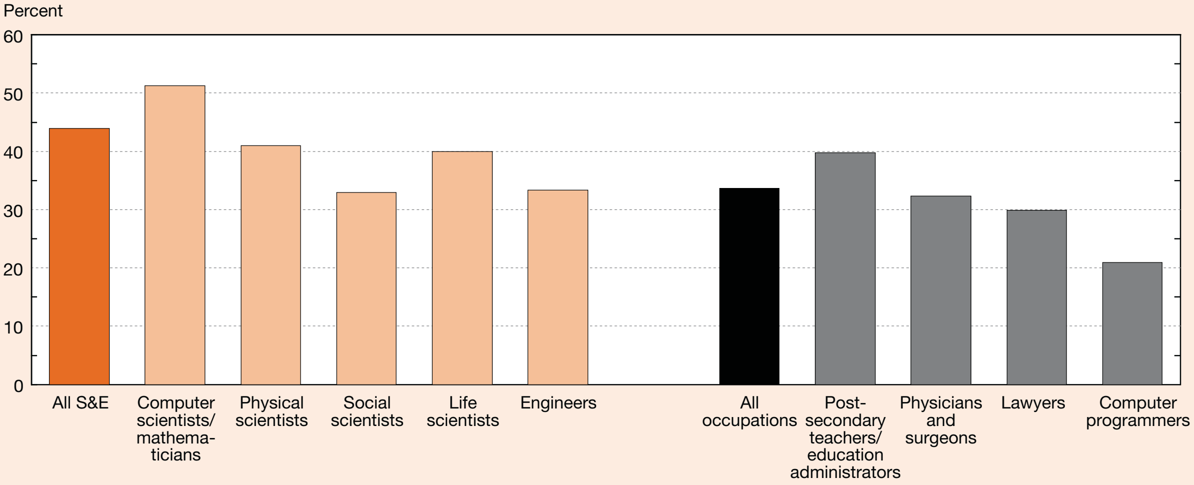
NOTES: Estimates of current and projected employment for 2006–16 period from BLS's National Employment Matrix. Data in matrix from Occupational Employment Statistics (OES) survey and Current Population Survey (CPS). Together, these sources cover paid workers, self-employed workers, and unpaid family workers in all industries, agriculture, and private households. Because derived from multiple sources, data can often differ from employment data provided by OES, CPS, or other employment surveys alone. BLS does not make projections for S&E occupations as a group; numbers in table based on sum of BLS projections in occupations that National Science Foundation considers S&E.

SOURCE: BLS, Office of Occupational Statistics and Employment Projections, National Industry-Occupation Employment Projections, 2006–2016 (2007).

Science and Engineering Indicators 2010

Figure 3-B

Bureau of Labor Statistics projections of 2006–16 job openings as percentage of 2006 employment



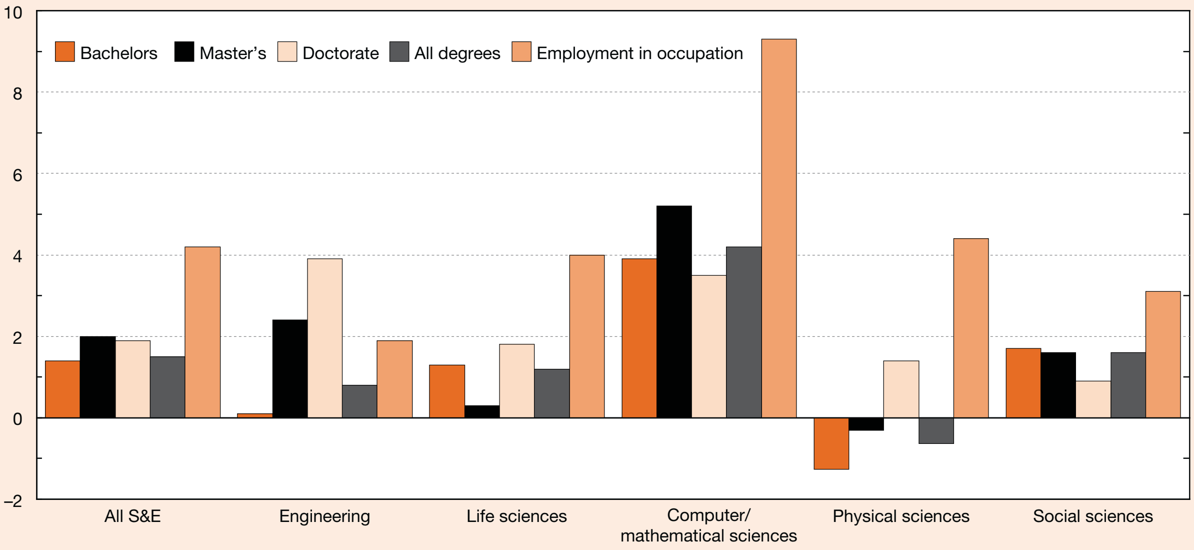
BLS = Bureau of Labor Statistics

SOURCE: BLS, Office of Occupational Statistics and Employment Projections. See appendix table 3-1.

Science and Engineering Indicators 2010

Figure 3-4

Annual average growth rate of degree production and occupational employment, by S&E field: 1980–2000



SOURCES: University of Michigan, Integrated Public Use Microdata Series, 1980–2000 Decennial Census files, http://usa.ipums.org/usa/, and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov, special tabulations.

Science and Engineering Indicators 2010

private sector, which is the largest employer of individuals in S&E occupations. The section also briefly describes the metropolitan areas and size of firms in which S&E degree holders are found.

Because the workforce's capacities for R&D, invention, and innovation are a continuing focus of policy concern, this section also features data on R&D and patenting activities in the workforce. Data on work-related training, which can foster innovation through organizational and individual learning, are also presented.

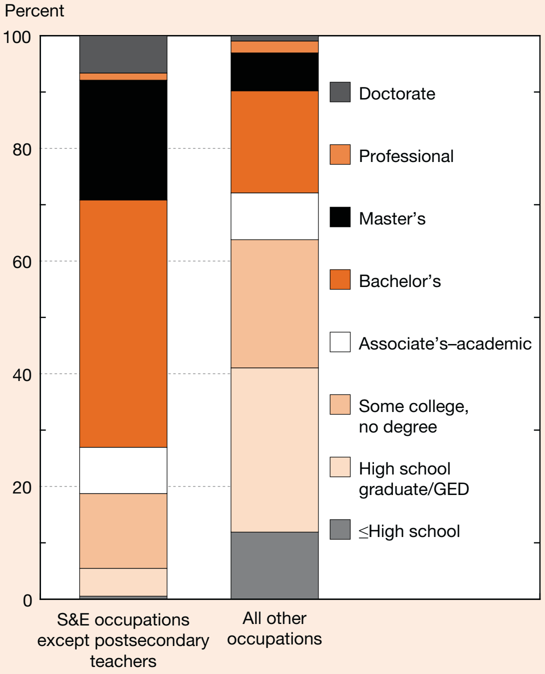
Educational Distribution of Those in S&E Occupations

Workers in S&E occupations have undergone more formal education than the general workforce (figure 3-5). Nonetheless, these occupations include workers with a range of educational qualifications. For all workers in S&E occupations except postsecondary teachers,[5] 2007 ACS data indicate that slightly more than one-quarter had not earned a bachelor's degree. For an additional 44%, a bachelor's was their highest degree. The proportion of workers with advanced degrees was about equal to that of those without a bachelor's degree. Only about 7% of all S&E workers (except postsecondary teachers) had doctorates.

Technical issues of occupational classification may inflate the estimated size of the nonbaccalaureate S&E workforce. Even so, these data indicate that many individuals enter the S&E workforce with marketable technical skills

Figure 3-5

Educational attainment by type of occupation: 2007



GED = General Equivalency Diploma

SOURCE: Census Bureau, American Community Survey (2007).

Science and Engineering Indicators 2010

Table 3-3
Educational background of workers in S&E occupations: 2006

Educational background	Number	Percent
S&E occupations	5,023,635	100.0
At least one S&E degree	4,294,666	85.5
First bachelor's degree in S&E	4,023,000	80.1
Highest degree in S&E	3,929,860	78.2
All degrees in S&E	3,696,443	73.6
At least one degree in—		
Computer/mathematical sciences	1,052,725	21.0
Life sciences	576,922	11.5
Physical sciences	495,985	9.9
Social sciences	651,519	13.0
Engineering	1,867,172	37.2
No S&E degrees but at least one S&E-related degree	216,509	4.3
No S&E or S&E-related degrees	512,459	10.2

NOTE: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

from technical or vocational school training (with or without earned associate's degrees) or college courses, and many acquire such skills through workforce experience or on-the-job training. In information technology, and to some extent in other occupations, employers frequently use certification exams, not formal degrees, to judge skills. (See "Who Performs R&D?" and the discussion in chapter 2.)

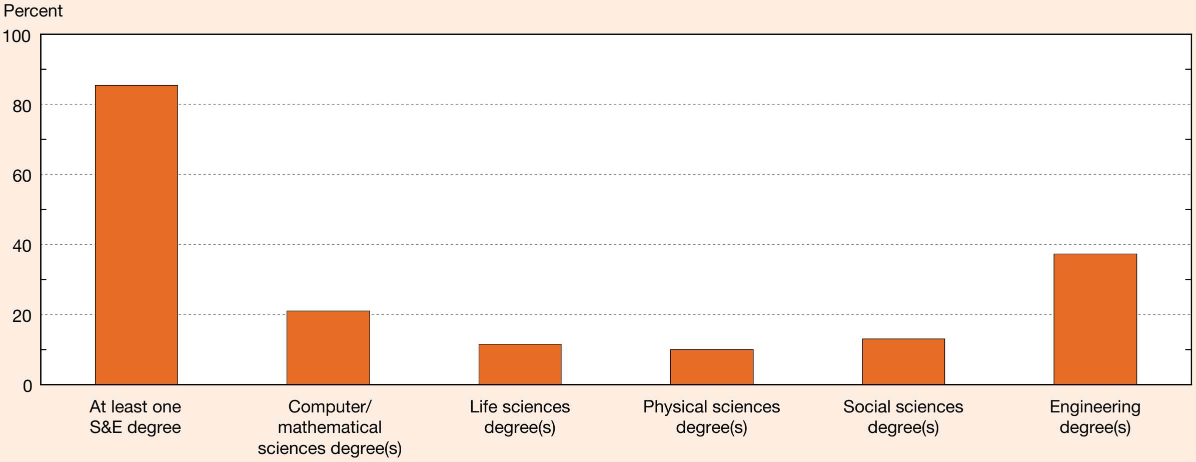
Among individuals with at least a bachelor's degree who work in S&E occupations, a large proportion (86%) have at least one S&E degree, and 74% have S&E degrees only (table 3-3). S&E workers who have both S&E and non-S&E degrees very likely earned their first bachelor's degree in S&E, even if their highest degree was not in an S&E field. Among workers in S&E occupations, the most common degrees are in engineering (37%) and computer and mathematical sciences (21%) (figure 3-6).

Employment in Non-S&E Occupations

S&E degree holders work in all manner of jobs. For example, they work in S&E-related jobs such as health occupations (1.3 million workers) or in S&E managerial positions (267,000 workers), but they also hold non-S&E jobs such as college and precollege teachers in non-S&E areas (622,000 workers) or work in social services occupations (632,000 workers). In 2006, 6.2 million workers whose highest degree was in an S&E field did not work in an S&E occupation. Some 1.1 million worked in S&E-related occupations, while just over 5.0 million worked in non-S&E jobs. The largest category of non-S&E jobs was management and management-related occupations, with 1.4 million workers, followed by sales and marketing occupations, with 990,000 workers (NSF/SRS 2006).

Only about 39% of college graduates whose highest degree is in an S&E field work in S&E occupations (figure 3-7). The proportion is higher for those with more advanced degrees. The overall proportion varies substantially by field, ranging from engineering (66%) at the top, followed closely by computer and mathematical sciences (59%) and physical sciences (55%). Although a smaller percentage (31%) of biological/agricultural sciences degree holders work in S&E

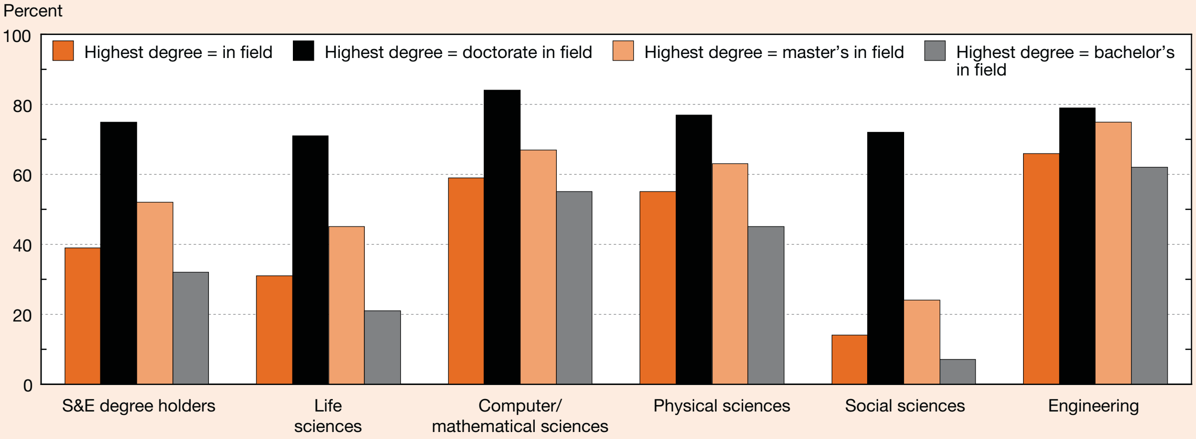
Figure 3-6
S&E degree background of workers in S&E occupations: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-7
S&E degree holders working in S&E occupations, by degree field: 2006



NOTE: Individuals may have degrees in more than one S&E degree field.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

occupations, an additional 25% of persons with degrees in these fields work in S&E-related occupations. Individuals with social science degrees (14%) are least likely to work in S&E occupations. This pattern of field differences generally characterizes individuals whose highest degree is either a bachelor's or a master's. At the doctoral level, these field differences shrink substantially.

By field, holders of degrees in computer and mathematical sciences and engineering most often work in the broad occupation group in which they were trained (51% and 45%, respectively). S&E doctorate holders more often work in the same broad S&E occupation (64%) compared with individuals whose highest degree is an S&E bachelor's (24%) (appendix table 3-1).

Relationships Between Jobs and Degrees

Most individuals with S&E highest degrees who work in S&E-related and non-S&E occupations do not see themselves as working entirely outside their field of degree. Rather, they indicate that their jobs are either closely (31%) or somewhat (32%) related to their degree field (table 3-4). Among those in managerial and management-related occupations, for example, 31% characterize their jobs as closely related and 41% as somewhat related. Almost half (47%) of workers in sales and marketing say their S&E degrees are closely or somewhat related to their jobs. Among S&E precollege teachers whose highest degree is in S&E, 74% say their jobs are closely related to their degrees.

Workers with more advanced S&E education more often do work that is at least somewhat related to their field of degree. One to 4 years after receiving their degrees, 96% of S&E doctorate holders say that they have jobs closely or somewhat related to their degree field, compared with 92% of master's degree holders and 72% of bachelor's degree holders (figure 3-8). Even when the fit between an individual's job and field of degree is assessed using a stricter criterion ("closely related"), the data indicate that many S&E bachelor's degree holders who received their degree 1–4 years earlier are working in jobs that use skills developed during their college training (figure 3-9). In the natural sciences and engineering fields, about half characterized their jobs as closely related to their field of degree: 57% in engineering and physical sciences, 50% in computer sciences, and 48% in biological/agricultural sciences. The comparable figure for social science graduates (30%) was substantially lower.

The stronger relationship between S&E jobs and S&E degrees at higher degree levels holds at all career stages, as evidenced by comparisons among groups of bachelor's, master's, and doctoral degree holders at comparable numbers of years since degree award. However, for each group, the relationship between job and field of degree becomes weaker over time. There are many reasons for this decline: individuals may change their career interests, gain skills in different areas, take on general management responsibilities, forget some of their original college training, or even find that some of their original college training has become obsolete. Against this background, the career-cycle decline in the relevance of an S&E degree appears modest.

Figures 3-10 and 3-11 summarize the loose relationship among jobs, degrees, and individuals' perceptions of the expertise they need to do their work. In figure 3-10, the intersecting area, which shows individuals whose highest degree is in S&E who are working in S&E occupations, is less than

Table 3-4
Individuals with highest degree in S&E employed in S&E-related and non-S&E occupations, by highest degree and relationship of highest degree to job: 2006
(Percent)

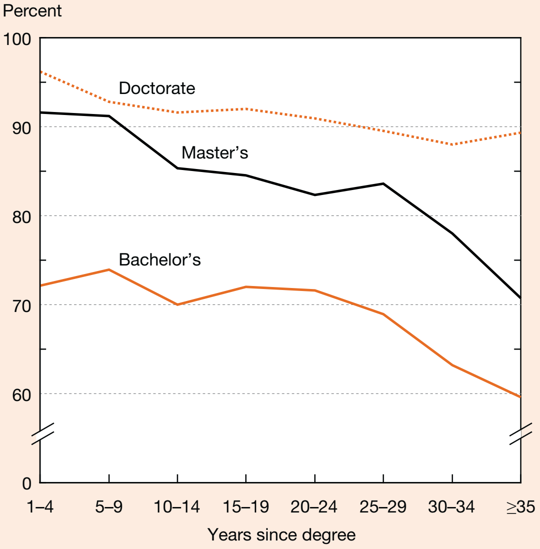
Highest degree	Employment (thousands)	Degree related to job		
		Closely	Somewhat	Not
All degree levels[a]	6,226	31.3	32.4	36.3
Bachelor's	5,071	28.3	32.3	39.4
Master's	975	44.9	31.9	23.2
Doctorate	176	41.4	39.0	19.6

[a] Includes professional degrees not broken out separately.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-8
Employed S&E degree holders in jobs related to highest degree, by years since degree: 2006

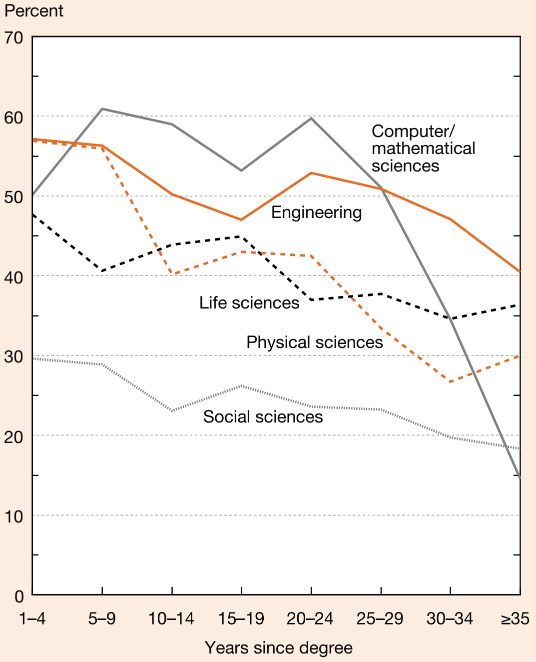


NOTE: Includes those who say their job is either closely related or somewhat related to field of their highest degree.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-9
S&E bachelor's degree holders employed in jobs closely related to degree, by field and years since degree: 2006

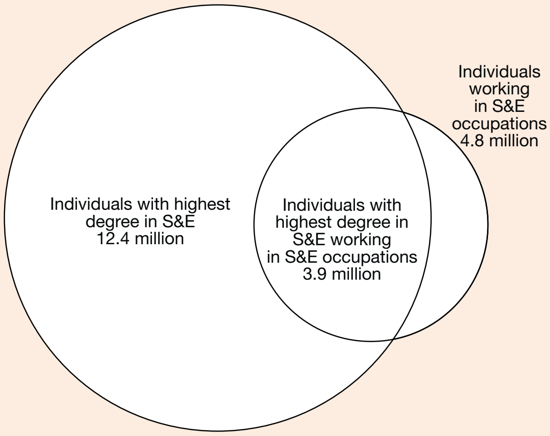


SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

one-third the size of the area comprising individuals with only one or the other attribute. Figure 3-11 compares the following three groups of individuals who hold at least a bachelor's degree: those in S&E occupations, those whose highest degree is in S&E and who say their job is at least somewhat related to their degree, and those who say they need at least a bachelor's degree level of S&E expertise to perform their job. In 2003, the most recent year in which the SESTAT surveys asked about S&E technical expertise, about 15 million Americans fell in one or more of these categories. Only 21% had all three characteristics, and just over half had only one. Even among those in S&E occupations, only about two-thirds also had S&E degrees, had jobs at least somewhat related to S&E, and believed they needed at least a bachelor's degree level of S&E expertise. Among the people who claimed they needed the technical expertise associated with an S&E bachelor's degree for their job, more

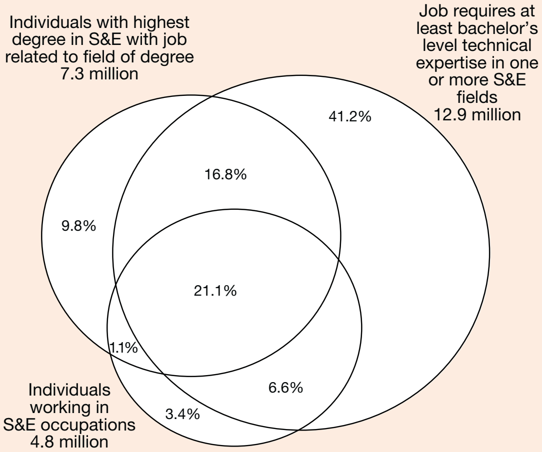
Figure 3-10
Intersection of highest degree in S&E and S&E occupation: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-11
Measures of the S&E workforce: 2003



NOTE: Data from special analytic file comprising 2003 Scientists and Engineers Statistical Data System (SESTAT) integrated file and 2003 National Survey of College Graduates (NSCG).

SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT (2003) and NSCG (2003).

Science and Engineering Indicators 2010

than half said either that their job was unrelated to their actual degree or that their highest degree was not in S&E.

Work-Related Training

Education for most scientists and engineers does not end when they receive their college degree. About two-thirds of SESTAT survey respondents (persons who received a bachelor's degree or higher in S&E, or S&E-related fields, plus persons holding a non-S&E bachelor's or higher degree who were employed in an S&E or S&E-related occupation) participated in work-related training in 2006. Those in S&E-related occupations (health-related occupations, S&E managers, S&E precollege teachers, and S&E technicians and technologists) had the highest participation rate (79%) (table 3-5).

Most who took training did so to improve skills or knowledge in their current occupational field (56%) (appendix table 3-3). Others did so for licensure/certification in their current occupational field (21%) or because it was required or expected by their employer (14%).

Table 3-5
Scientists and engineers participating in work-related training, by occupation: 2006

Occupation	All employed	Participated in training	
		Number	Percent
All occupations	18,927,000	12,696,000	67.1
S&E occupations	5,024,000	3,037,000	60.4
Computer and mathematical scientists	2,112,000	1,202,000	56.9
Life scientists	487,000	296,000	60.8
Physical and related scientists	334,000	183,000	54.8
Social and related scientists	470,000	301,000	64.0
Engineers	1,621,000	1,056,000	65.1
S&E-related occupations	5,246,000	4,167,000	79.4
Non-S&E occupations	8,657,000	5,492,000	63.4

NOTES: Scientists and engineers include those with one or more S&E or S&E-related degrees at bachelor's level or higher or who have a non-S&E degree at bachelor's level or higher and were employed in an S&E or S&E-related occupation in 2006. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Women participated in work-related training at a higher rate than men: 72% compared with 64% of men (appendix table 3-4). Smaller percentages of the oldest (aged 65 and older) and youngest (24 and under) age groups of workers attended training. SESTAT survey respondents at companies of all sizes took work-related training, but more of those who worked for larger organizations did so: 58% of respondents working in organizations with 10 or fewer people compared with 72% in organizations that employ 500 to 24,999 people (appendix table 3-5).

Who Performs R&D?

Although individuals with S&E degrees use their knowledge in many ways, there is a special interest in work in research and development. R&D creates new knowledge and new types of goods and services that fuel economic growth. (See sidebar, "Patenting Activity of Scientists and Engineers.") Figure 3-12 shows the distribution of individuals with S&E degrees, by degree level, who report R&D as a major work activity—the activity involving the greatest or second greatest number of work hours from a list of 14 choices.

Individuals with doctorates constitute only 6% of all individuals with S&E degrees but represent 12% of individuals who report R&D as a major work activity. However, the majority of S&E degree holders who report R&D as a major work activity have only bachelor's degrees (53%). An additional 31% have master's degrees and 4% have professional degrees, mostly in medicine.

Figure 3-13 shows the distribution by field of highest degree of individuals whose highest degree is in S&E and who reported R&D as a major work activity. Individuals with engineering degrees constitute more than one-third (36%) of the total R&D workforce, followed by those with social science degrees (22%).

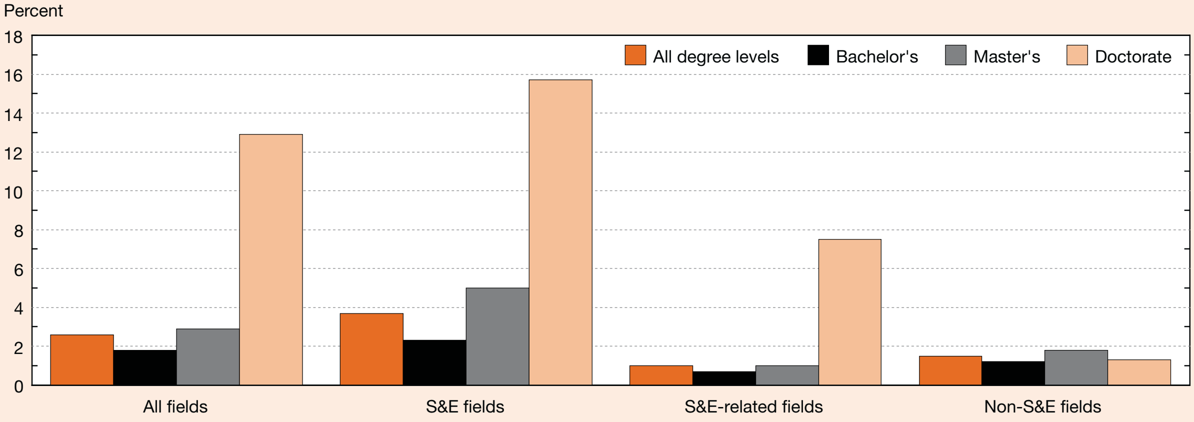
Patenting Activity of Scientists and Engineers

The U.S. Patent and Trademark Office (USPTO) grants patents to inventions that are new, useful, and nonobvious. Thus, patenting is a limited but useful indicator of the inventive activity of scientists and engineers.

In its 2003 SESTAT surveys of the S&E workforce, NSF asked scientists and engineers to report on their recent patenting activities. Among those who had ever worked, 2.6% reported that from fall 1998 to fall 2003, they had been named as an inventor on a U.S. patent application (appendix table 3-6). This patent activity rate was 3.5% for those working in the business/industry sector, 1.7% in the education sector, and 0.9% in the government sector (appendix table 3-7).

By degree level, S&E doctorate holders have the highest patent activity rate (15.7%), while bachelor's degree holders in S&E-related fields have the lowest (0.7%) (figure 3-C). However, there are far fewer doctoral-level scientists and engineers, so they account for only about

Figure 3-C
Patenting activity rate of scientists and engineers, by broad field and level of highest degree: 2003



NOTES: "All degree levels" includes professional degrees not broken out separately; it does not include individuals who have never worked. Scientists and engineers include those with one or more S&E or S&E-related degrees at bachelor's level or higher or who have a non-S&E degree at bachelor's level or higher and were employed in an S&E or S&E-related occupation in 2003. For classification of degrees by S&E, S&E-related, and non-S&E, see Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov/docs/ed03maj.html. Patent activity rate is proportion of each group indicating they had been named as inventor on U.S. patent application during period from October 1998 to fall 2003.

SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT (2003). See appendix table 3-6.

Science and Engineering Indicators 2010

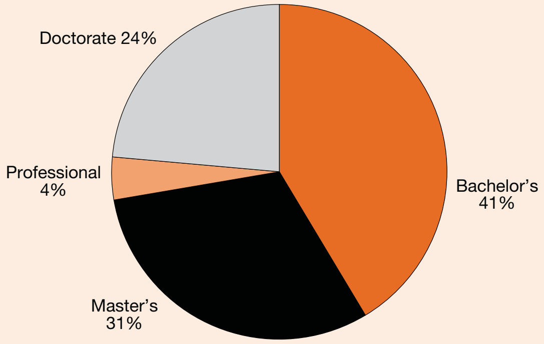
Patenting Activity of Scientists and Engineers *continued*

a quarter of all survey respondents named on a U.S. patent application. Bachelor's and master's degree holders account for 41% and 31%, respectively, of all patenting activity reported in the survey (figure 3-D).

USPTO does not grant all patent applications, and not all granted patents produce useful commercial products or processes. NSF estimates that in the 5-year period for which data were collected, U.S. scientists and engineers filed 1.8 million patent applications. USPTO granted some 1.0 million (although applicants may have applied for some of these at an earlier period). (See appendix tables 3-6 through 3-8.)

Of those patents granted between 1998 and 2003, about 54% resulted in a commercialized product, process, or license during the same period. Scientists and engineers employed in the business/industry sector reported the highest commercialization success rate (58%), much higher than the education (43%) and government (13%) sectors. The overall commercialization rate varies by degree level, at 60%–65% for bachelor's and master's degree holders but 38% for doctorate holders (many of whom work in education, which has a low commercialization rate relative to other sectors).

Figure 3-D
Distribution of patenting activity of scientists and engineers, by level of highest degree: 2003



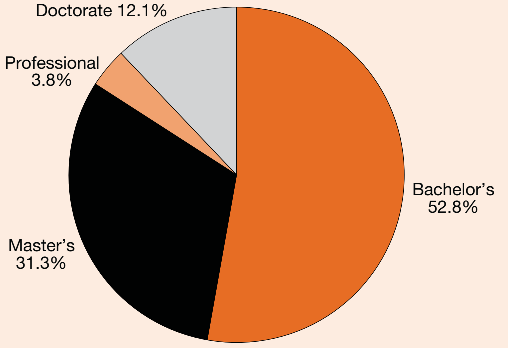
NOTES: Total does not include individuals who have never worked. Scientists and engineers include those with one or more S&E or S&E-related degrees at bachelor's level or higher or who have a non-S&E degree at bachelor's level or higher and were employed in an S&E or S&E-related occupation in 2003. For classification of degrees by S&E, S&E-related, and non-S&E, see Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov/docs/ed03maj.html.

SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT (2003). See appendix table 3-6.

Science and Engineering Indicators 2010

Individuals who are in non-S&E occupations do much R&D. Table 3-6 shows the occupational distribution of S&E degree holders who report R&D as a major work activity. Twenty-six percent of those for whom R&D is a major work activity are in non-S&E occupations. Among those S&E degree holders whose jobs have them spend at least 10% of their time on R&D, 39% are in non-S&E occupations (lawyers or S&E managers, for example).

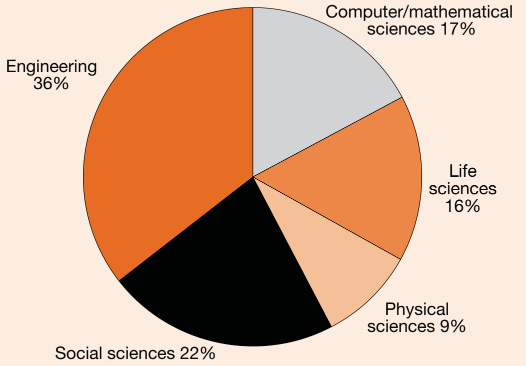
Figure 3-12
Distribution of S&E degree holders with R&D as major work activity, by level of education: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-13
Distribution of individuals with highest degree in S&E with R&D as major work activity, by field of highest degree: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-6
S&E degree holders with R&D work activities, by occupation: 2006

	Employed S&E degree holders		R&D as major work activity			R&D at least 10% of work time		
Occupation	Number	Percent	Number	Percent	R&D activity rate (%)	Number	Percent	R&D activity rate (%)
All occupations	13,752,000	100.0	4,155,000	100.0	30.2	7,369,000	100.0	53.6
S&E occupations	4,295,000	31.2	2,541,000	61.2	59.2	3,371,000	45.7	78.5
Computer/mathematical scientists	1,626,000	11.8	802,000	19.3	49.3	1,171,000	15.9	72.0
Life scientists	435,000	3.2	330,000	7.9	75.7	383,000	5.2	88.0
Physical scientists	319,000	2.3	220,000	5.3	68.9	264,000	3.6	82.8
Social scientists	412,000	3.0	197,000	4.7	47.7	271,000	3.7	65.6
Engineers	1,502,000	10.9	993,000	23.9	66.1	1,282,000	17.4	85.4
S&E-related occupations	2,236,000	16.3	524,000	12.6	23.4	1,110,000	15.1	49.6
Non-S&E occupations	7,221,000	52.5	1,090,000	26.2	15.1	2,888,000	39.2	40.0

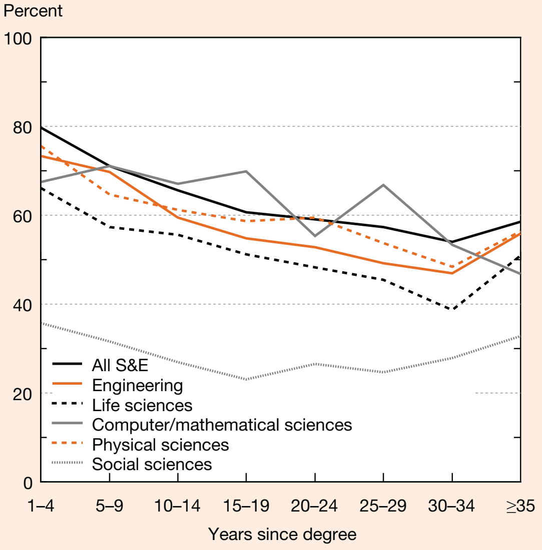
NOTE: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-14 shows the percentages of S&E doctorate holders reporting R&D as a major work activity by field of degree and by years since receipt of doctorate. Individuals working in physical sciences and engineering report the highest R&D rates over their career cycles, and those in the social sciences report the lowest R&D rates. The percentage of doctorate holders engaged in R&D activities declines with increasing time since award of the degree. The decline may reflect movement into management or other career interests. It may also reflect increased opportunity for more experienced scientists to perform functions involving the interpretation and use of, as opposed to the creation of, scientific knowledge.

Figure 3-14
S&E doctorate holders engaged in R&D as major work activity, by years since degree: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Employment Sectors

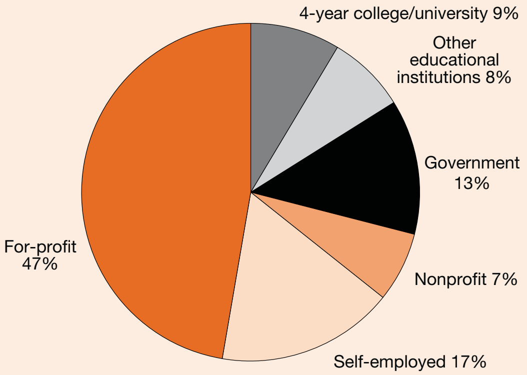
Individuals with S&E degrees are employed in all sectors of the U.S. economy. For-profit firms are their largest employer, but substantial numbers work in academia, nonprofit organizations, and government, or are self-employed.

For-profit firms employ the greatest number of individuals with S&E degrees (figure 3-15). They employed 47% of all individuals whose highest degree is in S&E and 28% of S&E doctorate holders. For those with an S&E doctorate, 4-year colleges and universities are an important but not a majority employer (42%). This 42% includes tenured and tenure-track faculty, individuals in postdoc and other temporary positions, and individuals with teaching, research, and administrative functions.

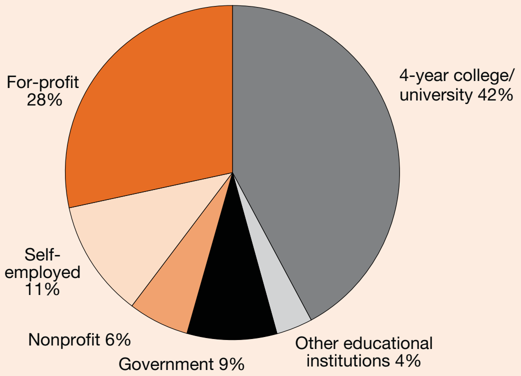
The OES survey provides more detailed estimates for sectors of employment, although it excludes the self-employed and those employed in recent startups (figure 3-16). The largest such employment segment for S&E occupations was “professional, scientific, and technical services” with 29%, followed by manufacturing with 17%. Government and educational services sectors each had less than 11% of total employment in S&E occupations in 2007.

Figure 3-15
Employment sector for individuals whose highest degree is in S&E and for S&E doctorate holders: 2006

Highest degree in S&E



S&E doctorate holders

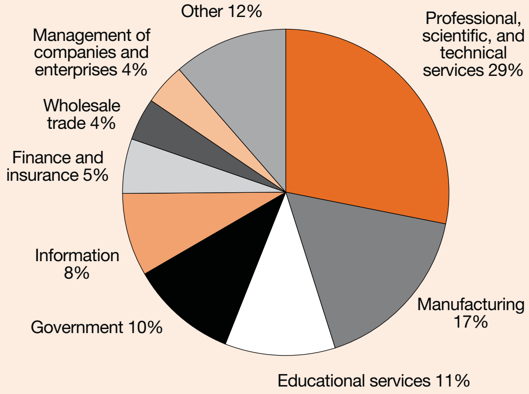


NOTE: Self-employment includes employment at both incorporated and unincorporated businesses.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-16
Largest sectors of employment for individuals in S&E occupations: May 2007

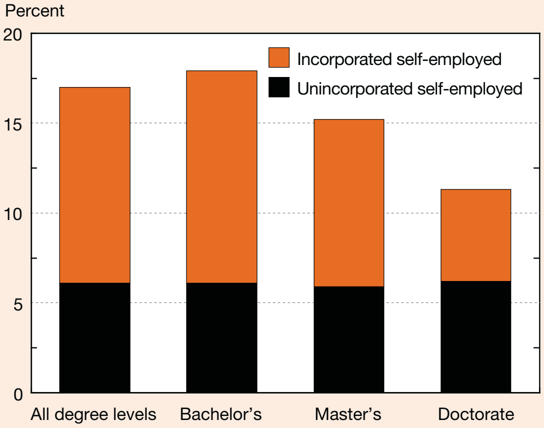


NOTE: Sector defined by North American Industry Classification System.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (2007).

Science and Engineering Indicators 2010

Figure 3-17
Self-employment rates of workers whose highest degree is in S&E, by degree level and type of self-employment: 2006



NOTE: "All degree levels" includes professional degrees not broken out separately.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Self-Employment

More than 1.7 million workers whose highest degree is in S&E were self-employed in 2006, 17% of the total (NSF/SRS 2006). This SESTAT estimate of S&E self-employment is much higher than others that have been published elsewhere because it uses a different definition. Most reports of federal data on self-employment include only individuals whose businesses are unincorporated. While only a minority (33%) of all self-employed workers in the United States work in incorporated businesses (Census Bureau 2007), the reverse is true for those whose highest degree is in S&E. As shown in figure 3-17, adding "incorporated self-employed" greatly increases the proportion of workers whose highest degree is in S&E who are also self-employed. The rate of incorporated self-employment is much higher for individuals with S&E degrees than for the U.S. workforce as a whole, where only 11% are self-employed, and only one-third of those are incorporated (Census Bureau 2007). Among those whose highest degree is in S&E who are also self-employed, 64% work in incorporated businesses. Similar to other types of employment for S&E degree holders, 64% of self-employed workers whose highest degree is in S&E report that their job is related to the field of their highest degree (NSF/SRS 2006).

The proportion of self-employed workers generally decreases by level of degree and increases with age (see figures 3-17 and 3-18). While 18% of S&E bachelor's degree holders are self-employed, the proportion falls to 11% for S&E doctorate holders. However, self-employment increases with age at all degree levels. By age 60–64 self-employment reached about 30% for bachelor's and master's degree holders and 20% for S&E doctorate holders.

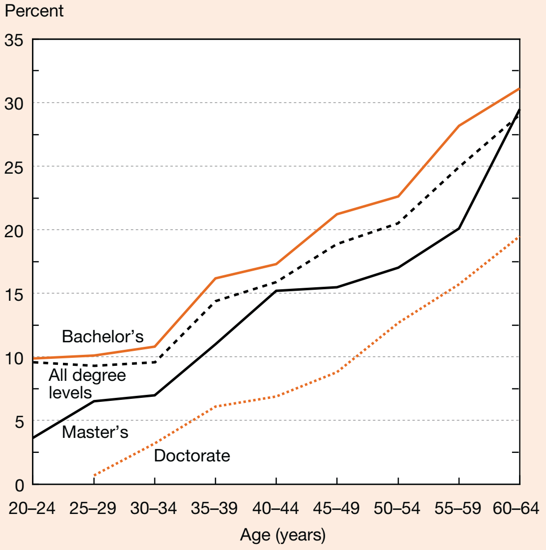
The rates of self-employment are similar across broad S&E fields, at the bachelor's degree level ranging from 14.8% in computer and mathematical sciences to 20.4% in the physical sciences (see figure 3-19). The highest self-employment rate among doctorate holders occurs in the social sciences (19%) and the lowest (6%) in computer and mathematical sciences.

Federal S&E Employment

The United States federal government is a major employer of scientists and engineers, largely limited to those with U.S. citizenship.[6] According to data from the U.S. Office of Personnel Management, the federal government employed approximately 210,000 persons in S&E occupations in 2005. Many of these workers were in occupations that, nationwide, include relatively large concentrations of foreign-born persons, some of whom are non-citizens, rendering them ineligible for many federal jobs. Among federal employees, 59% were in science occupations and 41% were

Figure 3-18

Self-employment rates of workers whose highest degree is in S&E, by degree level and age: 2006



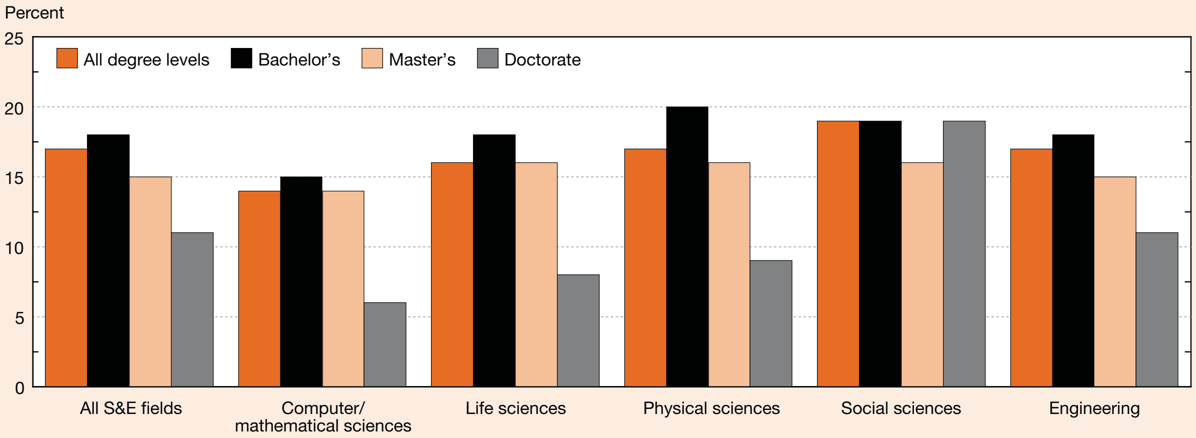
NOTE: "All degree levels" includes professional degrees not broken out separately.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-19

Self-employment rates of workers whose highest degree is in S&E, by degree level and field: 2006



NOTE: "All degree levels" includes professional degrees not broken out separately.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

in engineering occupations. The Department of Defense was the largest employer, with nearly 45% of the federal S&E workforce (NSF/SRS 2008a).

With regard to gender, the federal S&E workforce (defined by occupation) generally reflects the total S&E workforce. Women make up 26% of all U.S. employees in S&E occupations; for federal employees, the comparable proportion is 25%. The number of women in federal S&E positions shows a consistent decrease as age increases beyond the ages of 40–49; this is also true of the whole S&E workforce.

The S&E workforce at large is younger than the federal S&E workforce. Twenty-eight percent of the general S&E workforce is under 35 years of age, with only 15% of those in federal S&E occupations in that age group (appendix table 3-9).

S&E Occupation Density by Industry

High-technology employers are not the only companies who hire individuals in S&E occupations. As shown in table 3-7, workers with high-technology knowledge are found in industries with very different percentages of S&E occupations as a portion of total employment. Almost 1 million workers in S&E jobs are employed in industries whose S&E employment component is less than the national average of 4.2%. These industries employ 79% of all workers and 18% of all workers in S&E occupations. Illustrative examples include local government (at 3.0%, with 163,000 S&E jobs), hospitals (at 1.4%, with 68,000 S&E jobs), and plastic parts manufacturers (at 2.6%, with 16,000 S&E jobs).

Industries with higher proportions of individuals in S&E occupations tend to pay higher average salaries to both their S&E and non-S&E workers. The average salary of workers in non-S&E occupations employed in industries where more than 40% of workers are in S&E occupations is nearly double the average salary of workers in non-S&E occupations in industries with below-average proportions of workers in S&E occupations ($71,550 versus $36,146).

Metropolitan Areas

The availability of highly skilled workers can be relevant to an area's economic competitiveness. Two measures of availability with regard to S&E occupations are (1) the number of workers in S&E occupations and (2) the proportion of the entire metropolitan workforce that S&E occupations represent. These estimates should be used with care in comparing areas because the geographic scope of a metropolitan area varies significantly from city to city.

The Census Bureau divides some larger metropolitan areas into metropolitan divisions, and these divisions are used in comparisons with smaller metropolitan areas. Accordingly, table 3-8 lists metropolitan divisions with the largest estimated proportion of the workforce employed in S&E occupations. Table 3-9 lists areas and divisions with the largest estimated total number of workers employed in S&E occupations. Table 3-10 presents these data for larger metropolitan areas with multiple metropolitan divisions. These data are for May 2007.

The San Jose-Sunnyvale-Santa Clara and Boulder metropolitan areas had 14.3% and 14.2% of their workforces employed in S&E occupations, respectively. San Jose-Sunnyvale-Santa Clara had 18.2% of their workers in STEM occupations. No metropolitan areas had higher estimates for S&E or STEM occupations. Although the metropolitan areas with the highest estimated proportion of S&E employment are mainly smaller and perhaps less economically diverse, Washington, DC, Seattle, Boston, San Francisco, and San Jose also appear on the list of metropolitan areas with the greatest intensity of S&E occupational employment.

The largest numbers of workers in S&E occupations are in the Washington-Arlington-Alexandria, New York-White Plains-Wayne, Los Angeles-Long Beach-Glendale, and Chicago-Naperville-Joliet metropolitan divisions. These divisions have very large and diverse workforces even after being broken off from their larger metropolitan areas. With the exception of Washington-Arlington-Alexandria, each of

Table 3-7
Employment distribution and average earnings of workers in NAICS 4-digit industries, by proportion of employment in S&E occupations: 2007

Workers in S&E occupations (%)	All occupations	S&E occupations	Average annual worker salary ($) Non-S&E occupations	 S&E occupations
>40	2,456,900	1,150,410	71,550	81,093
20-40	3,533,150	952,320	54,039	80,230
10–20	10,558,950	1,444,490	56,319	74,833
4.2–10	12,158,410	880,540	47,237	68,179
<4.2 (below national average)	105,112,220	988,950	36,146	64,961

NAICS = North American Industry Classification System

NOTE: NAICS has hierarchal structure that uses 2 to 4 digits; 4-digit NAICS industries are subsets of 3-digit industries, which are subsets of 2-digit sectors.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (May 2007).

Science and Engineering Indicators 2010

Table 3-8
Metropolitan areas with highest percentage of workers in S&E occupations: 2007

Metropolitan area	Percentage of workforce: S&E occupations	Percentage of workforce: STEM occupations	Workers employed: S&E occupations	Workers employed: STEM occupations
San Jose-Sunnyvale-Santa Clara, CA	14.3	18.2	130,180	165,400
Boulder, CO	14.2	17.4	22,830	28,010
Huntsville, AL	12.8	16.2	25,680	32,630
Framingham, MA NECTA Division	12.7	16.6	19,900	25,940
Durham, NC	11.1	15.5	29,880	41,560
Lowell-Billerica-Chelmsford, MA-NH NECTA Division	11.1	14.1	13,100	16,580
Washington-Arlington-Alexandria, DC-VA-MD-WV Metropolitan Division	10.6	12.7	242,350	290,700
Bethesda-Gaithersburg-Frederick, MD Metropolitan Division	9.6	12.0	54,370	68,340
Seattle-Bellevue-Everett, WA Metropolitan Division	9.3	11.8	131,620	167,060
Olympia, WA	8.7	10.1	8,300	9,700
Kennewick-Richland-Pasco, WA	8.4	11.2	7,300	9,700
Austin-Round Rock, TX	8.4	11.0	62,270	82,100
Ithaca, NY	8.0	12.5	4,020	6,270
Bloomington-Normal, IL	8.0	10.1	6,880	8,680
Ann Arbor, MI	8.0	10.3	15,620	20,250
Boston-Cambridge-Quincy, MA-NH NECTA Division	7.9	10.3	134,190	174,180
Palm Bay-Melbourne-Titusville, FL	7.9	10.7	16,210	21,800
Ames, IA	7.8	10.7	3,270	4,480
San Francisco-San Mateo-Redwood City, CA Metropolitan Division	7.6	9.7	75,700	96,170
Fort Walton Beach-Crestview-Destin, FL	7.2	8.8	5,860	7,200

NECTA = New England City and Town Area; STEM = science, technology, engineering, and mathematics

NOTES: Larger metropolitan areas broken into component metropolitan divisions. Differences among employment estimates may not be statistically significant.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (2007).

Science and Engineering Indicators 2010

these areas has about the same proportion of workers in S&E occupations as the national workforce.

Looking just at the larger metropolitan areas, without breaking them into divisions, New York-Northern New Jersey-Long Island has the largest number (350,670) of individuals employed in S&E occupations but the same proportion (4.2%) as the workforce nationwide (see table 3-10 and figure 3-3).

Employer Size

For individuals whose highest degree is in S&E and who are employed in business/industry, the distribution of employer size is shown in figure 3-20. Across all degree levels, companies with fewer than 100 employees employ 36% of S&E degree holders. About 33% work at large firms with more than 5,000 employees. In general, there is a similar pattern of employment across employer size by degree levels, except that S&E doctorate holders are more concentrated at very small firms.

Demographics

Age and Retirement

The age distribution and retirement patterns of the S&E labor force affect its size, productivity, and the opportunities it offers for new S&E workers. For many decades, rapid increases in new entries into the workforce created a relatively young pool of workers, with only a small percentage near traditional retirement age. Now, individuals who earned S&E degrees in the late 1960s and early 1970s are moving into the later part of their careers.

The increasing average age of S&E workers may mean increased experience and greater productivity among them. However, it could also reduce opportunities for younger researchers to make productive contributions by working independently. In many scientific fields, folklore and empirical evidence indicate that the most creative research comes from younger people (Stephan and Levin 1992).

Table 3-9
Metropolitan areas with largest number of workers in S&E occupations: 2007

Metropolitan area	Workers employed		Percentage of workforce	
	S&E occupations	STEM occupations	S&E occupations	STEM occupations
Washington-Arlington-Alexandria, DC-VA-MD-WV Metropolitan Division	242,350	290,700	10.6	12.7
New York-White Plains-Wayne, NY-NJ Metropolitan Division	209,670	279,960	4.1	5.5
Los Angeles-Long Beach-Glendale, CA Metropolitan Division	160,480	215,970	3.9	5.2
Chicago-Naperville-Joliet, IL Metropolitan Division	156,390	209,890	4.1	5.5
Boston-Cambridge-Quincy, MA-NH NECTA Division	134,190	174,180	7.9	10.3
Seattle-Bellevue-Everett, WA Metropolitan Division	131,620	167,060	9.3	11.8
San Jose-Sunnyvale-Santa Clara, CA	130,180	165,400	14.3	18.2
Houston-Sugar Land-Baytown, TX	128,020	182,920	5.2	7.4
Dallas-Plano-Irving, TX Metropolitan Division	119,910	161,610	5.8	7.9
Minneapolis-St. Paul-Bloomington, MN-WI	103,280	137,400	5.8	7.7
Atlanta-Sandy Springs-Marietta, GA	102,540	139,350	4.3	5.8
Philadelphia, PA Metropolitan Division	94,350	128,750	5.1	6.9
Santa Ana-Anaheim-Irvine, CA Metropolitan Division	80,170	107,300	5.2	7.0
Denver-Aurora, CO	79,030	99,430	6.4	8.1
San Diego-Carlsbad-San Marcos, CA	78,860	105,470	6.0	8.0
Warren-Troy-Farmington Hills, MI Metropolitan Division	76,870	103,390	6.6	8.9
San Francisco-San Mateo-Redwood City, CA Metropolitan Division	75,700	96,170	7.6	9.7
Phoenix-Mesa-Scottsdale, AZ	73,920	107,260	3.9	5.7
Baltimore-Towson, MD	71,660	93,720	5.6	7.3
Oakland-Fremont-Hayward, CA Metropolitan Division	63,540	85,240	6.2	8.3

NECTA = New England City and Town Area; STEM = science, technology, engineering, and mathematics

NOTES: Larger metropolitan areas broken into component metropolitan divisions. Differences among employment estimates may not be statistically significant.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (2007).

Science and Engineering Indicators 2010

Table 3-10
Workers in S&E and STEM occupations in larger metropolitan areas: 2007

Metropolitan area	Workers employed		Percentage of workforce	
	S&E occupations	STEM occupations	S&E occupations	STEM occupations
New York-Northern New Jersey-Long Island, NY-NJ-PA	350,670	474,540	4.2	5.7
Washington-Arlington-Alexandria, DC-VA-MD-WV	296,720	359,040	10.4	12.6
Los Angeles-Long Beach-Santa Ana, CA	240,650	323,270	4.2	5.7
Boston-Cambridge-Quincy, MA-NH	187,950	244,130	7.6	9.9
Chicago-Naperville-Joliet, IL-IN-WI	179,070	241,800	4.0	5.4
Dallas-Fort Worth-Arlington, TX	149,470	206,810	5.2	7.1
San Francisco-Oakland-Fremont, CA	139,240	181,410	6.9	9.0
Seattle-Tacoma-Bellevue, WA	138,710	177,150	8.2	10.5
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	133,990	183,810	4.9	6.7
Detroit-Warren-Livonia, MI	129,550	172,140	6.6	8.8
Miami-Fort Lauderdale-Miami Beach, FL	68,500	94,400	2.9	4.0

STEM = science, technology, engineering, and mathematics

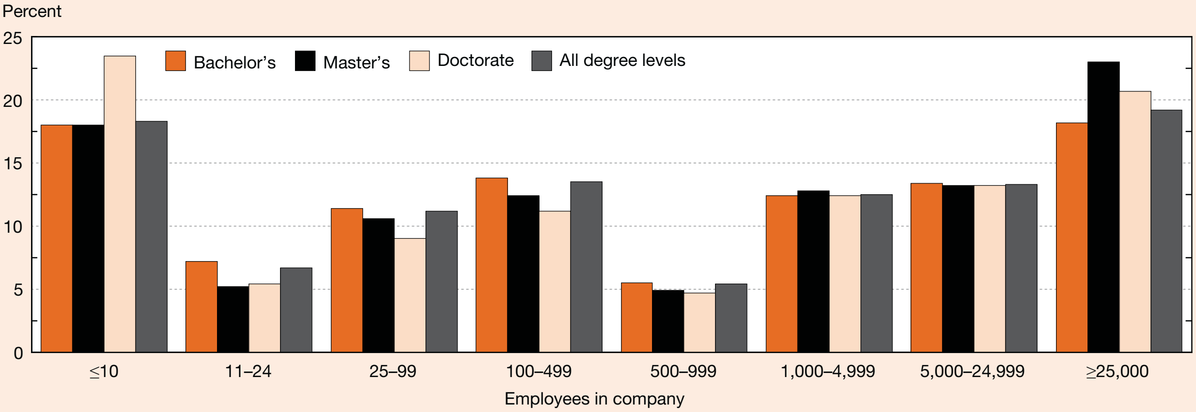
NOTE: Includes only metropolitan statistical areas with multiple metropolitan divisions. Differences among employment estimates may not be statistically significant.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (2007).

Science and Engineering Indicators 2010

Figure 3-20

Individuals with highest degree in S&E employed in private business, by employer size: 2006



NOTE: Includes self-employment, employment by noneducation for-profit firms, and by noneducation nonprofit firms.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Aside from the possible effects on productivity, early career opportunities, and, perhaps, the culture within some scientific fields, the age structure of the S&E labor force has important implications for its growth rate. This section does not attempt to project future S&E labor market trends; however, it posits some general conclusions. Absent changes in degree production, retirement patterns, or immigration, the number of S&E-trained workers in the labor force will continue to grow for some time, but the growth rate may slow considerably as an increasing proportion of the S&E labor force reaches traditional retirement age. With slowing growth, the average age of the S&E labor force will increase.

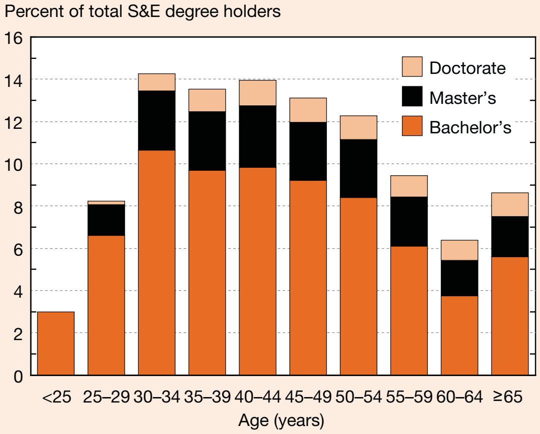
Age Distribution of the S&E Workforce

Net immigration, morbidity, mortality, and, most of all, historical S&E degree production patterns affect the age distribution of scientists and engineers in the workforce. With the exception of new fields such as computer sciences (in which 56% of degree holders are younger than age 40), the greatest population density of individuals with S&E degrees occurs between the ages of 40 and 49. Figure 3-21 shows the age distribution of the labor force with S&E degrees broken out by level of degree. In general, the majority of individuals in the labor force with S&E degrees are in their late thirties through their early fifties, with the largest group at ages 40–44. More than half of workers with S&E degrees are age 40 or older, and the 40–44 age group is more than twice as large as the 60–64 age group.

This general pattern also holds for individuals with S&E doctorates. Because of the length of time needed to obtain a doctorate, those who hold these degrees are somewhat older than individuals who have less advanced S&E degrees. The greatest population density of S&E doctorate holders occurs between the ages of 40 and 54. This can be seen most easily in figure 3-22, which compares the age distribution of S&E degree holders in the labor force at each level of degree, and in figure 3-23, which shows the cumulative age distribution for individuals at each degree level. Even if one takes into account the somewhat older retirement ages of doctorate holders, a much larger proportion of S&E doctorate holders are near traditional retirement ages than are individuals with either S&E bachelor's or master's degrees.

Figure 3-21

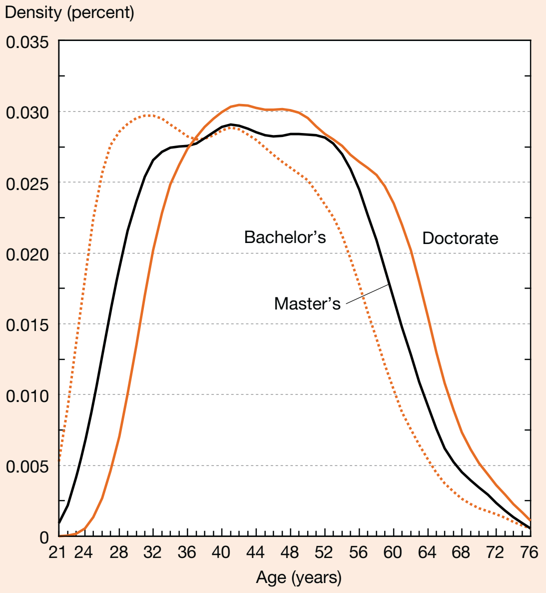
Age distribution of individuals in labor force with highest degree in S&E: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-22
Age distribution of individuals in labor force with highest degree in S&E, by degree level: 2003



NOTE: Age distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

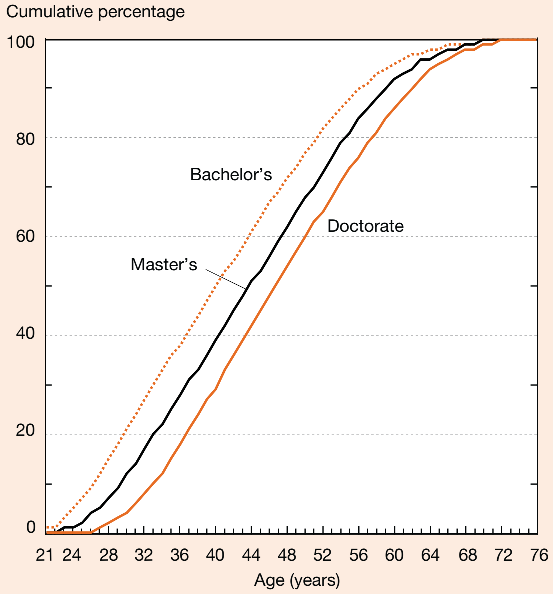
Figure 3-24, which compares the age distributions of S&E doctorate holders in 1993 and 2003, highlights the extent of the shift in the age structure of the S&E labor force. S&E doctorate holders under age 35 are about the same proportion of the S&E doctorate holders in the total labor force in both years. However, over the decade, the 35–54 age group became a much smaller proportion of the doctoral-level S&E labor force. What grew was the proportion of S&E doctorate holders age 55 and older.

Across all degree levels and fields, 26.4% of the labor force with S&E degrees is older than age 50. The proportion ranges from 15% of individuals with their highest degree in computer sciences to 41% of individuals with their highest degree in geosciences (figure 3-25).

Altogether, the age distribution of S&E-educated individuals suggests the following likely effects on the future of the S&E labor force:

- Barring large changes in degree production, retirement rates, or immigration, the number of trained scientists and engineers in the labor force will continue to increase, because the number of individuals currently receiving S&E degrees exceeds the number of workers with S&E degrees nearing traditional retirement age.
- However, unless large increases in degree production occur, the average age of workers with S&E degrees will rise.

Figure 3-23
Cumulative age distribution of individuals in labor force whose highest degree is in S&E, by degree level: 2003



NOTE: Age distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

- Barring large reductions in retirement rates, the total number of retirements among workers with S&E degrees will increase over the next 20 years.

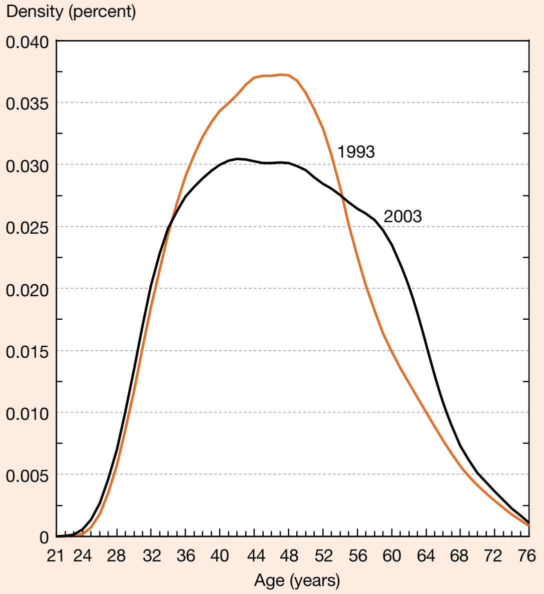
Taken together, these factors suggest a slower growing and older S&E labor force. Both trends would be accentuated if either new degree production were to drop or immigration were to slow, both concerns raised by a 2003 report of the Committee on Education and Human Resources Task Force on National Workforce Policies for Science and Engineering of the National Science Board (NSB 2003).

S&E Workforce Retirement Patterns

The retirement behavior of individuals can differ in complex ways. Some individuals retire from one job and continue to work part time or even full time at another position, sometimes even for the same employer. Others leave the workforce without a retired designation from a formal pension plan. Table 3-11 summarizes three ways of looking at changes in workforce involvement for S&E degree holders: leaving full-time employment, leaving the workforce, and retiring from a particular job.

By age 61, slightly more than 50% of those with an S&E bachelor's degree as their highest degree are no longer working full time. The age at which at least half of S&E

Figure 3-24
Age distribution of S&E doctorate holders in labor force: 1993 and 2003

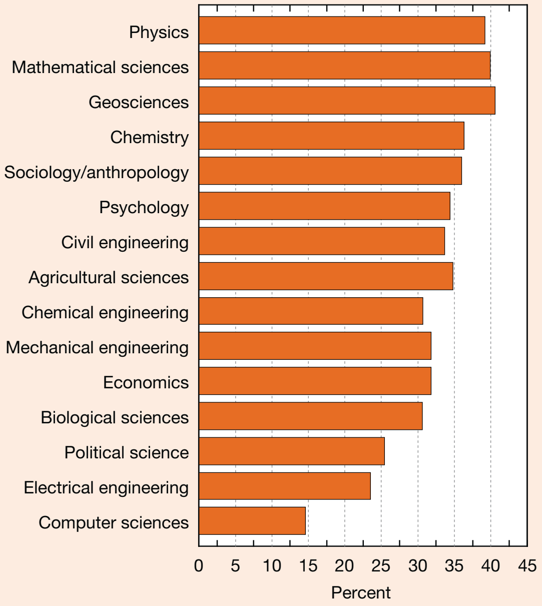


NOTE: Age distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993 and 2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-25
Employed S&E degree holders older than 50, by selected field of highest degree: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-11
Labor force participation for individuals with highest degree in S&E, by education level and age: 2003

	Age at which more than half were—		
Highest degree	No longer employed full-time	Not in labor force	Ever retired
Bachelor's	61	65	65
Master's	62	66	66
Doctorate	66	69	67

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

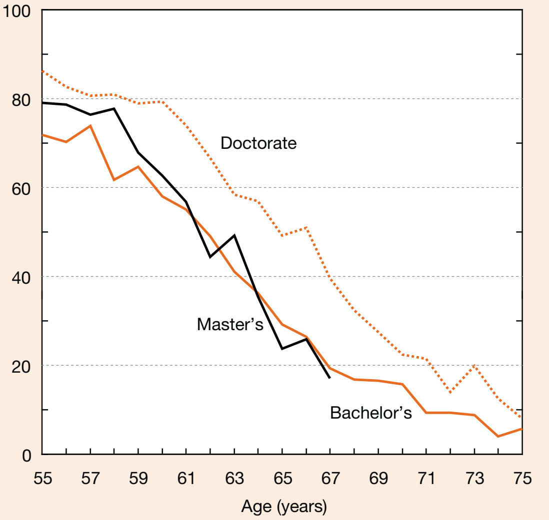
Science and Engineering Indicators 2010

degree holders no longer work full time increases by degree level—to age 62 at the master's level and age 66 at the doctoral level. Longevity also differs by degree level when measuring the number of individuals who leave the workforce entirely: half of all S&E bachelor's degree holders left the workforce entirely by age 65, compared with S&E master's degree and doctorate holders who left the workforce at ages 66 and 69, respectively. Although many S&E degree holders who formally retire from one job continue to work full time or part time, formal retirement occurs at similar ages for all levels of degree holders: more than 50% of bachelor's, master's, and doctoral degree holders have formally retired from jobs by age 65, 66, and 67, respectively.

Figure 3-26 shows data on S&E degree holders working full time at ages 55–69. For all degree levels, the proportion of S&E degree holders who work full time declines fairly steadily by age, but after age 55, full-time employment for doctorate holders becomes significantly greater than for bachelor's and master's degree holders. At age 69, 27% of doctorate holders work full time, compared with 16% of bachelor's degree recipients.

Table 3-12 shows the rates at which holders of U.S. S&E doctorates left full-time employment, by sector of employment, between October 2003 and April 2006. For every age group, the retirement rates for S&E doctorate holders were slightly higher for those working in the private sector than those employed in education or government. Although many S&E degree holders who formally retire from one job continue to work full time or part time, this occurs most often among individuals younger than age 63 (table 3-13). However, of retired S&E degree holders age 71 to 75, only 12% of bachelor's degree holders keep working either full time or part time, 17% of master's degree holders, and 19% of doctorate holders.

Figure 3-26
Full-time labor force participation by older individuals with highest degree in S&E, by age and degree level: 2006



NOTES: Calculated from 2-month pooled samples. Data for master's degree holders shown only through age 67 due to small sample sizes.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-12
Proportion of employed S&E doctorate holders who had left full-time employment since October 2003, by employment sector and age: April 2006
(Percent)

	October 2003 employment sector			
Age (years)	All sectors	Education	Private	Government
50–55	6.7	4.5	9.7	4.4
56–62	15.0	11.8	18.6	14.9
63–70	28.0	26.2	31.5	25.2

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-13
Employment status of retired individuals with highest degree in S&E, by education level and age: 2003
(Percent)

Degree level and employment status	Age (years)			
	50–55	56–62	63–70	71–75
Bachelor's	100.0	100.0	100.0	100.0
Part time	8.2	13.8	10.7	9.0
Full time	51.1	28.9	9.0	2.6
Not working	40.7	57.3	80.3	88.4
Master's	100.0	100.0	100.0	100.0
Part time	14.0	15.8	18.3	9.3
Full time	62.3	35.3	11.8	8.0
Not working	23.7	48.9	69.9	82.7
Doctorate	100.0	100.0	100.0	100.0
Part time	22.6	24.1	21.2	14.7
Full time	50.6	33.1	12.9	4.7
Not working	26.8	42.8	65.9	80.6

NOTES: Retired individuals are those who said they had ever retired from any job. Percents may not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Women and Minorities in S&E

An important part of the growth of the S&E labor force comes from the increased presence of women and ethnic minorities. In 2006, white males constituted 58% of those in the labor force over age 50 whose highest degree was in S&E. Among those under age 30, only 35% were white males (NSF/SRS 2006). This represents both a change in the composition of the total U.S. labor force and a growth in the participation of women and minorities in S&E.

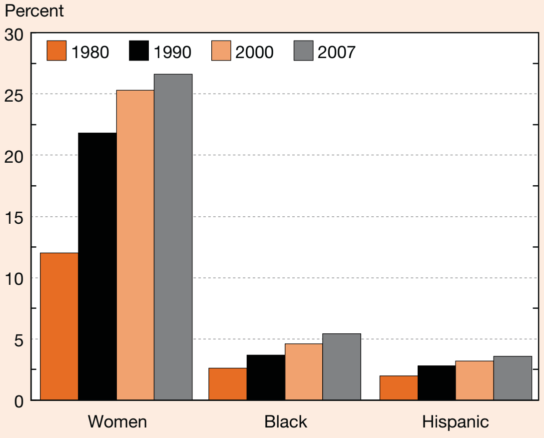
Both women and underrepresented ethnic minorities have shown steady growth in their proportion of the S&E labor force (see figures 3-27 and 3-28, which look at sex and ethnic representation within S&E occupations).

Representation of Women in S&E

Women constituted more than one-fourth (26%) of the college-educated workforce in S&E occupations and two-fifths (40%) of those with S&E degrees in 2006, according to NSF's SESTAT data.

Census data on S&E occupations from 1980 to 2007 show the number of women in S&E occupations rising from 12% to 27% over those 27 years (figure 3-27). Figures 3-29 and 3-30 show the growth in the number of women with education in S&E for different graduation cohorts and broad fields of degree. The notable exception is in computer and mathematical sciences at the bachelor's degree level, where the proportion of women in the workforce is lower for 2002–05 graduates (27%) than it is for 1972–76 graduates (35%). In contrast, the proportion of women in the most recent bachelor's degree cohorts in both the social sciences and the life sciences has risen to above 60%. Among S&E doctorate holders in the workforce, the proportion of women is generally higher in more recent cohorts, including the computer and mathematical sciences.

Figure 3-27
College-educated women and racial/ethnic minorities in S&E occupations: 1980, 1990, 2000, and 2007

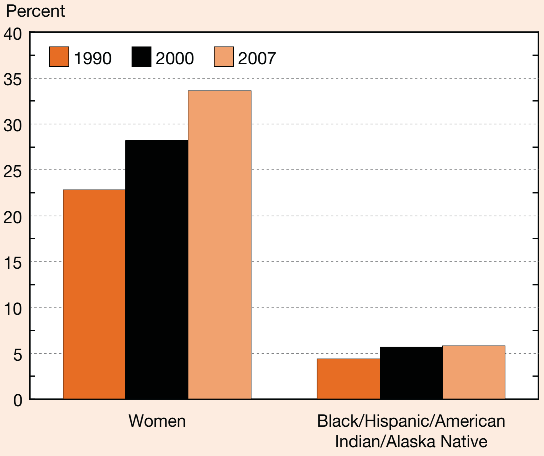


NOTE: Postsecondary S&E teachers not included because they cannot be identified in data source.

SOURCE: University of Michigan, Integrated Public Use Microdata Series, 1980–2000 Decennial Census files and 2007 American Community Survey, http://usa.ipums.org/usa/, special tabulations.

Science and Engineering Indicators 2010

Figure 3-28
Women and racial/ethnic minority doctorate holders in S&E occupations: 1990, 2000, and 2007

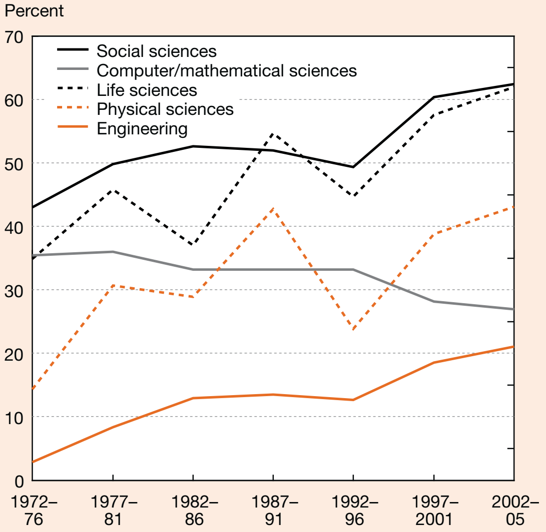


NOTE: Postsecondary S&E teachers not included because they cannot be identified in data source.

SOURCE: University of Michigan, Integrated Public Use Microdata Series, 1990–2000 Decennial Census files and 2007 American Community Survey, http://usa.ipums.org/usa/, special tabulations.

Science and Engineering Indicators 2010

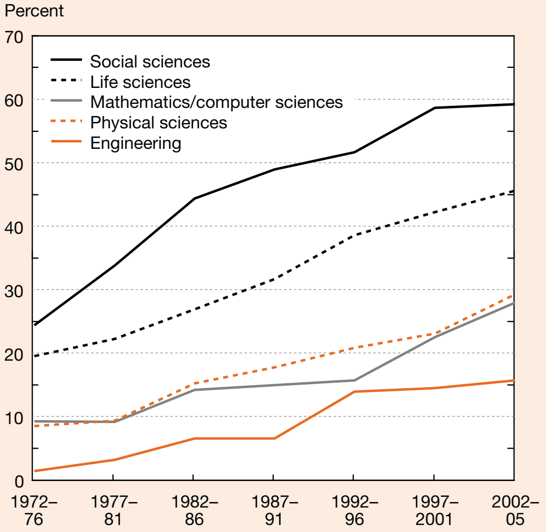
Figure 3-29
Representation of women among workers whose highest degree is S&E bachelor's, by year of degree: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-30
Representation of women among workers whose highest degree is S&E doctorate, by year of doctorate: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Age Distribution and Experience. On average, women in the S&E workforce are younger than men (figures 3-31 and 3-32). Forty-six percent of women and 31% of men employed in science and engineering in 2003 received their degrees within the previous 10 years. The difference is even more profound at the doctoral level, which has a much greater concentration of women in their late thirties. Consequently, a much larger proportion of male scientists and engineers at all degree levels, but particularly at the doctorate level, will reach traditional retirement age during the next decade. This will affect sex ratios and potentially the number of female scientists in senior-level positions.

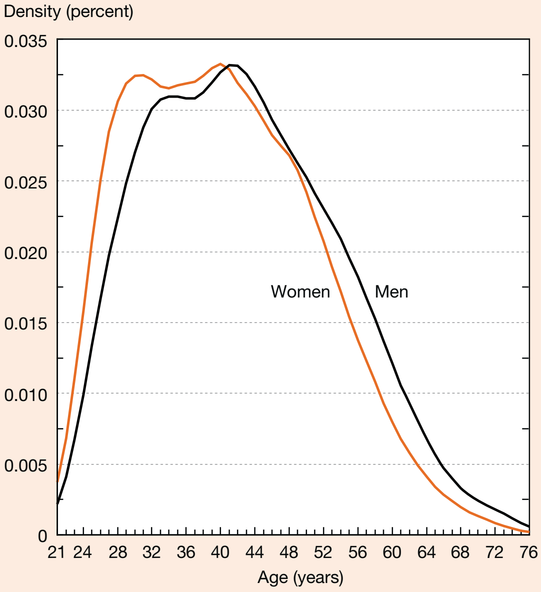
Unemployment. Unemployment rates in 2006 were somewhat higher for women in S&E occupations than for men: 2.2% of men and 2.9% of women were unemployed. In contrast, the unemployment rate in 1993 was 2.7% for men and 2.1% for women (table 3-14).

Representation of Racial and Ethnic Minorities in S&E

With the exception of Asians/Pacific Islanders, racial and ethnic minorities represent only a small proportion of those employed in S&E occupations in the United States.

Figure 3-31

Age distribution of individuals in S&E occupations, by sex: 2003



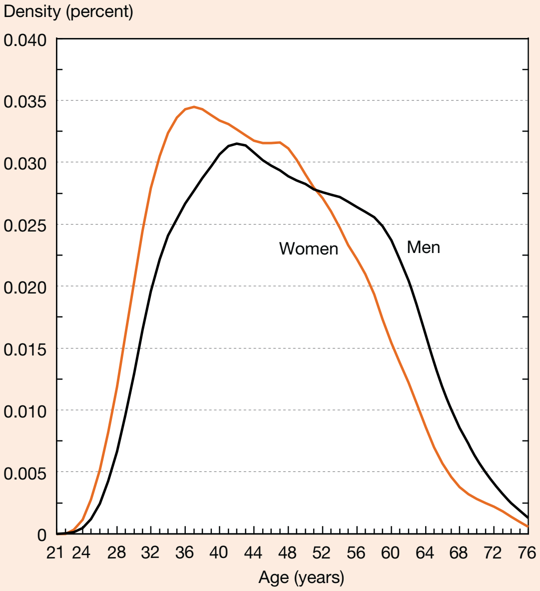
NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-32

Age distribution of doctorate holders in S&E occupations, by sex: 2003



NOTE: Age distribution smoothed with kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-14

Unemployment rate for individuals in S&E occupations, by sex, race/ethnicity, and visa status: 1993, 2003, and 2006

(Percent)

Characteristic	1993	2003	2006
All individuals in S&E occupations	2.6	3.3	2.4
Sex			
Male	2.7	3.3	2.2
Female	2.1	3.5	2.9
Race/ethnicity			
White	2.4	2.9	2.2
Asian/Pacific Islander	4.0	5.7	2.8
Black	2.8	4.2	4.4
Hispanic	3.5	2.5	2.5
Temporary residents	3.4	2.7	2.8

NOTE: 2003 and 2006 data include some individuals with multiple races in each category.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993, 2003, and 2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Collectively, blacks, Hispanics, and other ethnic groups (the latter category includes American Indians/Alaska Natives) constitute 24% of the total U.S. population, 13% of college graduates, and 10% of college-educated individuals employed in S&E occupations.

Conversely, Asians/Pacific Islanders, despite constituting only 5% of the U.S. population, accounted for 7% of college graduates and 14% of those employed in S&E occupations in 2003. Although most (82%) Asians/Pacific Islanders in S&E occupations were foreign born, those born in the United States were also more highly represented in S&E than in the total workforce.

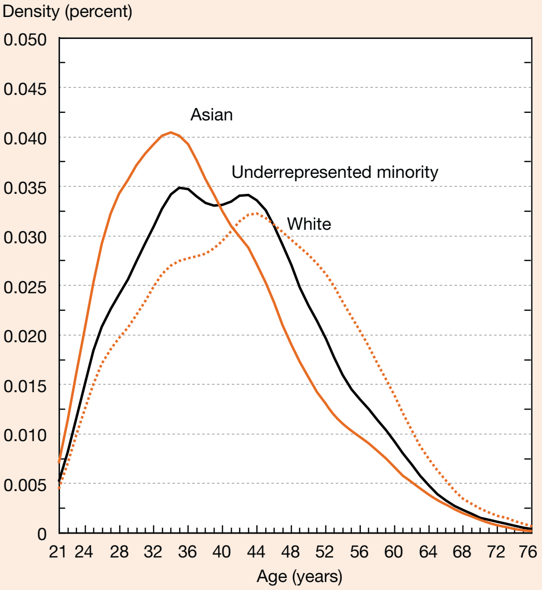
Age Distribution. As is the case for women, underrepresented racial and ethnic minorities in the S&E workforce are much younger than non-Hispanic whites in the same S&E jobs (figure 3-33), and this difference is even more pronounced for doctorate holders in S&E occupations (figure 3-34). This finding could point to an upcoming shift in the overall composition of the S&E workforce. In the near future, a much greater proportion of non-Hispanic white doctorate holders in S&E occupations will be reaching traditional retirement ages. This circumstance could signal a more rapid increase in the number of non-Hispanic white doctorate holders who will retire or otherwise leave S&E employment. On the other hand, Asian/Pacific Islander doctorate holders in S&E occupations (measured by race and not by place of birth) are on average the youngest racial/ethnic group, and thus the least likely to have large numbers of retirees.

Salary Differentials for Women and Minorities

Trends in Median Salaries. Women and members of underrepresented minority groups have generally lower earnings than their male and nonminority counterparts. However, differences in average age, work experience, fields of degree, sector of employment, and other characteristics can make direct comparison of salary and earnings statistics misleading. This section discusses these income gaps and explores some of the underlying factors that may affect them.

Factors Influencing Salary Differentials. Regression analysis is a statistical method that can be used to examine salary and other differences simultaneously.[7] Although this type of analysis can provide insight, it cannot give definitive answers to questions about the openness of S&E to women

Figure 3-33
Age distribution of individuals in S&E occupations, by race/ethnicity: 2003

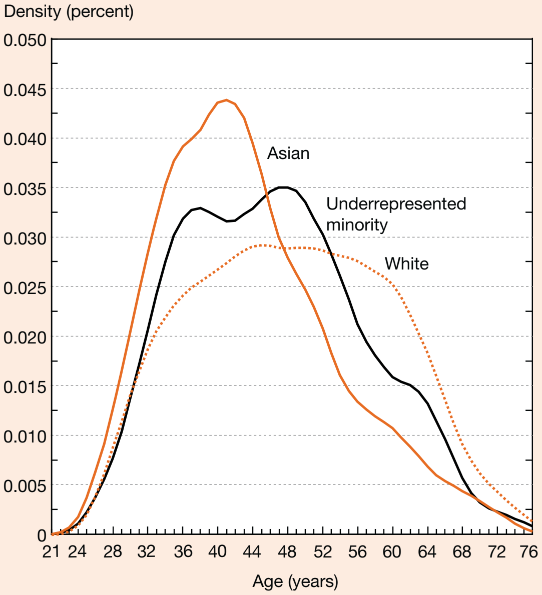


NOTES: Age distribution smoothed with kernel density techniques. Underrepresented minority includes Hispanic, Black, Native Hawaiian/Pacific Islander, American Indian/Alaska Native, and multiple race.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-34
Age distribution of S&E doctorate holders in S&E occupations, by race/ethnicity: 2003



NOTES: Age distribution smoothed with kernel density techniques. Underrepresented minority includes Hispanic, Black, Native Hawaiian/Pacific Islander, American Indian/Alaska Native, and multiple race.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

and minorities. The most basic reason is that no labor force survey ever captures information on all characteristics that may affect compensation.

Figures 3-35 and 3-36 show estimates of salary differences for different groups after controlling for several individual characteristics. Differences in mean annual salary are substantial when comparing all individuals with S&E degrees by level of degree only.

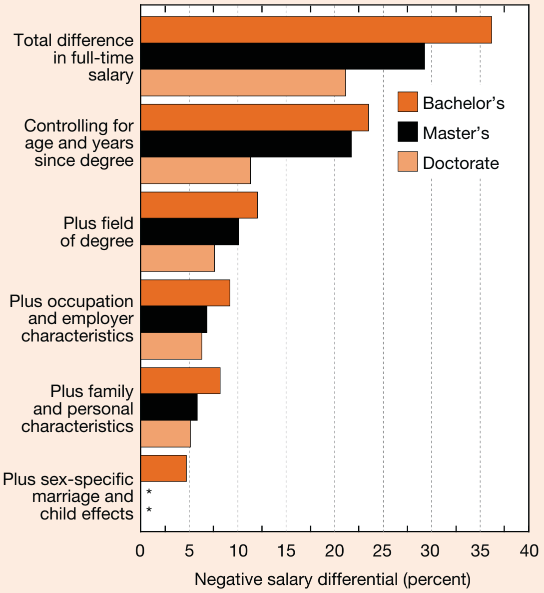
In 2006, women with S&E bachelor's degrees working full time had mean salaries that were 36.2% less than those of their male counterparts. Likewise, full-time salaries of blacks, Hispanics, and individuals in other underrepresented ethnic groups with S&E bachelor's degrees were 25.8% less than those of non-Hispanic whites and Asians/Pacific Islanders with S&E bachelor's degrees.[8] While still substantial, these salary differentials decrease as level of degree increases for both women and ethnic minorities, reaching 21.1% and 15.0% respectively.

Effects of Age and Years Since Degree. On average, women and members of underrepresented minority groups are younger than their counterparts in most S&E fields. Controlling for differences in both age and years since receipt of degree reduces the estimated salary differential for both women and minorities at every degree level.

For women, it reduces salary differentials by about one-third at the bachelor's and master's degree levels, and by about half at the doctorate level.[9] Statistical controls may make less difference at lower degree levels because similar proportions of men and women with S&E degrees are in mid-career, but a larger proportion of men are at older ages, where salaries begin to decline.

For underrepresented ethnic minorities, controlling for age and years since degree produces proportionally larger reductions in salary differentials than is the case for women. Introducing these controls reduces salary differentials between underrepresented minorities and both non-Hispanic whites and Asians/Pacific Islanders by more than half at all degree levels.

Figure 3-35
Estimated differences in full-time salary between women and men with highest degree in S&E, controlling for level of degree and other characteristics: 2006



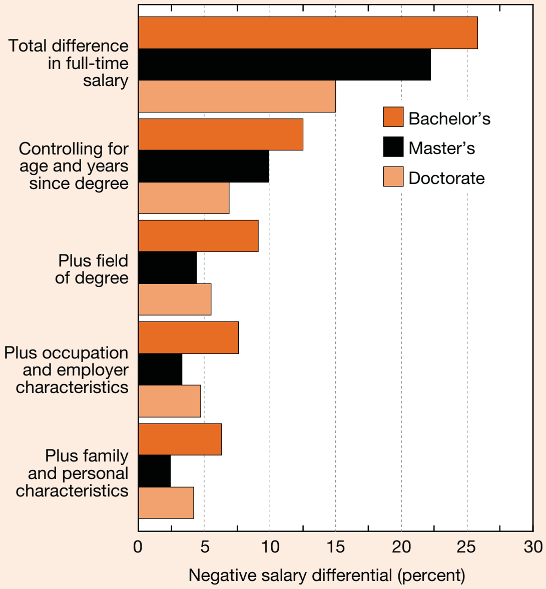
* = not significantly different from zero at $p = .05$

NOTES: Salary differentials represent estimated differences in full-time salary for women compared to men in regression analyses including different characteristics. Regression coefficients are estimated using the natural log of full-time annual salary as the dependent variable.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-36
Estimated differences in full-time salary of underrepresented minorities versus non-Hispanic whites and Asians with highest degree in S&E, controlling for level of degree and other characteristics: 2006



NOTES: Salary differentials represent estimated differences in full-time salary for underrepresented ethnic minorities compared to non-Hispanic whites and Asians in regression analyses including different characteristics. Regression coefficients are estimated using the natural log of full-time annual salary as the dependent variable.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Effects of Field of Degree on Salary Differentials. Controlling for field of degree in addition to age and years since degree reduces the estimated salary differentials for women with S&E degrees to –12.0% at the bachelor's degree level and to –7.6% at the doctorate level.[10] These reductions generally reflect the greater concentration of women in the lower-paying social and life sciences as opposed to engineering and computer sciences.

Field of degree is also associated with reduction of estimated salary differentials for underrepresented ethnic groups. Controlling for field of degree further reduces salary differentials to –9.1% for individuals with S&E bachelor's degrees and to –5.5% for individuals with S&E doctorates. At the doctoral level, field of degree, age, and years since degree together account for two-thirds of salary differentials for underrepresented ethnic groups.

Effects of Occupation and Employer Characteristics on Salary Differentials. Occupation and employer characteristics affect compensation.[11] Academic and nonprofit employers typically pay less for the same skills than employers pay in the private sector, and government compensation falls somewhere between the two groups. Other factors affecting salary are the sector of the economy, the U.S. region where a person works, and whether the person is working in S&E or in R&D. However, occupation and employer characteristics may not be determined solely by individual choice; they may also in part reflect an individual's career success.

When comparing women with men and underrepresented ethnic groups with non-Hispanic whites and Asians/Pacific Islanders, controlling for occupation and employer further reduces salary differentials. At the doctoral level, controlling for occupation leaves no statistically significant difference between the salaries of underrepresented ethnic groups compared with non-Hispanic whites and Asians/Pacific Islanders.

Effects of Family and Personal Characteristics on Salary Differentials. Marital status, the presence of children, parental education, and other personal characteristics are often associated with differences in compensation. Although these differences may involve discrimination, they may also reflect many subtle individual differences that can affect work productivity.[12] For example, having highly educated parents is associated with higher salaries for individuals of all ethnicities and both sexes. It may well be associated with greater academic achievement not directly measured in these data; alternatively, it may be associated with family and personal networks that are conducive to career success. In any event, for many individuals in many ethnic groups, historical discrimination probably affected parents' educational opportunities and achievement.

Controlling for these additional characteristics changes salary differentials only slightly for each group and degree level.[13] An additional issue for the wage differentials of women, however, is that family and child variables often have different effects for men and women. In these estimates, both marriage and children are associated with higher salaries for men with S&E degrees at all levels, but have a negligible association with women's earnings. Allowing for these differences in sex effects reduces the salary differential at the bachelor's degree level to 4.7% and leaves no statistically significant difference in salary at the master's degree and doctorate levels.

S&E Labor Market Conditions

Labor market conditions for scientists and engineers affect the attractiveness of S&E fields to both students and those already in the labor force. In general, holders of S&E degrees have higher rates of pay and lower rates of unemployment than other college graduates. However, this does not exempt them from unemployment due to overall business cycles or specific events affecting individuals with training in their fields. This section looks at both long-term and recent trends using NSF, Census Bureau, and BLS data.

Earnings

The estimated annual wages of individuals in S&E occupations, based on BLS's OES survey, are considerably higher than the average of the total workforce. Median annual wages in 2007 (regardless of education level or field) in S&E occupations were $70,600, more than double the median ($31,410) for total U.S. employment (table 3-15). The spread in average (mean) wage was less dramatic but still quite wide, with individuals in S&E occupations again earning considerably more on average ($74,070) than workers in all occupations ($40,690). Mean S&E wages ranged from $66,370 for social science occupations to $81,050 for engineering occupations. Mean annual wages for technology occupations ranged from $53,165 for technicians and programmers to $114,470 for S&E managers.

The 2004–07 growth in mean wages for both the S&E and STEM occupation groups (3.4%) was slightly greater than that for all workers included in the OES survey (3.2%). Among S&E occupations, those in physical S&E occupations experienced the highest wage growth (3.7% average annual rate) and those in social science occupations experienced the lowest (3.1% average annual rate).

Workers with S&E degrees also have higher earnings than those with degrees in other fields. Figure 3-37 shows estimates of median salary at different points in life for individuals with a bachelor's degree as their highest degree in a variety of fields. Except in the first 4 years after earning their degrees, holders of S&E bachelor's degrees earn more than those with non-S&E degrees at every year since degree. Median salaries for S&E bachelor's degree holders in 2003 peaked at $65,000 at 15–19 years after receiving their degree, compared with $49,000 for those with non-S&E bachelor's degrees. Median salaries of individuals with bachelor's degrees in S&E-related fields (such as technology, architecture, or health) peaked at $52,000 at 25–29 years after degree, but were higher than those for non-S&E bachelor's degree holders at most years since receiving their degree.

Table 3-15

Annual earnings and earnings growth in science and technology and related occupations: May 2004–May 2007

Occupation	Mean: 2007 annual earnings ($)	Mean: Average annual growth rate since 2004 (%)	Median: 2007 annual earnings ($)	Median: Average annual growth rate since 2004 (%)
All U.S. employment	40,690	3.2	31,410	3.0
STEM occupations	72,000	3.4	66,950	3.3
S&E occupations	74,070	3.4	70,600	3.4
Computer/mathematical scientists	71,940	3.4	68,910	3.5
Life scientists	71,700	3.3	63,170	3.1
Physical scientists	73,720	3.7	67,190	3.9
Social scientists	66,370	3.1	60,380	3.2
Engineers	81,050	3.7	77,750	3.5
Technology occupations	67,870	0.3	NA	NA
S&E managers	114,470	4.7	NA	NA
S&E technicians/computer programmers	53,165	2.8	NA	NA
S&E-related occupations (not included above)	66,150	4.1	50,540	4.5
Health-related occupations	66,000	4.4	55,310	4.8
Other S&E-related occupations	73,110	3.3	50,250	3.8

NA = not available

STEM = science, technology, engineering, and mathematics

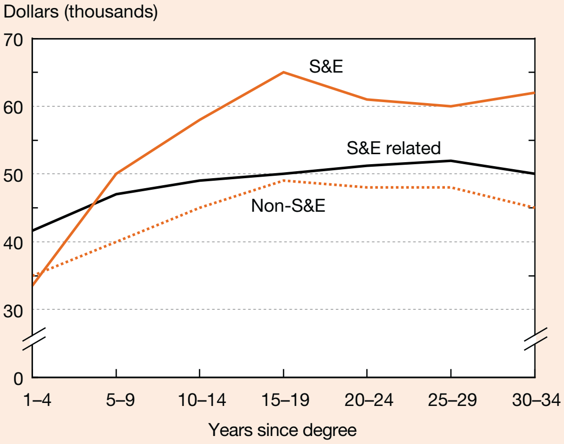
NOTE: Occupational Employment Statistics (OES) employment data do not cover employment in agriculture, private household, or among self-employed, and therefore do not represent total U.S. employment.

SOURCE: Bureau of Labor Statistics, OES Survey (May 2004 and May 2007).

Science and Engineering Indicators 2010

Figure 3-37

Median salaries for bachelor's degree holders, by broad field classification and years since degree: 2003



NOTE: See table 3-1 for definitions of S&E, S&E-related, and non-S&E degrees.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, 2003.

Science and Engineering Indicators 2010

Earnings at Different Degree Levels

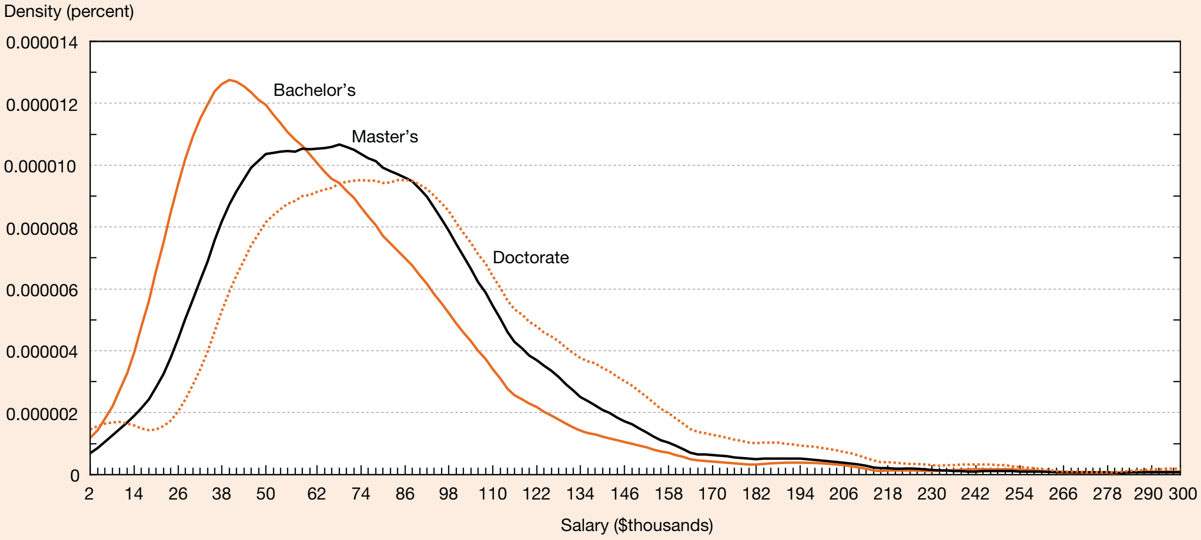
Figure 3-38 illustrates the distribution of median salaries earned by individuals with S&E degrees at various levels. (The distributions are heavily skewed, making the median a preferred summary statistic.) Not surprisingly, salaries are higher for those with more advanced degrees. In 2003, 11% of S&E bachelor's degree holders had salaries higher than $100,000, compared with 28% of doctorate holders. Similarly, 22% of bachelor's degree holders earned less than $30,000, compared with 8% of doctorate holders.[14]

Figure 3-39 shows a cross-sectional profile of median 2003 salaries for S&E degree holders over the course of their career. Median earnings generally increase with time since degree, as workers add on-the-job knowledge to the formal training they received in school. For holders of bachelor's and master's degrees in S&E, average earnings adjusted for inflation begin to decline in mid to late career, a common pattern that is often attributed to "skill depreciation." In contrast, earnings for S&E doctorate holders continue to rise even late in their careers. Median salaries in 2003 peaked at $65,000 for bachelor's degree holders, $73,000 for master's degree holders, and $96,000 for doctorate holders.

Unemployment in S&E Occupations

Along with higher salaries, relatively low unemployment rates are among the labor market rewards of the S&E labor force. Historically, unemployment rates in S&E occupations have tended to be lower than those for college-educated

Figure 3-38
Salary distribution of S&E degree holders employed full time, by degree level: 2003

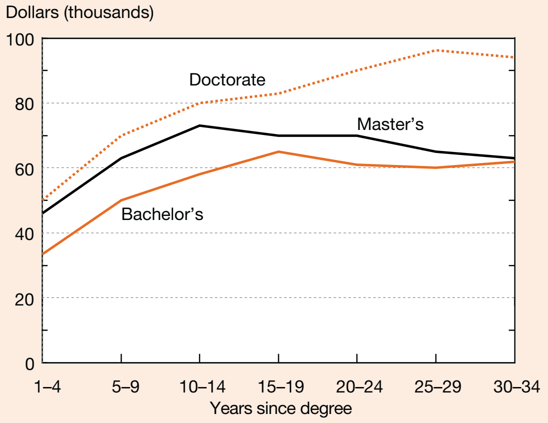


NOTE: Salary distribution smoothed using kernel density techniques.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-39
Median salaries of S&E graduates, by degree level and years since degree: 2003

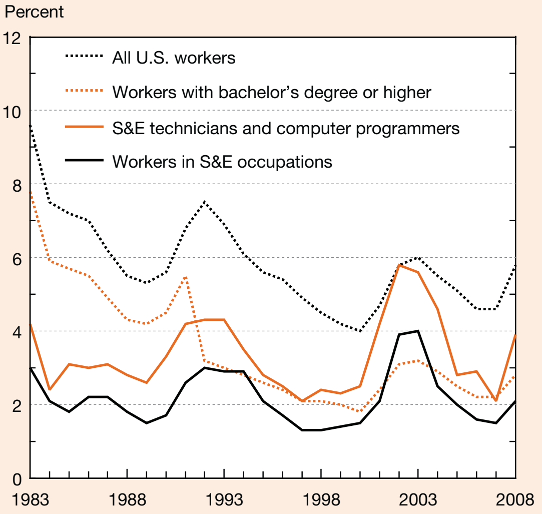


SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

workers generally and much lower than those for workers with less than a bachelor's degree, although the present recession, like that of the early 2000s, is a partial exception to these patterns. Unemployment rates in S&E occupations are also generally less volatile than unemployment rates for these other groups (figure 3-40). The Census Bureau's

Figure 3-40
Unemployment rate, by occupation: 1983–2008



SOURCES: National Bureau of Economic Research, Merged Outgoing Rotation Group Files; and Bureau of Labor Statistics, Current Population Survey (various years).

Science and Engineering Indicators 2010

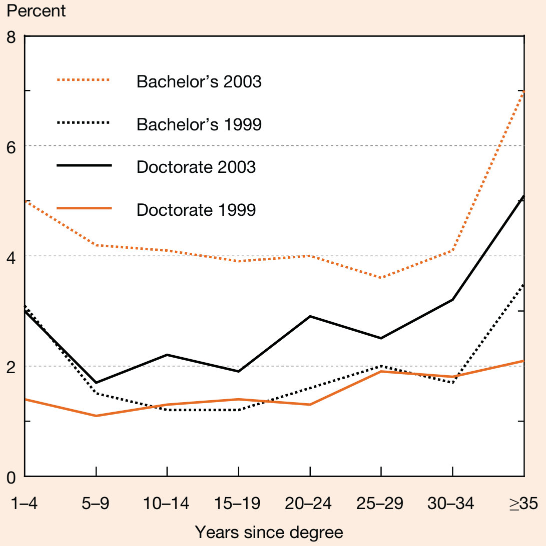
Current Population Survey data for 1983–2008 indicate that the unemployment rate for all individuals in S&E occupations ranged from 1.3% to 4.0%, which contrasted favorably with rates for all U.S. workers (ranging from 4.0% to 9.6%)

and all workers with a bachelor's degree or higher (from 1.8% to 7.8%). The rate for S&E technicians and computer programmers ranged from 2.1% to 5.8%. During most of the period, computer programmers had an unemployment rate similar to that of S&E occupations, but greater volatility (from 1.2% to 6.7%).

Data on the economic downturn that began in late 2007 initially fit with long-term trends. In 2008, workers in S&E occupations or S&E technician and computer programmer occupations had lower unemployment rates (2.1% or 3.9%, respectively) than all workers (5.8%). College-educated S&E workers had lower unemployment rates (2.1%) than all college graduates (2.8%). However, in the 3-month period ending in September 2009, the unemployment rate of college educated S&E workers rose to 5.5%, approximately the same rate as for all college graduates (5.4%). S&E technicians and computer programmers continued to experience a considerably lower unemployment rate (7.6%) than that of the general labor force (9.7%) (figure 3-41).

In most economic downturns, workers with advanced S&E degrees have been less vulnerable to changes in economic conditions than individuals who hold only S&E bachelor's degrees. Figure 3-42 compares unemployment rates over career cycles for persons with S&E bachelor's degrees and doctorates, regardless of their occupation, for 1999 and 2003—periods of relatively good and relatively difficult labor market conditions, respectively. The relatively difficult 2003 labor market had a greater effect on bachelor's degree holders: for individuals at various points in their careers, the unemployment rate increased by between 1.6 and 3.5 percentage points between 1999 and 2003. Labor market conditions had a smaller effect on doctorate holders, but some increases in unemployment rates affected individuals in most years-since-degree cohorts.

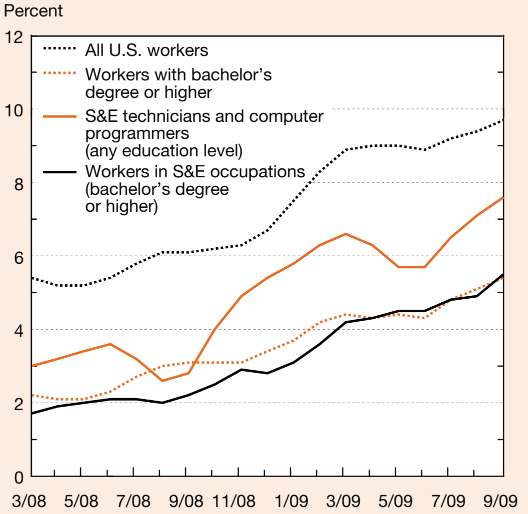
Figure 3-42
Unemployment rates for individuals whose highest degree is in S&E, by years since degree: 1999 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1999 and 2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-41
Estimated unemployment rates over previous 3 months for workers in S&E occupations and selected other categories: March 2008 to September 2009



NOTES: Estimates not seasonally adjusted. Estimates made from pooled microrecords of Current Population Survey and, while similar, are not same as 3-month moving average.

SOURCE: Current Population Survey, Public Use Microdata Sample (PUMS), January 2008–September 2009.

Science and Engineering Indicators 2010

Similarly among those who said they were working involuntarily out of the field (IOF) of their highest degree, labor market conditions from 1999 to 2003 had a greater effect on the proportion of bachelor's degree holders than on doctorate holders (figure 3-43). These rates ranged from 7% to 12% for bachelor's degree holders in 2003 versus 2% to 5% for those with doctorates. IOF rates for doctorate holders changed little between 1999 and 2003.

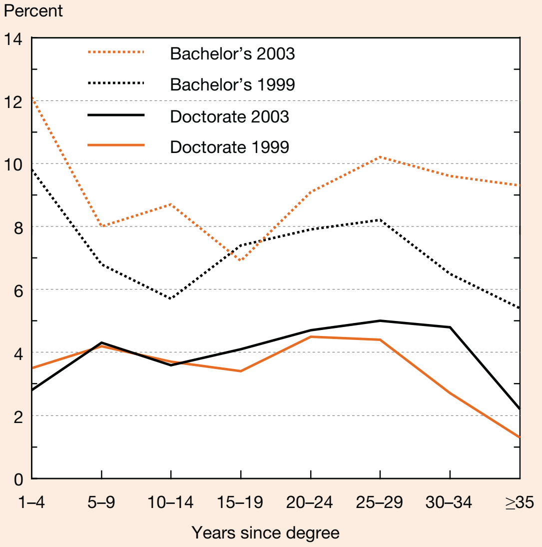
Although S&E qualifications may help workers weather recessions, they do not make them immune from adverse labor market conditions. The estimated 4.3% unemployment rate for S&E occupations in April 2009, although low relative to other occupations, was the highest in 25 years.

Recent S&E Graduates

Compared with experienced S&E workers, recent S&E graduates more often bring newly acquired skills to the labor market and have relatively few work or family commitments that limit their job mobility. As a result, measures of

Figure 3-43

Involuntarily out-of-field rate of individuals whose highest degree is in S&E, by years since degree: 1993 and 2003



NOTE: Individuals involuntarily employed out of field include those in jobs not related to field of highest degree because job in that field not available and those employed part-time because full-time work not available.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1999 and 2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

the success of recent graduates in securing good jobs can be sensitive indicators of changes in the S&E labor market.

This section looks at a number of standard labor market indicators for recent S&E degree recipients at all degree levels and examines a number of other indicators that may apply only to recent S&E doctorate recipients.

General Labor Market Indicators for Recent Graduates

Table 3-16 summarizes some basic labor market statistics for recent (1–5 years after receipt of degree) recipients of S&E degrees. Across all fields of S&E degrees in 2006, there was a 3.8% unemployment rate for bachelor's degree holders who received their degrees in the previous 1–5 years. This ranged from 1.9% for those with engineering degrees to 5.1% for social science degree recipients. Individuals early in their career tend to change jobs more often and have higher unemployment, yet most of these values are less than the unemployment rate of 4.7% for the full labor force in 2006. For doctorate recipients across all fields of degree, the unemployment rate was 1.1%.

A useful but more subjective indicator of labor market conditions for recent graduates is the proportion reporting that they sought, but could not find, full-time employment related to their field of degree. The involuntarily out of field (IOF) rate is a measure unique to NSF's labor force surveys. At the bachelor's degree level, across all S&E fields, the IOF rate was 11.0%, but it ranged from 3.6% for recent engineering graduates to 15.7% for recent graduates in the social sciences. In all fields of degree, the IOF rate decreases with

Table 3-16

Labor market indicators for recent S&E degree recipients 1–5 years after receiving degree, by field: 2006

		Highest degree field				
Indicator and degree	All S&E fields	Computer/ mathematical sciences	Life sciences	Physical sciences	Social sciences	Engineering
	Percent					
Unemployment rate						
Bachelor's	3.8	4.6	4.6	4.0	5.1	1.9
Master's	2.5	3.1	2.9	2.6	4.6	2.5
Doctorate	1.1	0.6	1.1	1.1	1.9	1.4
Involuntary out-of-field rate						
Bachelor's	11.0	8.5	9.9	9.4	15.7	3.6
Master's	4.2	3.5	4.1	6.4	9.5	2.9
Doctorate	1.8	1.6	0.6	4.1	4.0	2.5
	Dollars					
Average salary						
Bachelor's	39,500	48,600	31,700	35,900	34,400	54,000
Master's	55,000	65,000	45,500	44,700	42,100	67,300
Doctorate	56,000	72,700	54,700	63,300	57,800	75,000

NOTES: Average salary rounded to nearest $100. Unemployment rate for recent S&E degree recipients differs from rate for entire S&E labor force.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2006), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

level of education, reaching a low of 1.8% for recent doctorate recipients.

The average salary for recent S&E bachelor's degree recipients in 2006 was $39,500, ranging from $31,700 in the life sciences to $54,000 in engineering. Recent master's degree recipients had average salaries of $55,000 and recent doctorate recipients had salaries yielding only slightly more at $56,000. This reflects in part the relatively low postdoc salaries of some recent doctorate recipients (see discussion in next section) and the greater employment of doctorate holders in academia.

Recent Doctorate Recipients

The career rewards of highly skilled individuals in general, and doctorate holders in particular, often extend beyond salary and employment to more personal rewards that come from doing the kind of work for which they have trained. No single standard measure satisfactorily reflects the state of the doctoral S&E labor market; a range of available labor market indicators are discussed below, including unemployment rates, IOF employment, satisfaction with field of study, employment in academia versus other sectors, employment in postdoc positions, and salaries. Although a doctorate opens career opportunities both in terms of salary and type of employment, these opportunities come at the price of many years of foregone labor market earnings. Some doctorate holders also face an additional period of low earnings while in a postdoc position. In addition, some doctorate holders do not obtain the jobs they desire after completing their education.

In 2006, aggregate measures of labor market conditions for recent (1–3 years after receipt of degree) recipients of U.S. S&E doctorates showed improvement from the already generally good conditions found when last measured in 2003. Unemployment fell from 2.3% to 1.3% and IOF rates fell from 3.3% to 1.3% (table 3-17). In addition, the percentage of recent graduates entering tenure-track programs at 4-year institutions—a goal of many young doctorate holders—increased, rising from 17.8% in 2003 to 19.2% in 2006 (table 3-18).

Unemployment

The 1.3% unemployment rate for recent S&E doctorate recipients as of April 2006 was even lower than other generally low 2006 unemployment rates. The 2006 unemployment rate for all civilian workers was 4.6%, with lower rates of 2.2% for those with a bachelor's degree or above and 1.6% for those in S&E occupations (figure 3-40).

Table 3-17

Labor market rates for recent doctorate recipients 1–3 years after receiving doctorate, by selected field: 2001, 2003, and 2006

(Percent)

	Unemployment rate			Involuntarily out-of-field rate		
Field	2001	2003	2006	2001	2003	2006
All S&E	1.3	2.3	1.3	3.4	3.3	1.3
Computer/mathematical sciences	0.3	4.2	0.7	2.4	3.6	2.2
Computer sciences	0.4	4.4	1.7	2.3	1.4	2.3
Mathematics	0.3	4.0	0.0	2.4	5.6	2.1
Life sciences	1.1	2.5	0.9	2.5	1.5	0.3
Agriculture	0.3	3.1	0.0	4.1	2.9	1.7
Biological sciences	1.0	2.6	1.0	2.4	1.3	0.2
Physical sciences	1.3	0.9	1.6	5.0	3.6	2.3
Chemistry	0.8	1.2	1.9	3.2	4.3	0.9
Geosciences	1.9	1.5	1.9	3.0	0.0	0.0
Physics/astronomy	1.9	0.0	1.0	8.2	4.3	5.9
Social sciences	1.3	2.5	1.2	5.1	5.0	1.5
Economics	2.2	0.3	0.0	2.1	1.9	0.0
Political science	0.8	0.0	0.0	8.7	9.0	0.6
Psychology	1.4	2.8	1.2	3.8	5.2	1.3
Sociology/anthropology	1.2	5.0	2.4	6.3	4.5	4.8
Engineering	1.8	2.3	1.9	1.7	3.0	1.5
Chemical	1.6	2.1	0.7	2.0	8.9	9.8
Electrical	0.9	2.3	0.3	1.5	0.8	1.0
Mechanical	3.2	5.8	3.0	1.7	2.6	0.0

NOTES: Doctorate recipients in health fields included in life sciences. Rates of 0.0, like other rates in this table, are rounded estimates based on sample survey data and do not preclude possibility that some individuals in that field may be unemployed or working involuntarily out of field. Unemployment rates for recent doctoral recipients differ from those for the entire S&E labor force.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2001, 2003, and 2006), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-18

Doctorate recipients holding tenure and tenure-track appointments at academic institutions, by years since receipt of doctorate and selected field: 1993, 2003, and 2006

(Percent)

	1993		2003		2006	
S&E field	1–3 years	4–6 years	1–3 years	4–6 years	1–3 years	4–6 years
All fields	18.4	26.6	17.8	23.5	19.2	25.8
Computer/mathematical sciences	39.7	54.1	34.5	38.1	36.1	44.0
Computer sciences	37.1	51.5	30.9	30.3	37.8	36.4
Mathematics	41.8	56.0	37.7	43.8	34.7	50.6
Life sciences	12.6	24.8	8.0	20.3	13.4	20.8
Agriculture	15.6	27.0	23.7	35.1	18.9	30.0
Biological sciences	12.1	24.8	6.5	18.6	13.2	20.6
Physical sciences	9.7	18.2	13.7	18.2	10.7	23.8
Chemistry	7.7	16.3	14.5	16.0	11.0	22.2
Geosciences	12.7	26.2	21.6	35.1	13.9	30.5
Physics/astronomy	12.0	17.7	9.4	14.5	8.7	22.5
Social sciences	26.4	29.2	28.3	31.6	29.6	34.2
Economics	46.6	48.6	43.7	32.2	37.4	39.4
Political science	53.9	47.1	45.0	50.6	45.0	51.3
Psychology	12.7	15.5	14.5	21.1	18.7	21.9
Sociology/anthropology	37.9	46.9	43.3	48.0	62.1	65.0
Engineering	16.0	24.6	12.2	16.0	14.7	16.6
Chemical	8.1	14.0	4.9	6.0	8.2	9.4
Electrical	17.6	26.9	11.6	15.3	18.6	15.4
Mechanical	13.5	29.5	11.1	16.0	16.5	14.6

NOTES: Two-year institutions not included. Doctorate recipients in health fields included in life sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (1993, 2003, and 2006), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

The highest unemployment rates for recent doctorate recipients were in mechanical engineering (3.0%) and sociology/anthropology (2.4%). Unemployment in both fields (which also had the highest unemployment rates in 2003) fell from 5.8% and 5.0%, respectively, in 2003. The unemployment rate for recent S&E doctorate recipients in computer sciences, the field with the third highest unemployment rate in 2003, fell from 4.4% to 1.7% in 2006.

Working Involuntarily Outside the Field

In addition to the 1.3% who were unemployed in 2006, another 1.3% of recent S&E doctorate recipients in the labor force reported that they took a job that was not related to the field of their doctorate because a job in their field was not available. Comparable figures were 3.4% in 2001 and 3.3% in 2003.

The highest IOF rates were found for recent doctorate recipients in chemical engineering (9.8%), physics/astronomy (5.9%), and sociology/anthropology (4.8%).

Tenure-Track Positions

Many S&E doctorate recipients may aspire to tenure-track academic appointments, but most will end up working in other positions and sectors. Recently, the proportion of all recent doctorate recipients entering tenure-track academic jobs has increased, breaking a long-term decline. Such increases can be seen between 2001 and 2003, and again between 2003 and 2006. As a result, 2006 tenure-track rates for those 1–3 years after receiving their degree and those 4–6 years after receiving their degree were broadly the same as in 1993 (figure 3-44; table 3-18). From 2003 to 2006, the rate for those 1–3 years since receiving their degree rose from 18% to 19%, and the rate for those 4–6 years since receiving their degree increased from 24% to 26%. (See chapter 5 for a discussion of trends in tenure-track positions as a proportion of all academic positions.)

The availability of tenure-track positions may be counterbalanced by the availability of desirable nonacademic employment opportunities. One of the quickest declines in tenure-track employment occurred in computer sciences, from 52% in 1993 to 24% in 2001 despite the difficulties computer sciences departments had in finding faculty.

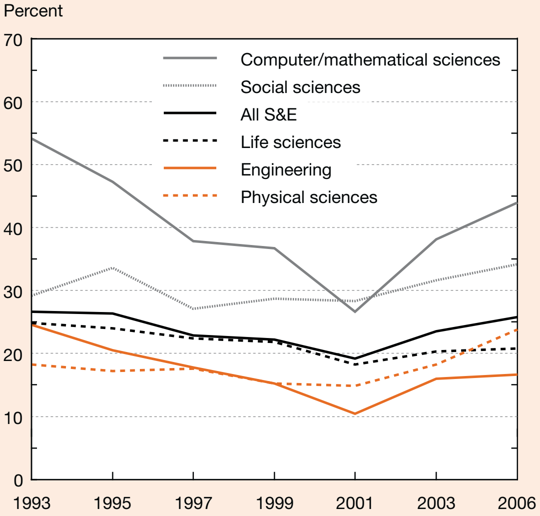
Salaries for Recent S&E Doctorate Recipients

In 2006 for all S&E degree fields, the median annual salary for recent doctorate recipients 1–5 years after they received their degrees was $52,000. Across various S&E fields of degree, median annual salaries ranged from a low of $46,000 in the life sciences to a high of $70,000 in engineering (table 3-19).

By type of employment, salaries for recent doctorate recipients ranged from $40,000 for postdoc positions to

Figure 3-44

Doctorate recipients holding tenure and tenure-track appointments at academic institutions 4–6 years after degree, by field: 1993–2006



NOTES: Two-year institutions not included. Life sciences includes doctorate recipients in health fields.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (1993–2006).

Science and Engineering Indicators 2010

Table 3-19

Salary of recent doctorate recipients 1–5 years after receiving degree, by degree field and percentile: 2006

(Dollars)

Degree field	25th percentile	50th percentile	75th percentile
All S&E fields	40,000	52,000	74,000
Computer/mathematical sciences	43,500	64,000	84,000
Life sciences	38,000	46,000	65,000
Physical sciences	40,000	53,000	75,600
Social sciences	40,000	51,300	65,000
Engineering	41,000	70,000	87,500

NOTE: Doctorate recipients in health fields included in life sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2006), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

$80,000 for those employed by private for-profit businesses (table 3-20).

Postdoc Positions

The growing number of recent doctorate recipients in postdoctoral appointments, generally known as postdocs,[15] has become a major issue and concern in science policy. Neither the reasons for this growth nor its effect on the health of science are well understood. Increases in competition for tenure-track academic research jobs, collaborative research in large teams, and needs for specialized training are possible factors explaining this growth. Although individuals in postdoc positions often perform cutting-edge research, there is a concern that time spent in a postdoc position is time added onto the already long time spent earning a doctorate, thereby delaying the start and advancement of independent careers. Because postdoc positions usually offer low pay, forgone earnings add significantly to the costs of a doctoral education and may discourage doctoral-level careers in S&E.

How Many Postdocs Are There?

The total number of postdocs in the United States is unknown; broad estimates depend upon a number of assumptions. NSF's Survey of Doctorate Recipients (SDR) covers U.S. residents with research doctorates in S&E and health fields from U.S. universities, but not those with non-U.S. doctorates. The NSF Survey of Graduate Students and Postdoctorates in Science and Engineering gathers information on postdocs from U.S. academic graduate departments, regardless of where their doctorate was earned. It does not cover people in nonacademic employment, at some university research centers, or at academic departments that lack graduate programs. Table 3-21 shows the SDR and GSS estimates of the U.S. postdoc population that these surveys cover.

Academic Postdocs. SDR estimates that 22,900 U.S. citizens and permanent residents were in academic postdoc positions in fall 2005, along with 7,700 temporary visa holders.[16] The corresponding 2005 GSS estimate is 16,200 U.S. citizens and permanent residents but 26,600 temporary visa holders.

Postdocs in FFRDCs. Many federally funded research and development centers (FFRDCs) employ postdocs as part of their efforts to assist government agencies with scientific research and analysis and to train the country's researchers and scientists. According to NSF's 2007 Survey of Postdocs at FFRDCs, 22 of the 38 FFRDCs on the master government FFRDC list maintained by the NSF reported employing 2,235 postdocs. Of those 2,235 postdocs, 1,336 (about 60%) were temporary visa holders and 2,030 (about 91%) received federal support.

Table 3-20

Median annual salary of recent doctorate recipients 1–5 years after receiving degree, by type of employment: 2006

(Dollars)

Field	All sectors	Private	Tenure track	Postdoc	Other education	Nonprofit/ government
All S&E fields	52,000	80,000	53,000	40,000	48,500	68,000
Computer/mathematical sciences	64,000	90,000	62,000	48,500	48,000	S
Life sciences	42,600	74,000	57,000	40,000	48,000	60,000
Physical sciences	53,000	78,000	50,500	42,000	48,000	76,000
Social sciences	51,300	65,000	52,000	39,600	50,000	62,000
Engineering	70,000	80,000	71,000	40,000	56,000	80,000

S = data suppressed for reasons of reliability

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2006), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Table 3-21

Postdoc estimates from two NSF/SRS surveys, by place of employment and citizen/visa status: Fall 2005

Place of employment and citizen/visa status	SDR		GSS	
	Estimate	Percent	Estimate	Percent
All places of employment				
All postdocs	43,400	100.0	43,100	100.0
U.S. citizens/permanent residents	33,400	77.0	16,200	37.5
Temporary visa	10,000	23.0	27,000	62.5
Higher education institutions[a]				
All postdocs	30,500	100.0	26,900	100.0
U.S. citizens/permanent residents	22,900	74.8	16,200	37.6
Temporary visa	7,700	25.2	26,900	62.4
All other educational institutions				
All postdocs	1,900	100.0	NA	NA
U.S. citizens/permanent residents	1,600	85.5	NA	NA
Temporary visa	300	14.5	NA	NA
Nonprofits/government/industry/all other institutions				
All postdocs	11,100	100.0	NA	NA
U.S. citizens/permanent residents	9,000	81.2	NA	NA
Temporary visa	2,100	18.8	NA	NA

NA = not available

GSS = Survey of Graduate Students and Postdoctorates in Science and Engineering; NSF/SRS = National Science Foundation, Division of Science Resources Statistics; SDR = Survey of Doctorate Recipients

[a] For SDR, individuals reporting postdoc in 4-year U.S. colleges and universities/medical schools/university-affiliated research institutes/unknown institution type in fall 2005; for GSS, postdocs in graduate S&E/health departments in U.S. graduate schools (excludes holders of medical and other professional degrees, some of whom may also hold doctorates).

NOTES: SDR gathers information from individuals with research doctorates in S&E and health fields earned at U.S. educational institutions. GSS gathers information from U.S. educational institutions with programs leading to graduate degrees in S&E/health fields and includes postdocs with doctorates/equivalent degrees from foreign institutions. Estimates of postdoc status from 2006 SDR constructed from postdoc history module; fall 2005 used rather than April 2006 for comparability with GSS data and to capture those who may have left a postdoc position early. Detail may not add to total because of rounding.

SOURCES: NSF/SRS, 2006 SDR, Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov, and 2005 GSS, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.

Science and Engineering Indicators 2010

Other Postdocs. Neither the GSS nor the SDR survey includes data on the number of foreign-educated postdocs in all sectors. SDR estimates that 29% of U.S.-educated postdocs, 13,000 in all, are in industry, nonprofits, government, and other types of educational institutions. Using these data, one might estimate as follows:

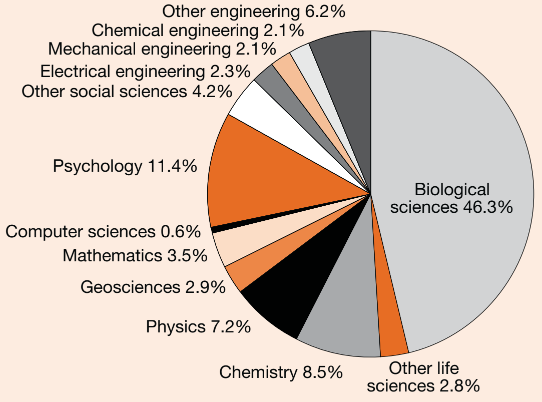
- 22,900 U.S. citizens and permanent residents in academic postdoc positions (SDR)
- 26,900 persons on temporary visas in academic postdoc positions (GSS)
- 13,000 U.S.-educated persons in postdoc positions not covered by GSS (SDR)
- 26,500 postdocs on temporary visas in positions not covered by GSS, based on the assumption that proportions of temporary visa postdocs in sectors and parts of academia not covered by GSS are the same as in the GSS estimates.

These assumptions yield approximately 89,300 postdocs, but other comparably plausible assumptions lead to substantially different totals.

Postdocs by Academic Discipline

About half of all U.S.-educated postdocs in 2005 (49%) had doctorates in the biological and other life sciences (figure 3-45). In this field, postdoc training has been common for a long time and individuals remain in postdoc positions longer than in other fields. Psychology, chemistry, and physics also have high rates of graduates entering postdoc positions and together make up another one-quarter of postdoc positions. The remaining quarter come from all other fields of S&E, most of which do not have a strong postdoc tradition as part of their career paths.

Figure 3-45
Field of doctorate of U.S.-educated S&E doctorate recipients in postdoc positions: Fall 2005



NOTE: Percentages do not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2006).

Science and Engineering Indicators 2010

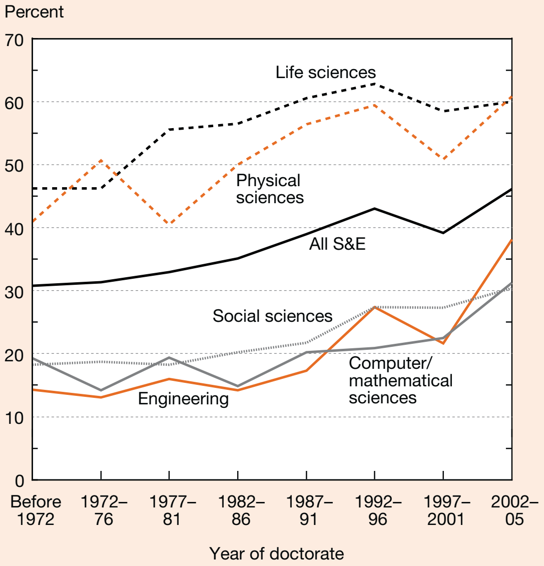
Increase in the Likelihood and Length of Postdoc Positions

Among holders of U.S. S&E doctorates received before 1972,[17] 31% reported having had a postdoc position earlier in their careers (figure 3-46). This proportion has risen over time to 46% among 2002–05 graduates and has increasingly involved fields in which formerly only a small number of doctorate recipients went on to postdoc positions. In traditionally high-postdoc fields such as the life sciences (from 46% to 60%) and the physical sciences (from 41% to 61%), a majority of doctorate recipients now have a postdoc position as part of their career path. Similar increases were found in mathematical and computer sciences (19% to 31%), social sciences (18% to 30%) and engineering (14% to 38%). Recent engineering doctorate recipients are now almost as likely to take a postdoc position as physical sciences doctorate holders were 35 years ago.

Postdoc Pay and Benefits

Low pay and fewer benefits for postdocs are frequently raised as concerns by those worried about the effect of the increasing number of postdoc positions on the attractiveness of science careers. The median academic postdoc salary is one-third less than the median salary for nonpostdocs 1–3 years after receiving their doctorates (table 3-22). By broad field, this ranges from a 44% pay gap for recent recipients of engineering doctorates to a 25% gap for doctorate holders in the social sciences. Nonacademic postdocs are better paid

Figure 3-46
U.S. S&E doctorate holders ever holding postdoc, by field and year of doctorate: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2006).

Science and Engineering Indicators 2010

Table 3-22
Salary and benefits of U.S. S&E doctorate holders in postdoc positions: 2006

	Median salary ($)			Benefits (%)	
Field of doctorate	Academic postdoc	Nonacademic postdoc	Nonpostdocs 1–3 years after degree	Medical	Retirement
All S&E	40,000	48,000	60,000	90.1	48.9
Computer/mathematical sciences	47,000	55,000	72,000	93.0	69.1
Life sciences	40,000	44,000	55,000	92.9	47.7
Physical sciences	40,000	55,000	63,000	92.7	54.7
Social sciences	40,000	50,000	53,000	75.0	44.8
Engineering	40,000	60,000	71,400	92.4	56.2

NOTE: Doctorate recipients in health fields included in life sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2006), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

than academic postdocs, but their median salary is still 20% less than that of nonpostdocs.

Most individuals in postdoc positions in 2006 had employment benefits. Indeed, across all S&E fields, 90% of postdocs reported having medical benefits and 49% reported having retirement benefits. It is not possible to know from the survey how extensive medical benefits may be or how transferable retirement benefits are. In the social sciences, medical benefits are less available, with only 75% of postdocs reporting that they had medical benefits.

Postdoc Positions as a Sign of Labor Market Distress for Recent Doctorate Recipients

Former postdoc position holders reported reasons for accepting their appointment that are consistent with the traditional intent of a postdoc as a type of apprenticeship, such as seeking "additional training in doctorate field" or "training in an area outside of doctorate field." However, 9% of Survey of Doctorate Recipients respondents in a postdoc position in April 2006 reported that they took their current postdoc position because "other employment not available." This reason was given by 5% of postdocs in the life sciences, 8% in computer and mathematical sciences, 10% in the physical sciences, 14% in the social sciences, and 16% in engineering.

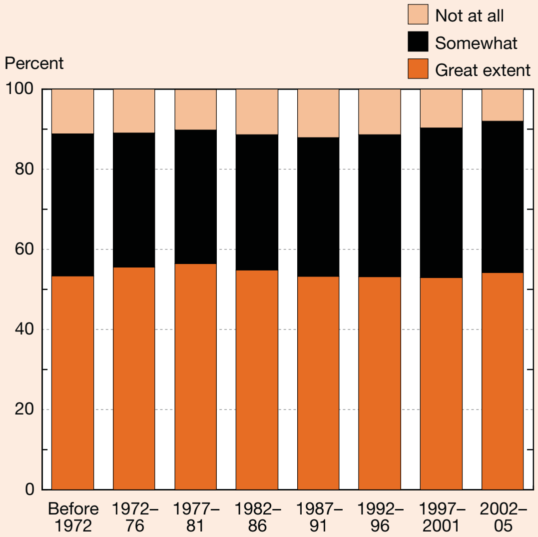
Postdoc Outcomes

Most former postdocs report that their most recent postdoctoral appointment enhanced their career opportunities, and the proportions who say this are similar for different cohorts (figure 3-47). Across all S&E fields and cohorts, 53%–56% of former postdocs said that their postdoc appointment enhanced their career opportunities to a "great extent"; an additional 33%–38% said that their postdoc appointment "somewhat" enhanced their career opportunities. The proportion of those completing postdoc positions who said that it was no help to their career opportunities ranged from only 8% for the 2002–05 graduation cohort to 12% for the 1987–91 cohort. For a more detailed look at perceived and actual outcomes from a postdoc experience, see chapter 3 of *Science and Engineering Indicators 2008* (NSB 2008) and NSF/SRS (2008b).

Global S&E Labor Force

Science is a global enterprise. The common laws of nature cross political boundaries, and the international movement of people and knowledge made science global long before "globalization" became a label for the increasing interconnections now forming among the world's economies. The rapid development of the capacity to make scientific and

Figure 3-47
Former postdocs' evaluation of how much most recent postdoc position enhanced career opportunities, by year of doctorate: 2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients (2006).

Science and Engineering Indicators 2010

technical innovations is creating a new competitive environment. New ways of doing business and performing R&D take advantage of gains from new knowledge discovered anywhere in the world, from increases in foreign economic development, and from the expanding international migration of highly trained scientists and engineers.

This section begins with an overview of what is known about S&E labor forces in advanced countries, which mostly concerns researchers and people performing R&D for multinational firms. The remainder of the section deals with foreign-born scientists and engineers in the United States.

Other chapters provide indirect indicators on the global S&E labor force. Chapter 2 reports on the production of new scientists and engineers through university degree programs. Chapter 4 provides indicators of R&D performed globally, chapter 5 discusses publications output and international collaboration, and chapter 6 has information on high-technology activities and global patenting activity.

Counts of Global S&E Labor Force

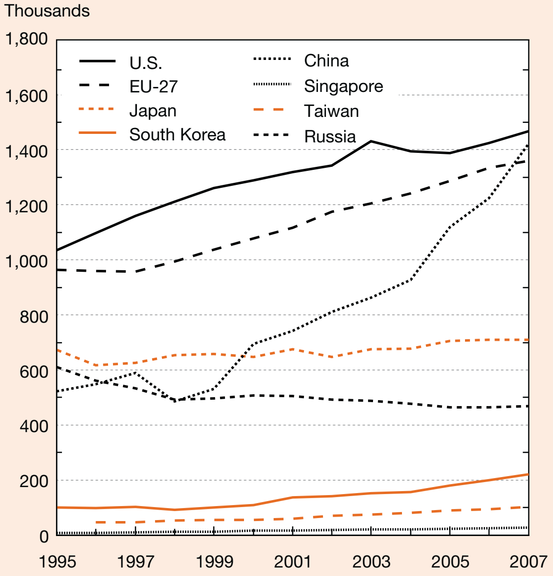
There are no comprehensive measures of the global S&E labor force, but fragmentary data on the global S&E labor force suggest that the U.S. world share is continuing to decline, even as U.S. reliance on foreign-born scientists and engineers may be near or at a historic high. Data exist within some national data systems, and some countries report data in standardized form to international agencies such as the Organisation for Economic Co-operation and Development (OECD). Existing data provide a strong indication of rapid growth in the number of individuals who pursue advanced education and find employment in technical fields, particularly in developing nations.

OECD collects data on researchers from its member countries and selected other countries. Unfortunately, this source misses many countries that appear to have high levels of S&T activity, including India, Brazil, and Israel.

Figure 3-48 shows the growth between 1995 and 2007 in the reported number of researchers in selected countries/economies. The United States had about the same growth of researchers as the EU-27, about 40% each over the time period. The number of researchers in Japan rose by just over 5%. Over the same 12-year period, the reported number of researchers in China rose by 173% to more than 1.4 million in 2007—close to the estimated U.S. figure and the number of the combined EU-27. An important caution in interpreting these data is that although countries used a common definition of "researcher" when reporting their data to OECD, there are many judgments necessary to translate from a wide variety of national data systems to the OECD definition.

Figure 3-48

Estimated number of researchers in selected regions/countries/economies: 1995–2007



EU = European Union

NOTES: Researchers are full-time equivalents. 2007 data for United States are estimated based on annual growth rate between 1995 and 2006.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1 and earlier years).

Science and Engineering Indicators 2010

Tertiary Education

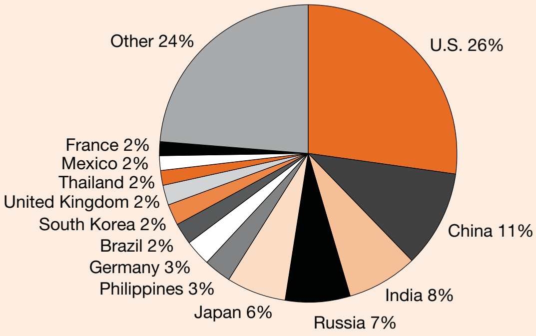
One widely available measure of the education level of a country's population is the number of its residents with a tertiary level of education. This is roughly equivalent in U.S. terms to individuals who have earned at least a technical associate's degree, but also includes all higher degrees up to the doctorate. Figure 3-49, based on estimates by Barro and Lee (2000), shows the global distribution of tertiary education graduates in 2000 or the most recent available year. About one-fourth of the world's tertiary graduates were in the United States; the next three largest countries in terms of tertiary education are China, India, and Russia, which are all non-OECD members.

Highly Skilled Migrants in OECD Countries

Docquier and Marfouk (2004) made estimates of the highly educated international migrants residing in OECD countries by using data from various national censuses. Based on their data, figure 3-50 shows the leading countries of origin of non-natives with tertiary-level education who lived in OECD countries in 2000. With 1.4 million, the United Kingdom has the largest high-skilled diaspora. (Although originally used to describe much less voluntary dispersals of population in history, the term *diaspora* is increasingly used to describe the internationally mobile portion of a country's nationals, which forms a network for contact and information flow. These networks can provide advantages for a country that help mitigate the loss of human capital through migration.)

The United States, ranking 11th with 448,000 tertiary-educated citizens who live in other OECD countries, has a fairly small high-skilled diaspora compared with its

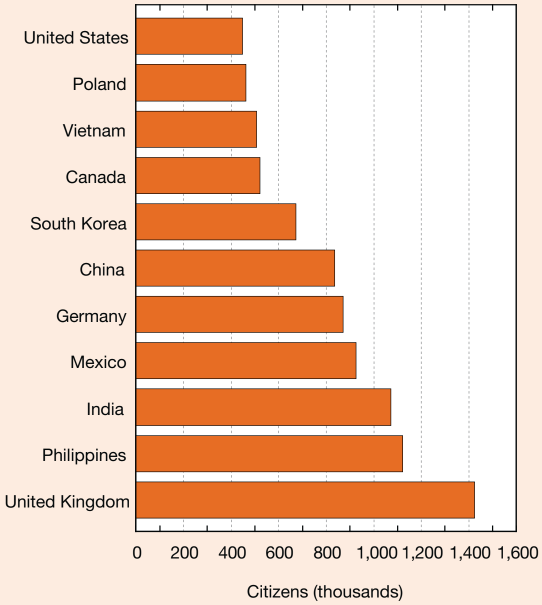
Figure 3-49
Tertiary-educated population more than 15 years old, by country: 2000 or most recent year



SOURCE: Adapted from Barro RJ, Lee J, International data on educational attainment: Updates and implications, Center for International Development Working Paper No. 042 (2000), http://www.cid.harvard.edu/cidwp/042.htm, accessed 9 September 2009.

Science and Engineering Indicators 2010

Figure 3-50
Top 11 countries of origin of persons having at least tertiary-level education and residing in OECD countries: 2000



OECD = Organisation for Economic Co-operation and Development

SOURCE: Docquier F, Marfouk A, International Migration by Educational Attainment (1990–2000), Release 1.1, http://team.univ-paris1.fr/teamperso/DEA/Cursus/M1/DM_ozdenschiff.pdf.

Science and Engineering Indicators 2010

population, and particularly compared with its number of educated workers.

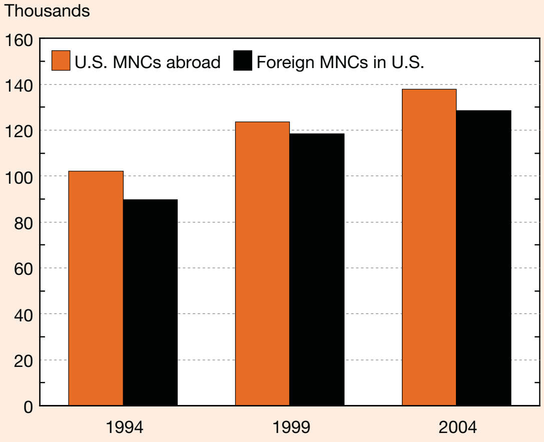
R&D Employment by Multinational Companies

MNCs perform a substantial proportion of R&D through foreign direct investment (FDI) (see chapter 4). Data on MNC R&D employment include all employees engaged in research and development, including managers, scientists, engineers, and other professional and technical employees. Data on R&D employment of parent companies of U.S. MNCs and their overseas affiliates are available every 5 years from the Survey of U.S. Direct Investment Abroad conducted by the Bureau of Economic Analysis (BEA). Separately, data on R&D employment by foreign-based MNCs in the United States are available from BEA's Survey of Foreign Direct Investment in the United States.

By definition, FDI does not include external arrangements ranging from R&D contracting to consulting work and strategic collaborations.[18] Nevertheless, R&D employment by subsidiaries is an important indicator of international R&D activity.

R&D employment in the United States by foreign firms grew slightly faster than R&D employment abroad by U.S. firms. R&D employment in the United States by majority-owned affiliates[19] of foreign firms rose from 89,800 in 1994 to 128,500 in 2004, for a 43% increase over the decade (figure 3-51). Over the same 10 years, R&D employment by U.S. firms at their majority-owned foreign affiliates grew 35%, from 102,000 in 1994 to 137,800 in 2004. Adding

Figure 3-51
R&D employment of U.S. MNCs at their foreign affiliates and foreign MNCs at their U.S. affiliates: 1994, 1999, and 2004



MNC = multinational corporation

NOTE: Includes only employment at majority-owned affiliates.

SOURCE: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States and Survey of U.S. Direct Investment Abroad (various years).

Science and Engineering Indicators 2010

U.S. parent company R&D employment of 716,400 workers, U.S. MNCs employed 854,200 R&D workers globally (figure 3-52) in 2004.

The average annual growth in R&D employment abroad by U.S. firms from 1994 to 2004 was only 3% and did not produce a large shift in their overseas employment, which rose from 14% to 16% of their total.

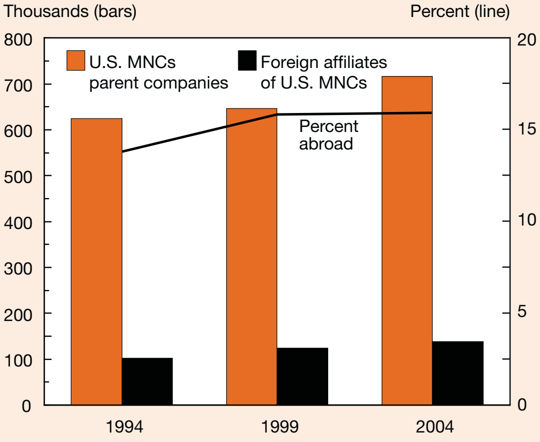
The data in both figure 3-51 and figure 3-52 are consistent with two trends discussed in this chapter: rapid growth in S&T employment in the United States coinciding with a general expansion of the ability to do S&T work throughout the world.

Migration to the United States

The knowledge and specialized skills of scientists and engineers can be transferred across national borders through the physical movement of people. Governments in many industrialized countries increasingly view the immigration of skilled S&E workers as an important contributor to the quality and flexibility of their S&E labor force. Many countries have not only increased their research investments, but have also made encouraging high-skilled immigration an important part of their national economic strategies.

The United States has benefited, and continues to benefit, from this international flow of knowledge and personnel (see Regets 2001 for a general discussion of high-skilled migration). However, competition for skilled labor continues to increase. A National Science Board taskforce noted that "global competition for S&E talent is intensifying, such that the United States may not be able to rely on the international S&E labor market to fill unmet skill needs" (NSB 2003). (See sidebar "High-Skill Migration to Japan and the UK.")

Figure 3-52
R&D employment of U.S. MNC parent companies in the United States and their foreign affiliates: 1994, 1999, and 2004



MNC = multinational corporation

NOTE: Includes only employment at majority-owned affiliates.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (various years).

Science and Engineering Indicators 2010

Broadly consistent estimates of U.S. reliance on foreign-born scientists and engineers are available from several sources. Table 3-23 shows upward trends in the percentage of foreign-born individuals in U.S. S&E occupations over time. The percentage changes since 2000 may appear small but are quite substantial, given the short time span and the overall growth of the number of persons in S&E occupations from 2000 to 2007: of an estimated 341,000 total increase, 100,000 were foreign born.

SESTAT surveys include only individuals who were counted in the most recent Decennial Censuses or who received a U.S. S&E degree, thereby missing recently arrived foreign-born and foreign-educated scientists and engineers. Yet, a large proportion of the foreign-born and foreign-educated members of the S&E labor force are recent arrivals. For example, in 2000, about 43% of all college-educated foreign-born workers in U.S. S&E occupations reported arriving in the United States after 1990; among doctorate holders 62% reported arriving after this date.

The 2000 census data provide a good estimate of the foreign born who were actually in the United States in April 2000 but give no information about those performing S&E tasks in a wide variety of non-S&E occupations (as discussed earlier in this chapter), nor about which postsecondary teachers are in S&E fields. Within these limitations, the Census Bureau's 2007 American Community Survey permits an analysis of trends in the proportion of the foreign born in S&E occupations at each degree level during the current decade. It shows growth of 3 percentage points overall, with an extra 4 percentage points each at the master's degree and doctorate levels.

Between 2003 and 2007, employment of college graduates in nonacademic S&E occupations, as measured by the ACS, increased by 345,000: 235,000 U.S. natives and 110,000 foreign born (figure 3-53). The estimated overall proportion of the foreign born rose only slightly over these 4 years (from 24.6% to 25.2%) but increased by 2 percentage points each for those with master's degrees and doctorates in this short span.

Details on the proportion of foreign-born S&E degree holders by field of degree are shown in table 3-24, based on 2003 SESTAT estimates. At the doctoral level, foreign-born individuals constitute about half the total number of workers in both engineering (51%) and mathematics/computer sciences (48%), up from 41% and 33% a decade earlier. Only in the geosciences and the social sciences are the foreign born significantly less than a third of doctorate holders in S&E fields. At the bachelor's degree level, 15% of S&E degree holders were foreign born, ranging from 7% of individuals in sociology/anthropology to 27% in physics/astronomy and 28% in electrical engineering. Given the continuing increase in foreign participation, it is likely that these 2003-based percentages are conservative estimates.

High-Skill Migration to Japan and the UK

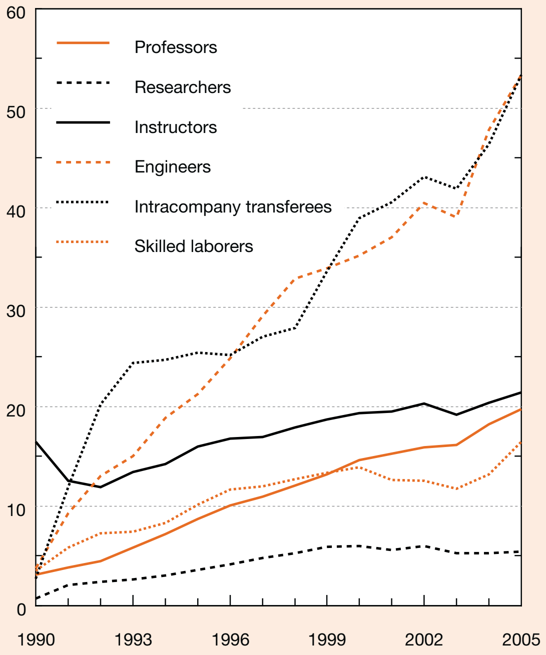
Recent debates and legislative changes in many developed (and sometimes less developed) countries have focused on visa programs for temporary high-skilled workers. The United Kingdom and Japan are just two examples of countries that have made temporary high-skilled migration important parts of national economic policies.

A 1989 revision of Japanese immigration laws made it easier for high-skilled workers to enter Japan with temporary visas, which allow employment and residence for an indefinite period (even though the same visa classes also apply to work visits that may last for only a few months). In 2005, 169,800 workers entered Japan in selected high-skilled temporary visa categories, compared with just over 30,000 in 1990 (figure 3-E). For comparison purposes, this equals half the number of Japanese university graduates entering the labor force each year and is more than the number entering the United States in roughly similar categories (H-1B, L-1, TN, O-1, O-2).

The United Kingdom's programs for the entry of high-skilled workers continue to evolve in ways to encourage migration and are currently part of an overall point system. Under the United Kingdom's recent Highly Skilled Migrant Program, admissions grew from 1,197 in 2002 to 21,939 in 2006. An important note for these numbers is that high-skilled EU citizens enter the UK without needing this visa, so actual high-skilled migration to the UK is likely to be much larger. During these years, the number of U.S. citizens entering the UK as high-skilled migrants grew from 273 to a still modest 629 (Salt 2007).

Figure 3-E
Entry to Japan of workers with selected classes of high-skilled temporary visas: 1990–2005

Thousands



SOURCE: Statistics Bureau, Japanese Ministry for Internal Affairs and Communications (various years).

Science and Engineering Indicators 2010

Table 3-23
Estimates of foreign-born individuals in S&E occupations from NSF/SRS and Census Bureau, by educational attainment: 1999, 2000, and 2003
(Percent)

			2003	
Education	1999 NSF/SRS SESTAT	2000 Census 5% PUMS	NSF/SRS SESTAT	Census Bureau ACS
All college educated[a]	15.0	22.4	22.5	25.0
Bachelor's	11.3	16.5	16.3	18.8
Master's	19.4	29.0	29.0	32.0
Doctorate	28.7	37.6	35.6	39.5

ACS = American Community Survey; NSF/SRS = National Science Foundation, Division of Science Resources Statistics; SESTAT = Scientists and Engineers Statistical Data System; 5% PUMS = Public Use Microdata Sample with 5% of sample cases

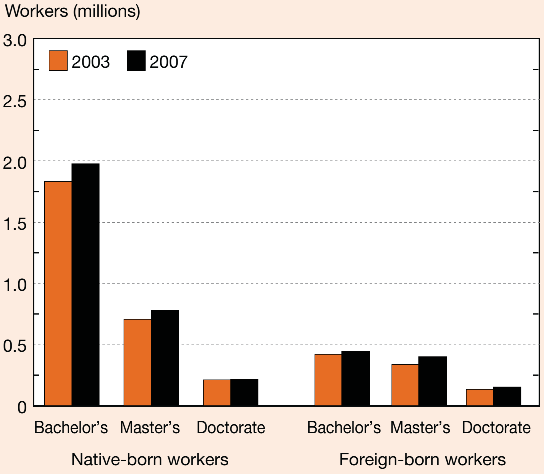
[a] Includes professional degrees not broken out separately.

NOTES: Includes all S&E occupations except postsecondary teachers because these occupations not separately reported in 2000 Census or 2003 American Community Survey data files.

SOURCES: NSF/SRS, SESTAT (1999 and 2003), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov; and Census Bureau, PUMS (2000) and ACS (2003).

Science and Engineering Indicators 2010

Figure 3-53
Native-born and foreign-born workers in S&E occupations, by degree level: 2003 and 2007



SOURCE: Census Bureau, American Community Survey, Public Use Microdata Files (PUMS) (2003 and 2007).

Science and Engineering Indicators 2010

Origins of S&E Immigrants

Immigrant scientists and engineers come from a broad range of countries. Figure 3-54 shows country of birth for the 2.2 million foreign-born persons with highest degree in S&E in the United States (country details are in appendix table 3-10). Although no one source country dominates, 16% came from India and 11% came from China. Source countries for the 276,000 foreign-born holders of S&E doctorates are somewhat more concentrated, with China providing 22% and India 14%.

Source of Education for S&E Immigrants

The majority of foreign-born scientists and engineers in the United States first came to the United States to study, but a substantial number came to the United States after receiving their university training abroad. Table 3-25 illustrates the various educational routes that highly skilled workers from around the world take into the United States workforce and indicates how these workers help connect the United States to universities and research institutions worldwide.

Across all levels of degree, 42% of the university-educated foreign born in the United States had their highest degree from a foreign educational institution and 56% had at least

Table 3-24
Foreign-born proportion of individuals with highest degree in S&E, by field and education level: 2003
(Percent)

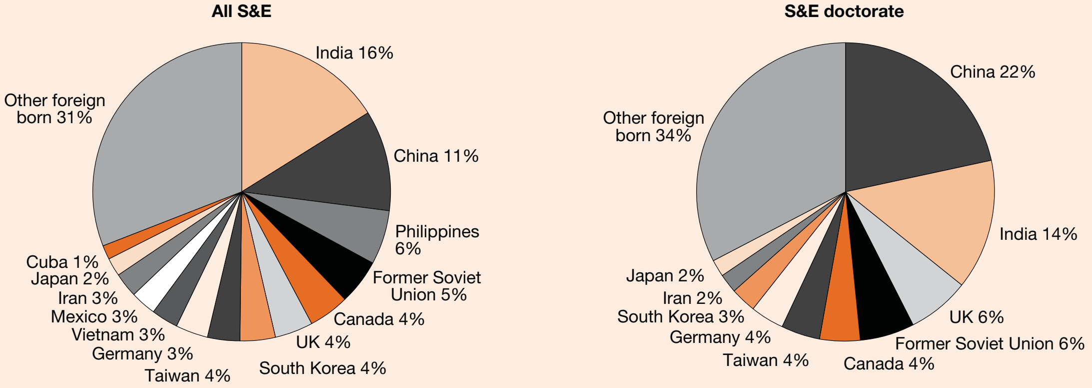
Field	All degree levels[a]	Highest degree: Bachelor's	Master's	Doctorate
All S&E	18.8	15.2	27.2	34.6
Computer/mathematical sciences	25.8	19.3	40.5	47.5
Computer sciences	29.9	22.3	46.5	57.4
Mathematics	18.5	14.4	25.5	43.1
Biological/agricultural/environmental life sciences	16.6	12.6	21.2	36.2
Agricultural and food sciences	11.6	8.8	15.9	32.7
Biological sciences	19.0	14.6	23.9	37.4
Environmental life sciences	6.6	4.3	13.5	13.3
Physical sciences	22.9	16.9	28.9	36.9
Chemistry	25.3	18.1	42.1	37.0
Geosciences	11.3	8.3	13.0	26.2
Physics/astronomy	32.6	27.4	34.4	40.1
Other physical sciences	16.3	14.1	11.1	48.7
Social sciences	11.5	10.8	13.3	16.9
Economics	21.7	19.8	30.5	31.5
Political science	11.0	9.5	17.1	24.2
Psychology	9.7	10.1	8.5	9.8
Sociology/anthropology	7.2	6.7	10.2	13.6
Other social sciences	13.0	10.6	18.2	31.3
Engineering	26.8	21.5	38.3	50.6
Aerospace/aeronautical/astronautical	16.4	9.7	29.6	52.6
Chemical	26.0	17.7	49.4	47.0
Civil	24.9	19.7	39.3	54.2
Electrical	34.1	28.1	45.9	57.5
Industrial	21.5	17.5	33.1	42.0
Mechanical	23.0	19.6	34.3	52.2
Other engineering	23.4	18.8	25.8	44.6

[a] Includes professional degrees not broken out separately.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-54
Foreign-born individuals with highest degree in S&E living in United States, by place of birth: 2003



UK = United Kingdom

NOTE: Percents may not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, SESTAT database, 2003, http://sestat.nsf.gov. See appendix table 3-10.

Science and Engineering Indicators 2010

one foreign degree. At the highest level of education, 33% of foreign-born doctorate holders earned their doctorates from a foreign school.

The prevalence of foreign degrees among foreign-born S&E degree holders has been increasing over time (figure 3-55). Among foreign-born S&E degree holders who entered the United States before 1980, only 20% of doctorate holders and 23% of bachelor's degree holders had their highest degree from a foreign school. These percentages increase for more recent entry cohorts of immigrants. It should be noted that some portion of the increase in the most recent entry years reflects immigrants who entered during those years but have not yet had sufficient time to complete an American degree.

Table 3-25
Share of college-educated, foreign-born individuals in United States holding foreign degrees, by education level: 2003
(Percent)

Highest degree	Highest degree from foreign school	Any foreign university degree	Foreign secondary school
All college graduates	42.4	56.2	70.0
Bachelor's	50.1	52.1	66.4
Master's	27.4	58.7	74.3
Professional	49.4	58.4	63.3
Doctorate	33.1	76.1	87.3
All S&E degree holders	37.3	55.9	NA
Bachelor's	45.6	48.0	63.8
Master's	27.2	63.0	76.9
Professional	28.7	34.6	42.2
Doctorate	34.9	79.7	NA

NA = not available (Data not collected from U.S.-trained S&E doctorates.)

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates (2003), Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Citizenship and Visa Status of Foreign-Born Scientists and Engineers in the United States

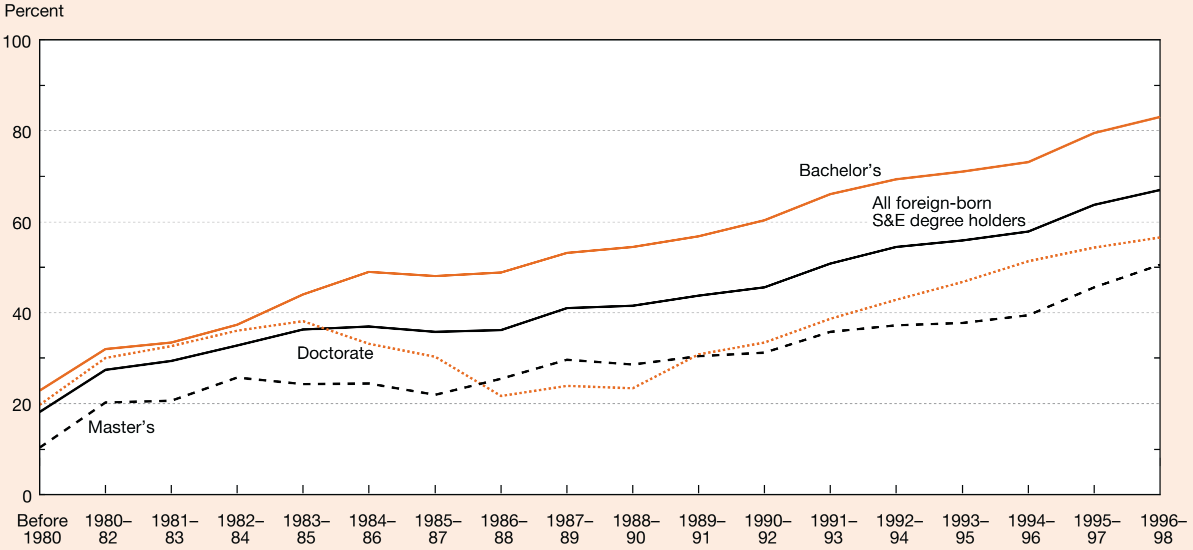
The length of time it takes for foreign scientists and engineers to earn U.S. citizenship affects both their decision to come to the United States and their subsequent decision to stay. As figure 3-56 shows, only about half of foreign S&E degree holders who entered the United States in 1991 and remained in 2003 had obtained citizenship. Citizenship status may particularly affect the supply of S&T talent available to segments of the U.S. economy that can typically hire only citizens: the federal government and private companies engaged in defense and other classified research.[20] While a significant portion of any group of immigrants never seeks citizenship, the type of visas that scientists, engineers, and other high-skilled workers use for initial entry into the United States affects their path to citizenship. Time spent in the United States on a student or temporary work visa does not count toward the 5-year waiting period before immigrants can apply for citizenship.

Temporary Work Visas

In recent years, policy discussion has focused on the use of various forms of temporary work visas by foreign-born scientists and other high-skilled workers. The use of these temporary visas for high-skilled workers has increased over time (as seen in figure 3-57). For all types of temporary work visas, the actual number of individuals using them is

Figure 3-55

Foreign-born S&E degree holders whose highest degree is from a foreign institution, by year of entry to United States: 2003



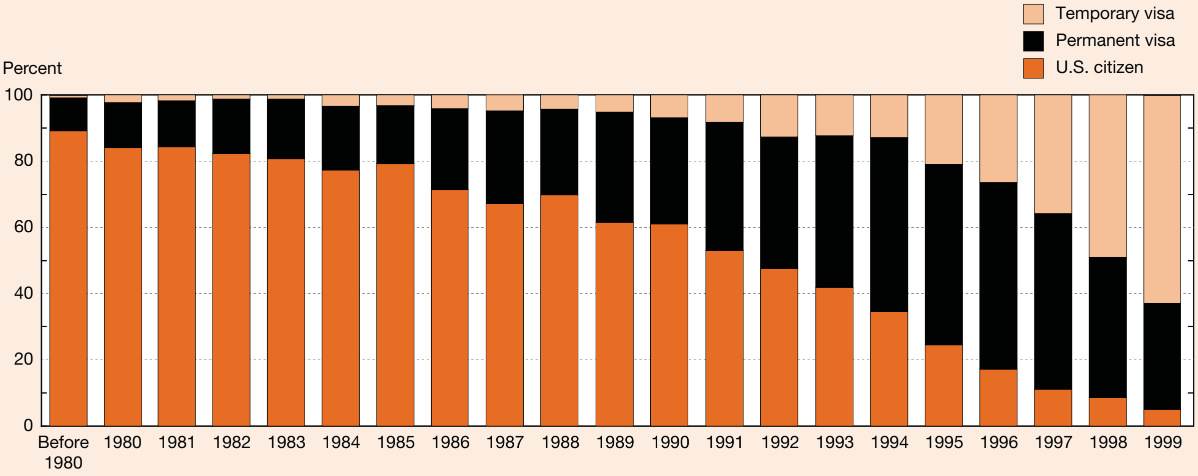
NOTE: Data are 3-year moving average.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

Science and Engineering Indicators 2010

Figure 3-56

Foreign-born S&E degree holders, by citizenship/visa status and year of entry to United States: 1980–99



NOTE: Some data on foreign-born S&E degree holders are available through 2003; however, data after 1999 exclude many individuals with foreign degrees.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003), http://sestat.nsf.gov.

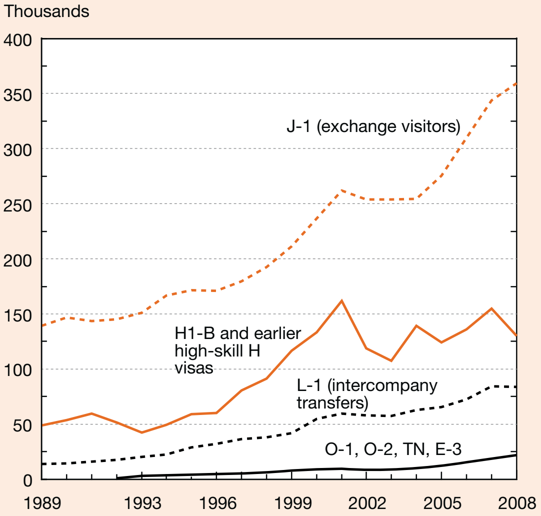
Science and Engineering Indicators 2010

less than the number issued. For example, some individuals may have job offers from employers in more than one country and may choose not to foreclose any options until a visa is certain.

J-1 Exchange Visas. Of the visa types shown, the J-1 exchange visitor visa is the most issued—more than 350,000 in FY 2008. However, many of these visas are given to lower skilled workers, and many J-1s are issued for semester or summer stays. U.S. Immigration and Customs Enforcement (ICE) showed approximately 165,000 J-1 visa holders in the United States, of whom 50% were in categories that were clearly highly skilled, including nearly 50,000 professors and research scholars.

Other Visa Types. There has also been growth in visas issued in other high-skilled categories. Between 2003 and 2008, issuances of L-1 (intracompany transfer) visas grew by 47% to 84,000. The smallest series shown in Figure 3-57 groups together four much smaller high-skilled visa programs: O-1 (a person of outstanding ability), O-2 (an assistant to an O-1, sometimes a postdoc), TN (college-degreed citizens of Canada and Mexico), and E-3 (college-degreed citizen of Australia). Taken together, these four visa types grew by 142% between 2003 and 2008, reaching nearly 22,000 in the number of visas issued.

Figure 3-57
Temporary work visas issued in categories that include many high-skilled workers: FY 1989–2008



NOTE: J-1 exchange visitor visa used for many different skill levels.

SOURCE: U.S. Department of State, Report of the Visa Office, various years. http://travel.state.gov/visa/frvi/statistics/statistics_1476.html.

Science and Engineering Indicators 2010

H-1B Visas

H-1B temporary work visas are likely to account for a larger number of high-skilled workers than other visa classes. The United States typically issues H-1B visas for 3 years with the possibility of a 3-year renewal. In October 2003, the United States lowered its annual ceiling on admissions from 195,000 to 65,000, but granted universities and academic research institutions exemptions in their own hiring. In 2005, the United States granted an additional 20,000 exemptions for students receiving master's degrees or doctorates from U.S. schools.

Although the occupational categories used in H-1B visa records do not precisely correspond to the classifications used elsewhere in this chapter, it is safe to say that the bulk of H-1B visa recipients work in S&E or S&E-related occupations (figure 3-58; table 3-1).

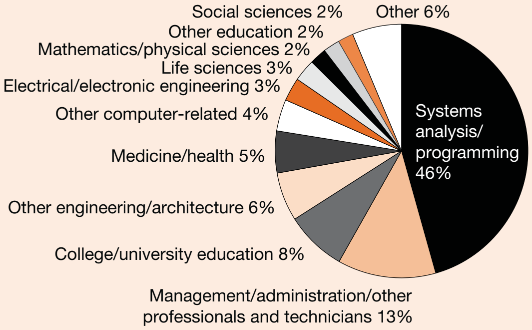
In 2006, half of new H-1B visa recipients were employed in computer-related occupations. This represents a recent increase from a low of 25% in 2002. Of those receiving new H-1B visas in 2006 who were in computer-related occupations, 44% had master's degrees and just over 1% had doctorates.

Characteristics of Workers Issued New H-1B Visas

Education Levels. In FY 2006, 57% of new H-1B visa recipients had advanced degrees, including 41% with master's degrees, 5% with professional degrees, and 11% with doctorates. This degree distribution differs by occupation, with 87% of those holding advanced degrees in math and physical sciences occupations (47% with doctorates) and 89% in life science occupations (61% with doctorates).

Many H-1B visa recipients earned their degrees abroad. In FY 2006, 41% of doctorate holders, 79% of professional degree holders, and 48% of master's degree holders who received H-1B visas indicated on their applications that they did

Figure 3-58
Occupations of new recipients of U.S. H-1B temporary work visas: FY 2006



SOURCE: Department of Homeland Security, U.S. Citizenship and Immigration Services; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

not have a graduate degree from a U.S. institution.[21] This indicates both the use of the H-1B visa as a way for graduates of U.S. schools to continue their careers in the United States and the importance of the H-1B visa in bringing foreign-educated individuals into the United States (DHS/ICE 2006).

H-1B Country of Citizenship. More than half of recent H-1B visa recipients were from India and an additional 9% from China. Among doctorate holders, one-third were from China and another 13% from India (figures 3-59 and 3-60). Altogether, Asian citizens made up three-quarters of all H-1B visa recipients; among doctorate holders, they were well above half.

Relatively few doctorate holders from countries with better university systems had U.S. degrees. For example, the United Kingdom (21%), Germany (28%), Canada (29%), France (30%), and Japan (31%). In contrast, 71% of doctorate holders from China and 59% of doctorate holders from India claimed advanced degrees from U.S. institutions on their visa applications.

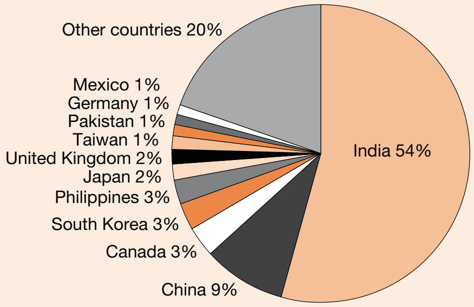
H-1B Salaries. Table 3-26 shows salaries paid to new recipients of H-1B temporary work visas by occupation group and level of degree. These starting salary figures, taken from final visa application forms sent to U.S. Citizenship and Immigration Services, are different from, and generally higher than, H-1B salaries that firms report on their applications to the Department of Labor, which are filed much earlier in the H-1B process. The relatively low average salaries for doctorate holders in the life sciences may reflect the common use of H-1B visas to hire individuals for relatively low-paid postdoc fellowships.

Visa Applications and Rejections for Students and Exchange Visitors

The F-1 and J-1 visas used by students and exchange visitors have recovered from the declines experienced after September 11, 2001 (see table 3-27). F-1 visa applications declined from 380,385 in FY 2001 to a low of 282,662 in FY 2004. After 2004, the number of applications increased each year; the number of F-1 applications was 21% higher in FY 2008 than in FY 2001. J-1 visa applications experienced smaller declines after September 11, 2001, and were 35% higher in FY 2008 than in FY 2001.

Figure 3-59

Country of citizenship for new recipients of U.S. H-1B temporary work visas: FY 2006



SOURCE: Department of Homeland Security, U.S. Citizenship and Immigration Services; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Stay Rates for U.S. Doctorate Recipients with Temporary Visas

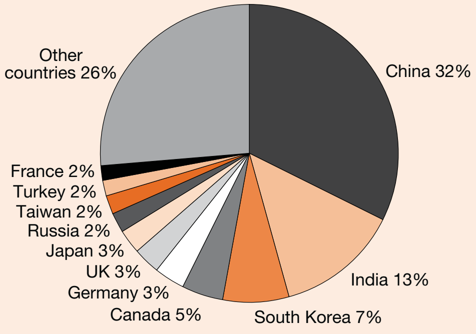
Many foreign students opt to stay in the United States after earning their degree. As reported in the Survey of Earned Doctorates, between 2004 and 2007, 76% to 82% of non-U.S. citizen S&E doctorates had firm commitments for work or study in the United States at the time of graduation. The rates were slightly lower for temporary visa holders over the same time period (75% to 81%) (see chapter 2 for further discussion).

Longer-term stay rates are also high. According to a report by Michael Finn (2009) of the Oak Ridge Institute for Science and Education, 62% of 2002 U.S. S&E doctorate recipients with temporary visas were in the United States in 2007. This is down slightly from a 65% 5-year stay rate found in 2005 (figure 3-61), but due to a long upward trend in stay rates, this was still higher than any other 5-year stay rate estimated between 1992 and 2003. As shown in figure 3-61, stay rates differ significantly by country of origin, but have generally been increasing for most major source countries.

New doctorate recipients in 2002 faced relatively poor labor market conditions (see discussions earlier in this chapter), and foreign students earning degrees may have also been worried about greater difficulties with securing visas for themselves and their families.

Figure 3-60

Country of citizenship of doctorate holders who are new recipients of U.S. H-1B temporary work visas: FY 2006



UK = United Kingdom

SOURCE: Department of Homeland Security, U.S. Citizenship and Immigration Services; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Table 3-26

Average annual salary of new recipients of H-1B temporary work visas, by occupation and degree: FY 2006

(Dollars)

Occupation	All degree levels	Bachelor's	Master's	Professional	Doctorate
Administrative specializations	53,500	49,600	56,200	70,100	85,100
Architecture/engineering/surveying	61,600	58,400	60,000	73,700	73,000
Art	44,800	44,500	44,400	na	na
Computer-related occupations	56,200	56,000	55,600	71,200	80,400
Education	48,500	36,700	43,800	67,000	51,900
Entertainment/recreation	38,900	38,000	40,700	na	na
Law/jurisprudence	100,100	63,200	83,200	114,600	na
Life sciences	45,600	40,400	43,900	47,700	46,700
Managers/officials nec	78,000	70,800	81,500	107,500	105,300
Mathematics/physical sciences	60,400	58,500	59,800	60,900	61,400
Medicine/health	72,300	48,100	51,700	86,800	62,700
Miscellaneous professional/technical/managerial	64,400	54,800	68,800	na	84,500
Museum/library/archival sciences	41,800	39,500	41,300	na	na
Religion/theology	37,400	NA	38,500	na	na
Social sciences	60,900	54,100	64,000	na	77,600
Writing	38,200	37,900	37,500	na	na

na = not applicable; NA = not available; nec = not elsewhere classified

SOURCE: Department of Homeland Security, U.S. Citizenship and Immigration Services, special tabulations.

Science and Engineering Indicators 2010

There was also a geographic pattern to the changes in 5-year stay rates for foreign S&E doctorate recipients. Stay rates actually showed large percentage point increases for students from the largest European source countries: the UK (+6 percentage points) and Germany (+3 percentage points). The overall decline in stay rate between 2005 and 2007 was driven largely by decreases in stay rates for several Asian source countries: Taiwan (–8 percentage points), Japan (–6 percentage points), and India (–4 percentage points).

Finn also estimates stay rates for doctorate recipients from graduate programs of different quality based on ratings

Table 3-27

Initial applications for student/exchange visitor visas: FY 2001–08

	Student (F-1)		Exchange visitor (J-1)	
Year	Applications	Refused (%)	Applications	Refused (%)
2001	380,385	22.9	275,959	5.1
2002	322,644	27.4	270,702	6.2
2003	288,731	25.3	275,335	7.8
2004	282,662	22.6	274,789	7.4
2005	333,161	19.8	311,728	5.8
2006	385,596	20.1	349,598	5.9
2007	386,144	24.0	346,946	6.2
2008	458,406	25.7	371,527	6.6

NOTE: Application counts and refusal rates adjusted for reapplications and appeals by same individual.

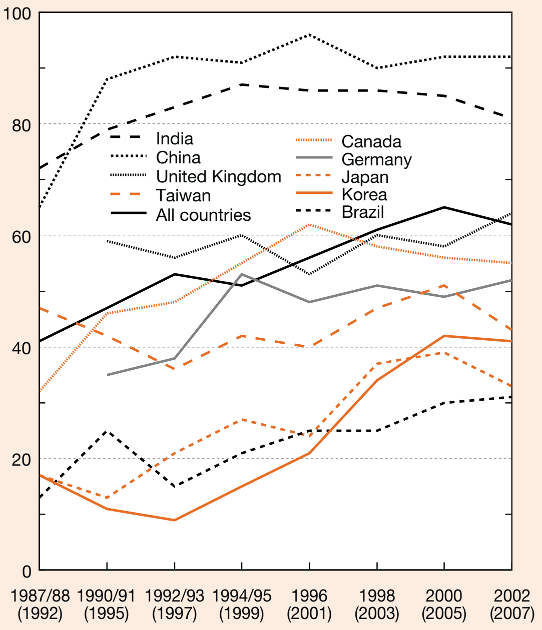
SOURCE: Department of State, Immigrant Visa Control and Reporting Division, administrative data (2001–08).

Science and Engineering Indicators 2010

Figure 3-61

Five-year stay rates for recipients of U.S. S&E doctorates who have temporary U.S. visas, by place of origin and year of doctorate: 1992–2007

Percent



NOTE: Year of observation in parentheses.

SOURCE: Finn M, Stay rates of foreign doctorate recipients from U.S. universities: 2009, Oak Ridge Institute for Science and Education (forthcoming).

Science and Engineering Indicators 2010

Table 3-28
Temporary residents who received S&E doctorates in 2002 who were in the United States, by program rating: 2003–07
(Percent)

Program rating	Foreign doctorate recipients (n)	2003	2004	2005	2006	2007
All programs	7,850	69	66	64	62	62
Top-rated programs	2,611	67	63	61	59	58
All other programs	5,239	70	68	65	64	63

NOTE: Characterization of programs as "top-rated" by Finn (forthcoming) using ratings of faculty reputation in research from *U.S. News and World Report* and National Research Council.

SOURCE: Finn M, Stay rates of foreign doctorate recipients from U.S. universities. Oak Ridge, TN: Oak Ridge Institute for Science and Education (forthcoming).

Science and Engineering Indicators 2010

of faculty by the publication *U.S. News and World Report* and on separate ratings by the National Research Council. Finn used these ratings to select 20 to 25 "top-rated" departments in major S&E fields. Doctorate recipients from the graduate programs that Finn designated as top rated were somewhat less likely to remain in the United States than were graduates of other programs (see table 3-28). For doctorate recipients, the difference in 1-year stay rates was 3 percentage points: 67% of those from the top-rated programs and 70% of other doctorate recipients remained in the United States 1 year after receiving their degrees. By 5 years after receiving their degree, the two groups showed differences that rose to 5 percentage points, with stay rates of 58% and 63%, respectively.

Conclusion

Growth of the U.S. S&E workforce continues to exceed that of the overall workforce. However, the 2000–07 period showed the smallest growth rate (2.2%) in S&E occupations since NSF began tracking these data in the 1950s. Although the U.S. recession that began in 2007 affected workers across all occupations, S&E occupations appear to be less severely affected. The unemployment rate in April 2009 was 9.0% for all workers, but 4.3% for those working in S&E occupations. The influence of the recession on longer-term S&E labor force behavior (e.g. retirement rates, part- and full-time employment) remains to be seen.

A large and growing number of Americans hold degrees in S&E fields; in 2006, 16.6 million individuals in the U.S. workforce held at least one S&E degree. Individuals in S&E occupations are highly educated, with more than 70% holding at least a bachelor's degree in any field; in contrast, less than 30% of persons working in all other occupations hold a bachelor's or higher degree. Workers in S&E occupations also received higher wages than those in other occupations.

The globalization of the S&E labor force continues to increase. The number of people with S&E is skills rising, especially in developing nations, and the location of S&E employment is becoming more internationally diverse. S&E workers are becoming more internationally mobile. These trends reinforce each other: as R&D spending and business investment cross national borders in search of available talent, talented people cross borders in search of interesting and lucrative work, and employers recruit and move employees internationally.

The growth rate of the S&E labor force would be significantly reduced if the United States became less successful in the increasing international competition for scientists and engineers. Compared with the United States, many other countries are more actively reducing barriers to highly skilled immigrants entering their labor markets. Nonetheless, the United States is still an attractive destination for many foreign scientists and engineers.

Notes

1. The standard definition of the term *labor force* includes the population that is employed or not working but seeking work (unemployed); other individuals are not considered in the labor force. When data refer only to employed persons, the term *workforce* is used. For data on unemployment rates by occupation, calculations assume that unemployed individuals are seeking further employment in their most recent occupation.

2. Despite the limitations of this subjective measure, variations among occupations in the proportions of workers who say they need this level of S&E technical expertise accord with common sense. For example, among doctoral level postsecondary teachers of physics, 99.7% said they needed at least a bachelor's level of knowledge in engineering, computer sciences, mathematics or the natural sciences, compared with 5% among doctoral level postsecondary teachers of English. Likewise, among the small numbers of S&E bachelor's degree holders whose occupation is "secretary/receptionist/typist," fewer than one in six reported that their job needed bachelor's level S&E expertise of any kind.

3. Estimates of the size of the S&E workforce vary across the example surveys because of differences in the scope of the data collection (SESTAT surveys collect data

from individuals with bachelor's degrees and above only); because of the survey respondent (SESTAT surveys collect data from individuals, OES collects data from establishments, and ACS collects data from households); or because of the level of detail collected on an occupation, which aids in coding. All of these differences can affect the estimates.

4. Although BLS labor force projections do a reasonable job of forecasting employment in many occupations (see Alpert and Auyer 2003), the mean absolute percentage error in the 1988 forecast of employment in detailed occupations in 2000 was 23.2%.

5. Many comparisons using Census Bureau data on occupations are limited to looking at all S&E occupations except postsecondary teachers because the current U.S. occupation taxonomy does not break out these teachers by field. Only NSF surveys of scientists and engineers collect data on postsecondary teachers by field.

6. Only U.S. citizens and nationals may be appointed in the competitive civil service; however, federal agencies may employ certain noncitizens who meet specific employability requirements in the excepted service or the Senior Executive Service.

7. Specifically presented here are coefficients from linear regressions using the 2003 SESTAT database of individual characteristics on the natural log of reported full-time annual salary as of October 2003.

8. Underrepresented ethnic group, as used here, includes individuals who reported their race as black, American Indian/Alaska Native, of Hispanic origin, or other ethnicity.

9. In the regression equation, this is the form: age^1, age^2, age^3, age^4; years since highest degree $(YSD)^1$, YSD^2, YSD^3, YSD^4.

10. The regressions included 20 dummy variables for SESTAT field-of-degree categories (out of 21 S&E fields; the excluded category was "other social science").

11. Variables added here include 34 SESTAT occupational groups (excluding "other non-S&E"), whether individuals worked in R&D, the employer's U.S. census region, and the sector of the economy.

12. Variables added here include dummy variables for marriage, number of children in the household younger than 18, whether the father had a bachelor's degree, whether either parent had a graduate degree, citizenship, nativity, and age at receipt of first bachelor's degree minus 20. Sex and ethnic minority variables are included in all regression equations.

13. This may be because differences between groups in many of these family and personal characteristics are not large. It is also possible that variations in these characteristics correlate with those in other controls already in the statistical model and in that sense have already been taken into account.

14. Many doctorate holders with salaries at this level are postdocs in temporary training positions.

15. Although the formal job title is often postdoctoral fellowship or research associate, titles vary among organizations. This chapter generally uses the shorter, more commonly used, and best understood name, postdoc. A postdoc is traditionally defined as a temporary position that graduate students take primarily for additional training—a period of advanced professional apprenticeship—after completion of a doctorate.

16. Some part of the citizen and permanent resident postdoc population in the fall of 2005 will not be counted even in the SDR. Excluded are summer 2005 graduates who may be in postdoc positions in the fall of 2005, doctorate holders who may have left the country before April 2006, and those who have foreign doctorates.

17. Respondents also had to be under age 76 and resident in the United States in April 2006. In a similar retrospective question on the 1995 SDR, 25% of those earning their doctorates before 1964 reported having had postdoc positions.

18. See section 'Business-to-business linkages' in chapter 4 for information on international transactions in R&D services and technology alliances.

19. An affiliate is a company or business enterprise located in one country but owned or controlled by a parent company in another country. Majority-owned affiliates are those in which the ownership stake of parent companies is more than 50%.

20. Outside of government, it is illegal to discriminate in employment on the basis of citizenship status. However, if the work requires a security clearance, this usually also requires citizenship.

21. These figures are likely to somewhat underestimate the proportion of H-1B recipients without U.S. graduate degrees. Because a portion of H-1B visas were restricted to applicants with advanced degrees from U.S. institutions, these applicants had an incentive to answer the optional question about where their degrees were earned; applicants whose degrees came exclusively from foreign institutions had no reason to answer this question.

Glossary

Career path job: A job that helps graduates fulfill their future career plans.

EU-27: The 27 member states of the European Union since 2007, including Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Federally funded research and development center (FFRDC): An organization that performs research and development and is exclusively or substantially financed by the federal government either to meet a particular research and development objective or, in some instances, to provide major facilities at universities for research and associated training purposes.

High-skilled diaspora: Networks of contact and information flow that form among the internationally mobile portion of a country's nationals.

Involuntarily out of the field (IOF) employment: Employment in a job not related to the field of one's highest degree because a job in that field was not available, or employment part time because full-time work was not available.

Labor force: A subset of the population that includes both those who are employed and those who are not working but seeking work (unemployed); other individuals are not considered to be in the labor force.

Postdoc: A temporary position awarded in academia, industry, government, or a nonprofit organization, primarily for gaining additional education and training in research after completion of a doctorate.

SESTAT: Scientists and Engineers Statistical Data System, a system of three surveys conducted by the National Science Foundation that measure the educational, occupational, and demographic characteristics of the science and engineering workforce. The three surveys are the National Survey of College Graduates (NSCG), the Survey of Doctorate Recipients (SDR), and the National Survey of Recent College Graduates (NSRCG).

Stay rate: The proportion of students on temporary visas who stay in the United States 1–5 years after receiving a doctorate.

Tertiary educated: Roughly equivalent in U.S. terms to individuals who have earned at least technical school or associate's degrees and includes all degrees up to doctorate.

Workforce: A subset of the labor force that includes only employed individuals.

References

Alpert A, Auyer J. 2003. Evaluating the BLS 1988–2000 Employment Projections. *Monthly Labor Review* October:13–37.

Barro R, Lee J. 2000. International data on educational attainment: Updates and implications. Cambridge, MA: Center for International Development at Harvard University.

Census Bureau. 2007. American Community Survey, Special tabulations. http://www.census.gov/acs.

Department of Homeland Security, Immigration and Customs Enforcement (DHS/ICE). 2006. Special tabulations.

Docquier F Marfouk A. 2004. International Migration by Education Attainment. Bonn, Germany: Institute for the Study of Labor. www.iza.org.

Finn M. 2009. Stay rates of foreign doctorate recipients from U.S. universities. Oak Ridge, TN: Oak Ridge Institute for Science and Education. Forthcoming.

Lowell L, Regets M. 2006. A half-century snapshot of the STEM workforce, 1950 to 2000. Washington, DC: Commission on Professionals in Science and Technology.

National Science Board (NSB). 2003. Report of the National Science Board Committee on Education and Human Resources Task Force on National Workforce Policies for Science and Engineering. Arlington, VA: National Science Foundation.

National Science Board (NSB). 2008. *Science and Engineering Indicators 2008*. Volume 1, NSB 08-01; volume 2, NSB 08-01A. Arlington, VA: National Science Foundation.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2006. Scientists and Engineers Statistical Data System (SESTAT), Special tabulations. http://sestat.nsf.gov. Accessed 15 October 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2008a. Federal scientists and engineers: 2003-05. NSF 09-302. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2008b. Postdoc participation of science, engineering, and health doctorate recipients. NSF 08-307, Hoffer T, Grigorian K, and Hedberg E. Arlington, VA.

Organisation for Economic Co-operation and Development (OECD). 2009. *Main Science and Technology Indicators*. Paris.

Price DJ de Solla. 1961. *Science Since Babylon.* New Haven: Yale University Press.

Regets MC. 2001. Research and policy issues in high-skilled international migration: A perspective with data from the United States. Bonn, Germany: Institute for the Study of Labor. ftp://ftp.iza.org/dps/dp366.pdf.

Salt, J. 2007. International Migration and the United Kingdom: Report of the United Kingdom SOPEMI Correspondent to the OECD, 2007. London: Migration Research United, Department of Geography, University College London. http://www2.geog.ucl.ac.uk/mru/docs/Sop07_20080131.pdf. Accessed 19 October 2009.

Stephan P, Levin S. 1992. *Striking the Mother Lode in Science: The Importance of Age, Place, and Time.* New York: Oxford University Press.

Chapter 4

Research and Development: National Trends and International Linkages

List of Sidebars

List of Tables

List of Figures

Highlights

Trends in National R&D Performance

U.S. R&D expenditures continued to rise in 2008, outpacing the overall expansion of the nation's economy.

- ♦ NSF estimates that overall spending on R&D conducted in the United States was $398 billion (current dollars) in 2008, up from $373 billion in 2007. This increase represents growth in 2008 of 6.7% over the 2007 level, or 4.5% in inflation-adjusted 2000 dollars. However, this 2008 figure may not fully reflect the effects of the downturn in U.S. and global economic conditions that intensified in late 2008.
- ♦ National R&D spending has increased mostly uninterrupted since 1953. Over the past 20 years, growth in R&D spending has averaged 5.6% in current dollars and 3.1% in constant dollars—somewhat ahead of the average pace of GDP growth over the same period (in both current and constant dollars).

The business sector accounts for most U.S. R&D performance and funding.

- ♦ The business sector performed an estimated $289 billion of R&D in 2008, or 73% of the U.S. total, drawing on both business and federal sources of R&D support. The business sector itself provided an estimated $268 billion of funding for R&D in 2008, or 67% of the U.S. total; almost all of it supported R&D performed by business. Over the past 5 years, expanded business spending has accounted for much of the nation's R&D growth.
- ♦ The academic sector is the second-largest performer of U.S. R&D, an estimated $51 billion in 2008, just under 13% of the U.S. total.
- ♦ The federal government is the second-largest funder of U.S. R&D, providing an estimated $104 billion, or 26% of the U.S. total in 2008.

U.S. R&D is dominated by development expenditures, largely performed by the business sector, and most basic research is conducted at universities and colleges.

- ♦ In 2008, basic research was about 17% ($69 billion) of the U.S. total, applied research was about 22% ($89 billion), and development was about 60% ($240 billion).
- ♦ Universities and colleges historically have been the main performers of U.S. basic research, an estimated 56% of total U.S. basic research in 2008. The federal government has been the prime source of basic research funding, accounting for 57% of the nation's total in 2008.
- ♦ The business sector, which currently accounts for more than half of all U.S. applied research funding, spends more than four times as much on applied research as on basic research.
- ♦ Development in the United States is chiefly a business sector activity, which performed 90% of the total development in 2008 and provided 84% of the funding. Most of the rest of development funding is provided by the federal government.

Location of R&D Performance

R&D is geographically concentrated, and states vary significantly in the types of research performed within their borders.

- ♦ In 2007, the 10 states with the greatest R&D expenditure levels accounted for 64% of all U.S. R&D expenditures. California alone represented 22% of U.S. R&D—triple that of Massachusetts, the next highest state. New Mexico, Massachusetts, and Maryland had the highest R&D-to-GDP ratios in 2006. California ranked seventh in R&D/GDP intensity.
- ♦ Massachusetts, Illinois, California, and Texas accounted for about two-thirds of the R&D performed by computer and electronics products companies in 2007; New Jersey, Connecticut, and Pennsylvania are the leaders in chemicals manufacturing, accounting for 41% of the R&D in that industry.
- ♦ Nationally, small companies (defined as having from 5 to 499 employees) perform 19% of the nation's total business R&D. The R&D performance of these small companies is concentrated geographically. Among the top 10 business R&D-performing states, New York and California had the highest totals of small companies performing business R&D, with 23% and 20%, respectively.

Business R&D

Business sector R&D rose to its highest level in 2007. Although 2008 projections show additional growth, they do not reflect the effects of the U.S. economic downturn.

- ♦ R&D performed by the business sector is estimated to have reached $269 billion in 2007 and is projected to have increased to $289 billion in 2008.
- ♦ The company-funded R&D-to-sales ratio of companies in all industries performing R&D in the United States varied between 3.2% and 3.4% during 2003–06; in 2007 it was 3.5%.
- ♦ Over three-fourths of business R&D is performed in six business sectors. The R&D-to-sales ratio for these sectors as a group was 8.0% in 2007, compared with 1.4% for all other business sectors.

Federal R&D

Federal R&D spending continued to grow in recently proposed and enacted budgets and received further increases through the American Recovery and Reinvestment Act.

- Budget appropriations for federal spending on R&D in FY 2009 totaled $147.1 billion (current dollars), an increase of $3.3 billion (or 2.4%) over the enacted FY 2008 spending level. The proposed overall increase for FY 2010 is smaller (0.4%).
- However, the American Recovery and Reinvestment Act (ARRA) of 2009 included a one-time additional increase in R&D funding that is estimated to total $18.3 billion in FY 2009.
- In the FY 2009 budget, increases in R&D funding were greatest for the National Institutes of Health (NIH), the Department of Energy (DOE), and the National Science Foundation (NSF). Along with the National Aeronautics and Space Administration and the National Institute of Standards and Technology, these agencies also received the largest increases from ARRA.
- Defense continues to be the largest function in the federal R&D budget. It accounted for 59% of the federal total (budget authority) in FY 2008.
- The most dramatic change in national R&D priorities over the past 25 years has been the large rise in health-related R&D, which grew from 25% of the federal nondefense R&D budget in FY 1980 to 55% in FY 2005. In FY 2008, health accounted for 52% of the nondefense R&D budget.

Federal R&D Tax Credit

- Along with direct funding of R&D, the government also promotes the conduct of R&D through tax incentives. About 11,000 U.S. companies claimed an estimated $7.3 billion in federal research and experimentation tax credits in 2006, compared with $6.4 billion in 2005.

International R&D Comparisons

Many countries conduct R&D, but much of global R&D performance continues to be concentrated in a few high-income countries and regions.

- Worldwide R&D expenditures totaled an estimated $1.107 trillion in 2007 (the latest year for which data are available). The United States accounted for about 33% of this total. Japan, the second-largest performer, accounted for about 13%. China was third, at about 9%. Germany and France, respectively, fourth and fifth (and the largest performers in Europe), accounted for 6% and 4%, respectively. The top 10 countries (also including South Korea, the United Kingdom (UK), the Russian Federation, Canada, and Italy) account for almost 80% of current global R&D performance.
- The 27 nations of the European Union (EU-27) accounted for about 24% of global R&D. R&D by the EU-27 grew at an average annual constant dollar rate of 3.3% between 1997 and 2007. By comparison, the U.S. pace of growth, on the same basis, averaged 3.3%.
- Recent growth in R&D expenditures has been most dramatic in China, averaging just above 19% annually in inflation-adjusted dollars over the past decade.

Wealthy economies generally devote larger shares of their gross domestic product (GDP) to R&D than do less developed economies.

- The U.S. R&D/GDP ratio was 2.7% in 2007 and has fluctuated between 2.6% and 2.8% over the past 10 years, largely reflecting changes in business R&D spending. In 2007, the United States ranked eighth among the economies tracked by the OECD; Japan, South Korea, and several smaller developed economies had higher ratios.
- Among the major European R&D-performing countries, Italy (2006) and the Russian Federation (2007) had R&D/GDP ratios of 1.1%. The UK ratio was 1.8% in 2007, and those of France and Germany were 2.1% and 2.5%, respectively, in 2007. Canada's R&D/GDP ratio was 1.9% in 2007. Over the past 10 years, these ratios were stable or changed only modestly.
- R&D/GDP ratios increased substantially in Japan, South Korea, and China over the past 10 years. The Japanese and South Korean ratios were among the highest in the world in 2007, at 3.4% and 3.5% respectively. China's ratio remains relatively low, at 1.5%, but has more than doubled from 0.6% in 1996.

Among the countries with the largest R&D expenditures, the business sector accounts for the bulk of total R&D performance.

- Among the top 10 countries for R&D expenditures, the business sector is the largest R&D performer, ranging from 77% for South Korea and Japan to 49% for Italy.
- No single industry accounted for more than 18% of total business R&D in the United States in 2007; many other countries displayed much higher industry and sector concentrations.
- The pharmaceuticals industry accounts for more than 25% of business R&D in Denmark and the United Kingdom, and more than 20% in Belgium and Ireland. The computers, office and accounting machines industry represents only a small share of business R&D in most countries; only Japan reports a double-digit concentration of business R&D in this industry. The service sector accounted for 30% or more of all business R&D in many countries of the Organisation for Economic Co-operation and Development (OECD), including the United States.

R&D by Multinational Companies

Multinational companies (MNCs) represent a substantial component of U.S. R&D. Overseas R&D by U.S. MNCs reflects gradual changes in their geographic focus.

- Majority-owned affiliates of foreign-based MNCs spent $34.3 billion on U.S. R&D in 2006, up from $31.1 billion in 2005. Their U.S. R&D expenditures have grown faster than total U.S. business R&D and have represented about 14% of U.S. business R&D since 2003, up from the single digits in the early 1990s.
- U.S. MNCs performed $216.3 billion in R&D worldwide in 2006, including $187.8 billion in the United States by parent companies and $28.5 billion by their overseas affiliates. The R&D by MNC parents represented 87% of their global R&D and about 76% of total U.S. business R&D. Both shares have changed little in recent years. However, the geographic distribution of R&D by their overseas affiliates is gradually reflecting the role of emerging markets.
- Europe, Canada, and Japan accounted for a decreasing share of R&D by overseas affiliates of U.S. MNCs, representing 90% in 1994 and 80% in 2006. Over the same period, the share performed in Asia (excluding Japan) rose from 5.4 % to 13.5%, driven by affiliates' R&D spending in China, Singapore, and South Korea.
- R&D performed by U.S.-owned affiliates located in China and India increased from less than $10 million in each country in 1994 to $804 million and $310 million, respectively, in 2006. Although the 2006 levels for China and India represented only about 3% and 1%, respectively, of total overseas R&D by U.S. MNCs, funding levels in some lower cost locations may still be significant from the perspective of purchasing power.

Technology and Innovation Linkages

Federal agencies and laboratories continue to engage in collaborative and technology transfer activities. Business increased its R&D funding to contractors within the United States.

- Federal agencies participated in more than 7,000 formal Cooperative Research and Development Agreements in 2007 and more than 9,000 less formally structured collaborative R&D relationships. Federal agencies issued more than 1,400 patents in 2007 and held more than 10,000 active licenses based on their total stock of intellectual property.
- Businesses in the United States reported contracting out an estimated $19.0 billion in R&D to other U.S.-located companies in 2007, compared with $12.4 billion in 2006. This increased the ratio of contracted-out R&D to company-funded and company-performed R&D from 5.5% in 2006 to 7.8% in 2007. For manufacturers, the ratio reached 8.5% in 2007, up from 5.7% in 2006.

International trade in R&D services and technology alliances indicate the role of external sources and cooperative arrangements aimed at acquiring or jointly developing new knowledge.

- In 2007, the United States maintained a trade surplus in research, development, and testing services of $3.3 billion. Trade within MNCs dominates these statistics—which is not surprising, given their large role in U.S. R&D performance.
- Almost 900 worldwide business technology alliances were established in 2006, approximately two-thirds of which involved at least one U.S.-owned company regardless of location. Since 1999, the proportion of U.S.-foreign alliances has surpassed U.S.-only alliances, a change driven by rapid growth in alliances with European companies. However, in 2006 the number of U.S. alliances with Asian non-Japanese partners (50) reached parity with U.S.-Japan alliances (54), reflecting growth of the former since 1990.

Introduction

As we come to the end of the first decade of the 21st century, global economic trends are leading governments of most nations to implement financial market support measures and economic recovery packages. These policies often include measures to stimulate productivity, growth, and innovation through support of R&D—widely viewed as a long-term contributor to economic growth and national competitiveness.

The importance accorded to investment in R&D and innovation in public policy discussions is reflected in the national and international initiatives that help us better understand and measure their results. The America COMPETES Act (Public Law 110-69) and the American Recovery and Reinvestment Act of 2009 (Public Law 111-5) both address the importance of the U.S. innovation system for national economic growth.

Federal statistical agencies seek to incorporate R&D in the system of national accounts to measure, for example, its relation to gross domestic product (GDP) and productivity growth. These agencies are also exploring the role of cross-border investment in R&D and other intangibles. The National Science Foundation (NSF) is conducting a new Business R&D and Innovation Survey to collect a broad range of indicators that will form a platform for future modules on innovation. (See sidebar "New U.S. Business R&D and Innovation Survey.")

An ongoing project conducted by the Organisation for Economic Co-operation and Development (OECD) to design an Innovation Strategy examines how changes in the innovation enterprise of OECD member nations may affect their ability to achieve certain government and socioeconomic goals. Concurrently, the OECD, United Nations Statistical Commission, and other international bodies are collaborating to update or develop statistical manuals on intangibles,

New U.S. Business R&D and Innovation Survey

To better understand how R&D is conducted in today's innovation- and global-based economy and to investigate ways to improve NSF's portfolio of R&D measurements, NSF commissioned a study by the National Research Council's Committee on National Statistics (CNSTAT) in 2004. The committee published its findings in the 2005 report *Measuring Research and Development Expenditures in the U.S. Economy* (NRC 2005a). The essence of CNSTAT's concerns and recommendations centered on the finding that a new, more comprehensive survey was needed to "keep up with the fast-changing environment for the conduct and organization of research in the private business sector" (NRC 2005a, p 4).

In early 2009, NSF and the U.S. Census Bureau launched a new Business R&D and Innovation Survey (BRDIS). The survey covers manufacturing and service companies and includes questions on a broad range of R&D topics (listed below). The survey also begins to collect innovation data, with the ultimate objective of increasing the number and breadth of innovation-related items in the future.

- Financial measures of R&D activity:
    - Domestic and worldwide sales and revenue
    - Detail on domestic and worldwide R&D activity
    - Company R&D expense by business segment, type of expense, and location (state and country)
    - Capital expenditures for R&D (buildings, software, equipment)
    - Projected R&D expense
- Measures of company R&D activity funded by others:
    - Funds for worldwide and domestic R&D activity
    - R&D funded by others—by business segment, type of organization, type of expense, state, and location (domestic vs. foreign)
- Measures of R&D employment:
    - R&D headcount (domestic and worldwide) by occupation and sex
    - Number of U.S. R&D employees working under a visa (H-1B, L-1, and so on)
    - R&D full-time equivalent counts
- Measures related to R&D management and strategy:
    - R&D partnerships
    - Share of R&D for the social sciences, new business areas, and specific applications
- Measures of intellectual property (IP), technology transfer, and innovation:
    - Participation in activities to introduce new or significantly improve existing goods, services, methods of production and distribution, or support systems
    - Patent-related data-number owned or applied for
    - Participation in specific technology transfer activities
    - Importance of types of IP protection
    - Licensing to outside parties

For more information on the new survey, see NSF/SRS (2008b).

national economic accounts, and trade in services. The purpose of these efforts is to better harmonize data that will serve as future indicators for measuring innovation.

Chapter Organization

This chapter is organized into seven main sections. An overview of national trends in the performance and funding of R&D is followed by a discussion of state-level R&D patterns and trends. A third section covers business, the largest performer and funder of U.S. R&D. This section is followed by a discussion of the patterns of federal government R&D, including how those patterns play out in the defense, energy, and health arenas, and concludes with federal tax incentives for business R&D.

The last three sections of the chapter cover international comparisons of R&D, investments by multinational companies (MNCs), and technology and innovation linkages, respectively. International comparisons of R&D include national R&D expenditures by performer and source, national R&D intensities, and government R&D priorities. The section devoted to MNCs covers overseas investments of U.S. MNCs and U.S. R&D by foreign-owned companies. Although global R&D is concentrated in a few developed countries or regions, China and other emerging Asian countries have increased their R&D expenditures and have become hosts to R&D conducted by U.S. MNCs. The last section covers business-to-business external sourcing, technology alliances, and international transactions in R&D services. The latter represents the convergence of service-oriented R&D and global innovation networking. This section concludes with a discussion of innovation-related federal programs and activities aimed at technology transfer, R&D, and new technology development and deployment by small firms.

Trends in National R&D Performance

R&D, along with other social, economic, and technological factors, creates new knowledge and contributes to innovation and the introduction of new goods, services, processes, and managerial practices. Suppliers and users of R&D include businesses, educational institutions, not-for-profit research organizations, and governments. Statistics on R&D expenditures reported by performing and funding organizations are used as metrics throughout the United States and internationally.[1] (See sidebar "Definitions of R&D.")

NSF estimates indicate that overall spending on R&D conducted in the United States was $397.6 billion (current dollars) in 2008, up from $372.5 billion in 2007 (table 4-1). This represents growth of 6.7%, or 4.5% in inflation-adjusted

Definitions of R&D

R&D. According to international guidelines for conducting R&D surveys, R&D, also called research and experimental development, comprises creative work "undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and the use of this stock of knowledge to devise new applications" (OECD 2002).

Basic research. The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed to fields of current or potential interest. This focus is often the case when performed by industry or mission-driven federal agencies.

Applied research. The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Development. Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

R&D plant. This term refers to the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Budget authority. Budget authority is the authority provided by federal law to incur financial obligations that will result in outlays. The basic forms of budget authority are appropriations, contract authority, and borrowing authority.

Obligations. Federal obligations represent the dollar amounts for orders placed, contracts and grants awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

Outlays. Federal outlays represent the dollar amounts for checks issued and cash payments made during a given period, regardless of when funds were appropriated or obligated.

For an annotated compilation of definitions of R&D by U.S. statistical agencies, tax statutes, accounting bodies, and other official sources, see NSF/SRS (2006).

(also called constant or real) 2000 dollars.[2] The 2008 figures are preliminary, however, and may not yet fully reflect the effects of the sharp downturn in the U.S. economy and globally beginning in late 2008.

Total estimated R&D expenditures in 2008 were $13.9 billion higher in real dollars than in 2007 (table 4-1). Most of this increase reflected estimated increases in business R&D expenditures and funding.

Over the longer term, increases in national R&D spending have been largely uninterrupted since 1953 in both current and real dollars (figure 4-1). The rates of the past several years have been above the average annual growth rate over the past 20 years (5.6% in current dollars, 3.1% in constant dollars). U.S. R&D spending crossed the $100 billion (current dollars) threshold in 1984, passed $200 billion in 1997, was nearly $300 billion in 2004, and almost reached

Table 4-1
U.S. R&D expenditures, by performing sector and funding source: 2003–08

Sector	2003	2004	2005	2006	2007	2008
	Current $millions					
All performing sectors	288,324	299,201	322,104	347,046	372,527	397,616
Business	200,724	208,301	226,159	247,669	269,267	289,105
Federal government	35,005	35,632	37,716	38,926	39,897	41,741
Federal intramural[a]	22,752	22,844	24,470	25,556	25,858	27,000
FFRDCs	12,253	12,788	13,246	13,369	14,039	14,741
Industry-administered[b]	2,458	2,485	2,601	3,122	4,839	5,031
U&C-administered[b]	7,301	7,659	7,817	7,306	5,892	6,023
Nonprofit-administered	2,494	2,644	2,828	2,941	3,308	3,688
Universities and colleges	40,484	43,128	45,197	46,983	49,021	51,163
Other nonprofit	12,111	12,140	13,032	13,469	14,341	15,606
All funding sources	288,324	299,201	322,104	347,046	372,527	397,616
Business	186,174	191,376	207,826	227,254	246,927	267,847
Federal government	83,618	88,766	93,817	98,036	101,764	103,696
Universities and colleges	7,650	7,937	8,579	9,307	9,993	10,600
Nonfederal government	2,742	2,883	2,922	3,021	3,249	3,453
Other nonprofit	8,140	8,239	8,960	9,429	10,593	12,020
	Constant 2000 $millions					
All performing sectors	270,971	273,335	284,962	297,444	310,913	324,791
Business	188,643	190,294	200,081	212,271	224,732	236,155
Federal government	32,898	32,551	33,367	33,362	33,299	34,096
Federal intramural[a]	21,383	20,869	21,648	21,904	21,582	22,055
FFRDCs	11,516	11,682	11,719	11,459	11,717	12,042
Industry-administered[b]	2,310	2,270	2,301	2,676	4,039	4,109
U&C-administered[b]	6,861	6,997	6,916	6,262	4,918	4,920
Nonprofit-administered	2,344	2,415	2,502	2,521	2,761	3,012
Universities and colleges	38,047	39,400	39,986	40,268	40,913	41,792
Other nonprofit	11,382	11,090	11,529	11,544	11,969	12,748
All funding sources	270,971	273,335	284,962	297,444	310,913	324,791
Business	174,969	174,831	183,862	194,773	206,087	218,790
Federal government	78,585	81,092	82,999	84,024	84,933	84,704
Universities and colleges	7,190	7,251	7,589	7,977	8,341	8,658
Nonfederal government	2,577	2,634	2,585	2,589	2,711	2,821
Other nonprofit	7,650	7,527	7,926	8,081	8,841	9,818

FFRDC = federally funded research and development center; U&C = universities and colleges

[a] Includes expenditures of federal intramural R&D and costs associated with administering extramural R&D.

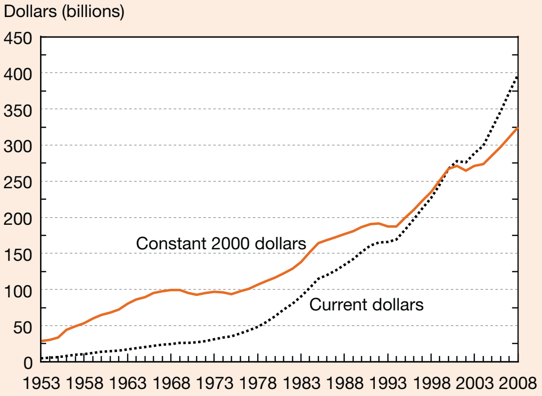
[b] In June 2006, Los Alamos National Laboratory (approximately $2 billion in annual R&D expenditures in recent years) became industry administered; previously, U&C administered. This shift is one reason for change in trends apparent in R&D expenditure figures between 2006 and 2007.

NOTES: Data for 2008 are preliminary. Data based on annual reports by performers except for nonprofit sector. Expenditure levels for academic and federal government performers are calendar-year approximations based on fiscal year data. For federal government expenditures, approximation equal to 75% of amount reported in same fiscal year plus 25% of amount reported in subsequent fiscal year. For academic expenditures, respective percentages are 50 and 50, because those fiscal years generally begin on 1 July instead of 1 October.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-7.

Science and Engineering Indicators 2010

Figure 4-1
U.S. total R&D expenditures: 1953–2008



NOTE: Data for 2008 are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-3.

Science and Engineering Indicators 2010

$400 billion in 2008. Over the past 20 years, the expansion of U.S. R&D spending has exceeded the pace of GDP growth, which averaged 5.3% in current dollars and 2.8% in constant dollars, with the difference becoming more substantial in the past few years.

The economic stimulus package enacted in early 2009 (American Recovery and Reinvestment Act of 2009 [Public Law 111-5]) provided a substantial increase in federal FY 2009 funding for R&D and R&D infrastructure ($18.3 billion). However, these one-time funds do not enter into the federal funding base for subsequent fiscal year budgets, as discussed in the federal R&D section of this chapter.

Estimates of U.S. R&D expenditures are generated by adding the annual R&D spending of all sectors of the economy for which expenditures can be reasonably estimated. The spending figures come from surveys of organizations that historically have performed the vast majority of R&D in the United States; however, some components of national R&D performance are not reflected in current NSF data, and measurement challenges remain. For a further discussion of R&D activities not currently captured in NSF's official R&D statistics, see the sidebar "Unmeasured R&D."

Unmeasured R&D

The estimates of U.S. R&D presented in this volume are derived from surveys of organizations that have historically performed the vast majority of R&D in the United States. To evaluate U.S. R&D performance over time and in comparison with other countries, however, it is necessary to gauge how much R&D goes unmeasured. The following paragraphs describe types of unmeasured R&D performance in the United States.

To reduce cost and respondent burden, U.S. industrial R&D estimates are derived from a survey of R&D-performing companies with five or more employees. Accordingly, no estimates of R&D performance are available for companies with fewer than five employees.

The activity of individuals performing R&D on their own time and not under the auspices of a corporation, university, or other organization is similarly omitted from official U.S. R&D statistics.

Social science R&D has been excluded from U.S. industrial R&D statistics. Also, R&D in the humanities is excluded from U.S. academic R&D statistics. Other countries include both in their national statistics, making their national R&D expenditures relatively larger when compared with those of the United States. (The new U.S. Business R&D and Innovation Survey, being fielded for the first time in 2009, includes social science R&D and will better capture total federally funded R&D performed by others. Furthermore, NSF is in the process of redesigning its Higher Education R&D Survey, which will include non-S&E R&D expenditures in its reported totals.)

NSF has not conducted a survey on R&D performance by nonprofit organizations since 1998, although the R&D performance of nonprofits is estimated for national R&D totals. NSF and the U.S. Census Bureau collected statistics for R&D performance by state governments in the United States for 2006 and 2007, but these data have not yet been included in the national time series. Data for these performers are discussed in "Location of R&D Performance."

Performers of R&D

NSF tracks the R&D spending patterns of several performers in the overall U.S. R&D system: businesses, the intramural R&D activities of federal agencies, federally funded R&D centers (FFRDCs),[3] universities and colleges, and other nonprofit organizations.

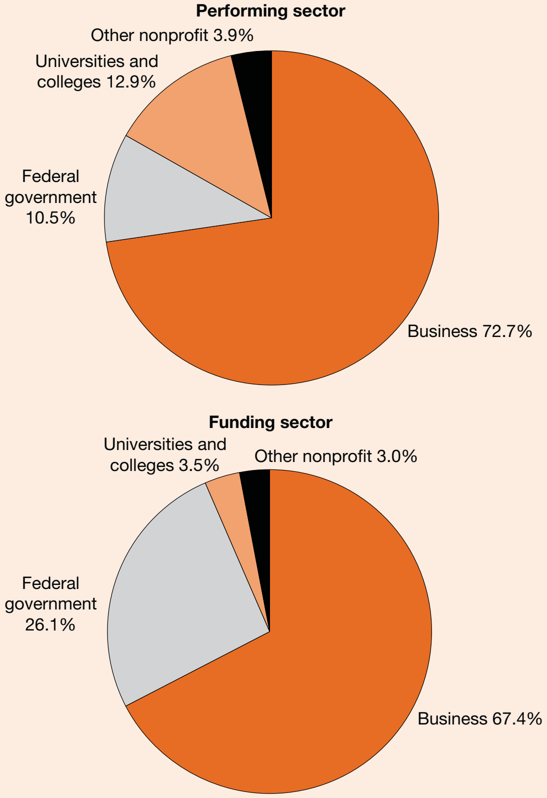
Business Sector

Estimated spending for R&D performed in the United States by businesses totaled $289.1 billion (current dollars) in 2008 (table 4-1). NSF estimates that business R&D expenditures in 2008 expanded in real terms (constant dollars) by 5.1%, outpacing the real growth of total U.S. R&D in the same year (4.5%). Similarly high rates of growth prevailed for business R&D in 2005, 2006, and 2007, and again, the growth in business R&D outpaced that of total U.S. R&D.

The business sector is by far the largest performer of U.S. R&D, accounting for 73% of the total in 2008 (figure 4-2). The high-water mark of the business sector's share of U.S. R&D to date was 75% in 2000. Over the next 4 years, its

Figure 4-2

Shares of national R&D expenditures, by performing and funding sectors: 2008



NOTES: Data for 2008 are preliminary. National R&D expenditures are estimated to be $398 billion in 2008. Federal performing sector includes federal agencies and federally funded research and development centers. State and local government support to industry is included in industry support for industry performance. State and local government support to universities and colleges is included in universities and colleges support of universities and college performance. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-7.

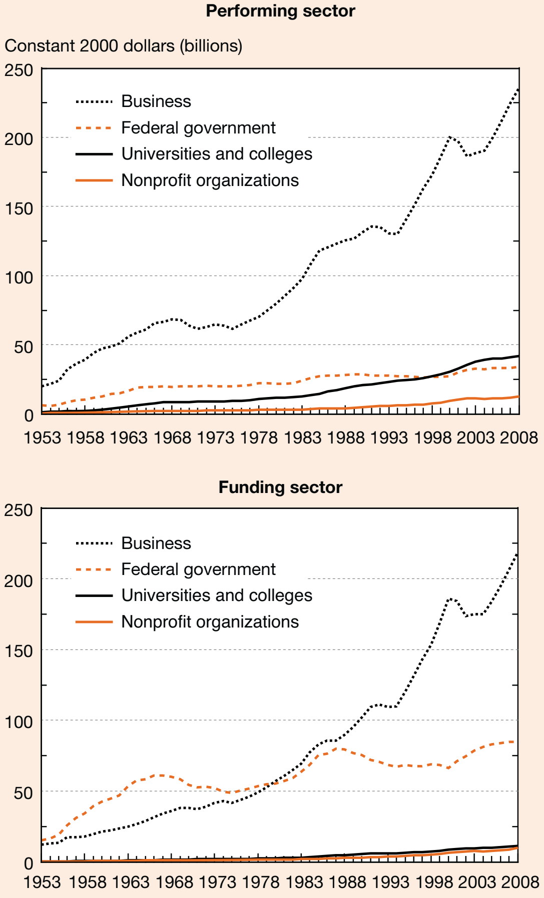
Science and Engineering Indicators 2010

share declined to about 70% in response to the slowdown of the U.S. economy in 2001 and 2002 and the associated curtailment of business activities by many R&D-performing firms. With the renewal of vigorous business activity thereafter, business spending on R&D moved to a higher-growth path. The business sector's share of R&D rose above 70% in 2005 and has since continued to increase.

Over the past 5 years, expanded business spending on R&D has accounted for much of the growth (in both current and real-dollar terms) in all U.S. R&D spending. The most striking trend when contrasting business-sector R&D with that of other performers over the past several decades is the sustained, far larger real-dollar expansion in the level of R&D spending by the business sector (figure 4-3).

Figure 4-3

National R&D, by performing and funding sectors, 1953–2008



NOTES: Data for 2008 are preliminary. Federal performers of R&D includes federal agencies and federally funded research and development centers. State and local government support to industry is included in industry support for industry performance. State and local government support to universities and colleges is included in universities and colleges support of universities and college performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-7.

Science and Engineering Indicators 2010

As discussed in the section "R&D by Character of Work," three-quarters of the business sector's R&D performance in recent years has been directed toward development activities rather than basic and applied research. Other U.S. R&D performers are relatively more active with respect to basic and applied research.

The business sector is the chief source of funding for its own R&D spending. In 2008, it is estimated that $263.3 billion, or 91%, of the business sector's overall R&D expenditures ($289.1 billion) came from the business sector itself (table 4-2), with the balance ($25.8 billion) coming from the federal government. Before the late 1960s, the

Table 4-2
U.S. R&D expenditures, by character of work, performing sector, and funding source: 2008

Sector	Total	Business	Federal government	Universities and colleges	Other nonprofit	Total expenditures (% distribution)
R&D	397,616	267,847	103,696	14,053	12,020	100.0
Business	289,105	263,310	25,795	*	*	72.7
Federal government	41,741	*	41,741	*	*	10.5
Federal intramural	27,000	*	27,000	*	*	6.8
FFRDCs	14,741	*	14,741	*	*	3.7
Industry-administered	5,031	*	5,031	*	*	1.3
U&C-administered	6,023	*	6,023	*	*	1.5
Nonprofit-administered	3,688	*	3,688	*	*	0.9
Universities and colleges	51,163	2,908	30,177	14,053	4,024	12.9
Other nonprofit organizations	15,606	1,629	5,982	*	7,995	3.9
Percent distribution by source	100.0	67.4	26.1	3.5	3.0	na
Basic research	69,146	12,222	39,379	10,188	7,357	100.0
Business	11,907	9,209	2,697	*	*	17.2
Federal government	10,189	*	10,189	*	*	14.7
Federal intramural	4,734	*	4,734	*	*	6.8
FFRDCs	5,455	*	5,455	*	*	7.9
Industry-administered	2,287	*	2,287	*	*	3.3
U&C-administered	1,736	*	1,736	*	*	2.5
Nonprofit-administered	1,432	*	1,432	*	*	2.1
Universities and colleges	38,822	2,108	23,608	10,188	2,918	56.1
Other nonprofit organizations	8,229	904	2,885	*	4,439	11.9
Percent distribution by source	100.0	17.7	57.0	14.7	10.6	na
Applied research	88,578	53,827	28,649	3,169	2,934	100.0
Business	61,437	52,758	8,679	*	*	69.4
Federal government	11,599	*	11,599	*	*	13.1
Federal intramural	7,573	*	7,573	*	*	8.5
FFRDCs	4,026	*	4,026	*	*	4.5
Industry-administered	1,067	*	1,067	*	*	1.2
U&C-administered	1,644	*	1,644	*	*	1.9
Nonprofit-administered	1,315	*	1,315	*	*	1.5
Universities and colleges	10,556	656	5,824	3,169	908	11.9
Other nonprofit organizations	4,985	413	2,546	*	2,026	5.6
Percent distribution by source	100.0	60.8	32.3	3.6	3.3	na
Development	239,891	201,798	35,669	696	1,729	100.0
Business	215,761	201,342	14,419	*	*	89.9
Federal government	19,953	*	19,953	*	*	8.3
Federal intramural	14,693	*	14,693	*	*	6.1
FFRDCs	5,260	*	5,260	*	*	2.2
Industry-administered	1,676	*	1,676	*	*	0.7
U&C-administered	2,643	*	2,643	*	*	1.1
Nonprofit-administered	941	*	941	*	*	0.4
Universities and colleges	1,785	144	746	696	199	0.7
Other nonprofit organizations	2,392	312	551	*	1,530	1.0
Percent distribution by source	100.0	84.1	14.9	0.3	0.7	na

* = small to negligible amount, included as part of funding provided by other sectors; na = not applicable

FFRDC = federally funded research and development center; U&C = universities and colleges

NOTES: Data for 2008 are preliminary. Federal intramural includes federal intramural R&D and costs associated with administering extramural R&D. Funding for FFRDC performance chiefly federal, but any nonfederal support included in federal figures. State and local government support to industry included in industry support for industry performance. State and local government support to universities and colleges ($3,453 million) included in universities and colleges support for universities and colleges performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 to 4-10.

Science and Engineering Indicators 2010

federal government was the primary source of funding for business R&D.

Note that the decline in federal funding of business R&D, as reported by businesses, differs somewhat from the trend apparent in R&D spending data collected from federal agencies. For details on this discrepancy, see the sidebar "Tracking R&D: The Gap Between Performer- and Source-Reported Expenditures" later in this chapter.

Universities and Colleges

Universities and colleges performed an estimated $51.2 billion of R&D in 2008. The academic sector is the second-largest performer of U.S. R&D. It currently represents just below 13% of total U.S. R&D performance, about a fifth of the size of business R&D. In the late 1990s and first years of the current decade, academic R&D grew faster than R&D in any other U.S. sector, with real annual growth rates in the range of 6% to 8%. After 2004, however, real growth has been much slower, falling to 2.1% in 2008, well below the real growth rates for business R&D and total U.S. R&D.

Universities and colleges are estimated to have performed more than half (56%) of the nation's basic research in 2008. (See "R&D by Character of Work.") They also rely much more than the business sector on external R&D funding. In 2008, about 27% of academic R&D was funded by the institutions themselves; 59% was funded by the federal government; and the balance was funded by state and local governments, nonprofits and other types of organizations, and private gifts (table 4-2).

Federal Agencies and FFRDCs

R&D performance by the federal government (which spans the activities of agency intramural research laboratories, agency planning and administration of both intramural and extramural R&D projects, and the FFRDCs) totaled an estimated $41.7 billion in 2008, about 11% of all U.S. R&D performance. Federal agencies' intramural R&D activities (including the aforementioned planning and administration costs) accounted for $27.0 billion (6.8%) of the U.S. total, and FFRDCs accounted for $14.7 billion (3.7%). Federal agencies' intramural R&D performance is entirely funded by the federal government; FFRDCs also rely chiefly on federal funding, with small amounts of nonfederal funds at some facilities.

Real expenditures for R&D conducted by federal agencies and FFRDCs combined grew rapidly from 2001 to 2003, reflecting increased defense spending following the terrorist attacks of September 11, 2001. From 2004 to 2007, federal government R&D performance was essentially flat. It is estimated to have returned to modest growth in 2008, with increases in both federal intramural and FFRDC R&D performance.

The volume of the federal government's R&D performance is small compared with that of the U.S. business sector. However, the federal sum of $41.7 billion exceeds the national R&D expenditures of every country except Japan, China, and Germany. Furthermore, this federal expenditure does not include sizable government investments in R&D infrastructure and equipment. In addition, the federal government maintains research facilities and conducts research projects that would be too costly or risky for a single company or university to undertake.

Other Nonprofit Organizations

The figure for R&D performed in the United States by other nonprofit organizations in 2008 was an estimated $15.6 billion. This amount represents about 4% of all U.S. R&D in that year, a share that has been fairly stable since 2000.

Sources of R&D Funding

The funding for R&D conducted by organizations in the United States comes from a variety of sources, including their own funds, as well as contracts and grants from other organizations. The funding mix varies across the main performing sectors. Data on the flows of R&D funding within sectors, such as between two companies, are limited, but data on the flows of R&D between sectors indicate that financial relationships between organizations play a significant role in the U.S. R&D system.

In 2008, an estimated 19% of U.S. R&D ($74 billion, current dollars) came from funding by an organization in a sector other than the performing sector (table 4-2). Most of this between-sector funding comes from the federal government, which supports significantly more R&D than it conducts in its own laboratories and FFRDCs. In sharp contrast, most businesses use a high percentage of their R&D budgets for internal projects or to contract for R&D performed by other businesses. The small remainder—about 2% of overall business funds for R&D—flows to universities and other nonprofit organizations to support R&D performance.

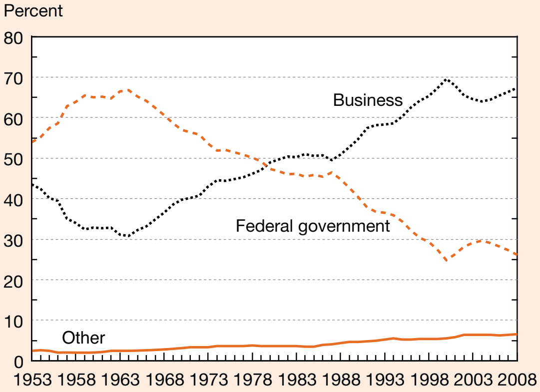
R&D Funding by the Federal Government

In 2008, according to the reports of R&D performers, the federal government funded an estimated $103.7 billion (current dollars) of R&D (table 4-1). This amount represented about 26% of all R&D funding in the United States (figure 4-2).

The federal government was once the predominant sponsor of the nation's R&D, funding some 67% of all U.S. R&D in 1964 (figure 4-4). But the federal share decreased in subsequent years, falling to below 50% in 1979 and to a low of 25% in 2000. This declining share of federal R&D funding is particularly evident in the business sector. In the late 1950s and early 1960s, more than half of the nation's business R&D was funded by the federal government, but by 2000, less than 10% of business R&D was federally funded (appendix table 4-3).

Between 2001 and 2004, however, this decades-long trend was attenuated as private investment slowed in the face of the 2001–02 recession. In addition, federal R&D spending expanded, first in health and then in defense and counterterrorism. By 2004, the federal share of the nation's

Figure 4-4
National R&D expenditures, by funding source: 1953–2008



NOTES: Data for 2008 are preliminary. Other includes universities and colleges, state and local government, and other nonprofit organizations.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-7.

Science and Engineering Indicators 2010

R&D funding reached 30%, but thereafter it declined again to an estimated 26% in 2008.

R&D Funding by Business

The business sector is both the largest performer and the largest source of R&D funding in the United States. Business provided an estimated $267.8 billion for R&D in 2008, 67% of the U.S. total.

The business sector's share of national R&D funding first surpassed the federal government's share in 1980 (figure 4-4). Almost all business funding for R&D is directed toward business R&D, with a small remainder (around 2%) allocated to academic and other nonprofit performers.

From 1980 to 1985, business support for R&D grew, in real dollars, at an average annual rate of almost 8%. From 1985 to 1994, real growth dropped to 3% per year, before expanding to 9% through 2000. Growth declined by 3% a year during the 2000–02 recession, was flat in 2003–04, and has increased robustly (5% or more real growth annually) since 2005. NSF's preliminary estimate for real growth in business-sector R&D funding in 2008 is about 6%.

R&D Funding From Other Sources

R&D funding from other nonfederal sources—academia's own institutional funds, other nonprofits, and state and local governments—is small in comparison to federal and business sources, and is estimated to have been below 7% of the total in 2008. Nonetheless, this funding has been growing fairly rapidly for some time. From 1998 to 2008, growth in funding from these sectors averaged 5.4% per year in real-dollar terms—ahead of the pace of funding growth in both the federal and business sectors. Most R&D funded by these nonfederal sources is performed by the academic sector.

Finally, unlike many countries, the United States does not currently have data on domestic R&D that is funded by foreign sources. However, NSF has begun to collect these data as part of a new business survey. Separately, foreign direct investment in R&D, which is measured in the United States, provides an indication of international participation in business R&D. However, foreign ownership does not necessarily imply foreign R&D funding, because an affiliate may fund activities through its own revenues and other domestic sources. (See "R&D by Multinational Companies.")

R&D by Character of Work

R&D encompasses a wide range of activities, from fundamental research in the physical, life, and social sciences; to research addressing such critical issues as global climate change, energy efficiency, and health care; to the development of general-purpose technologies and new goods and services. Because the activities are so diverse, it helps to classify them into distinct categories when analyzing R&D expenditures.

Historically, the most common categories used to classify R&D are basic research, applied research, and (experimental) development. (See sidebar "Definitions of R&D.") In light of the complex feedback loops involved in knowledge creation and exploitation, these categories have been criticized as simplistic and too linear in their implied progression. No alternative measurement frameworks, however, have been widely adopted. Accordingly, this chapter relies on these longstanding, widely used, and internationally comparable categories (OECD 2002) to describe the current trends in the character of U.S. R&D expenditures.[4]

In 2008, the United States performed an estimated $69.1 billion of basic research, $88.6 billion of applied research, and $239.9 billion of development (table 4-2). Basic research represented a little more than 17% of the total; applied research, 22%; and development, just over 60% (figure 4-5).

Historically, the federal government has been the prime source of funding for basic research, accounting for an estimated 57% of the nation's total in 2008 (figure 4-5). The share of federal funding to universities and colleges, the nation's largest performers of basic research, was 61%.

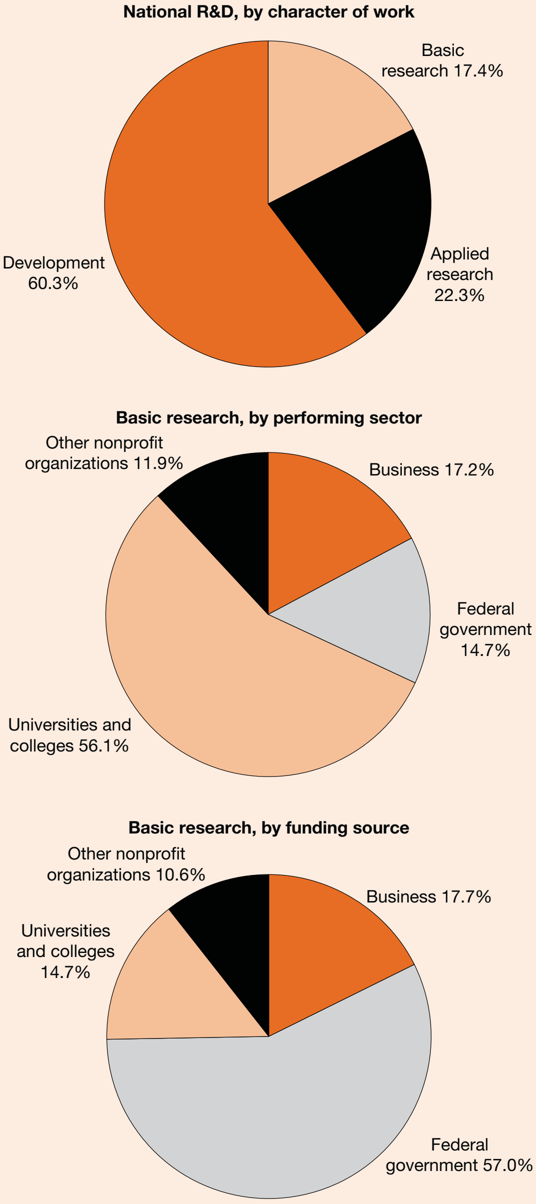
Industry directs only small portions of its R&D funding to basic research—an estimated 5% in 2008 (figure 4-6). Many businesses believe that basic research involves significant uncertainties regarding both the near-term commercial value of any discoveries and the firm's ability to enforce intellectual property rights and earn a return. Some firms, however, view engaging in basic research (whether performed internally or in cooperation with other performers) as a way to boost human capital resources by attracting and retaining talented scientists and engineers. This can strengthen the firm's capacity for innovation and improve its ability to absorb external scientific and technological knowledge. Not surprisingly, the industries that invest the most in basic research are those whose new products are most directly tied to ongoing science and technological advances, such as the pharmaceuticals and scientific R&D service sectors.

The business sector currently spends more than four times on applied research than basic research, accounting for greater than half of U.S. applied research funding. In 2008, industry invested an estimated $53.8 billion in applied research funding, 61% of the U.S. total. Industries that perform a relatively large amount of applied research include chemicals, aerospace (mostly funded by the Department of Defense [DOD]), and R&D services (where many companies engage in the licensing of technologies).

The bulk of the federal government's applied research funds support work that is performed by the federal agencies themselves or by FFRDCs.

Figure 4-5

National R&D, by character of work, and basic research, by funding and performing sectors: 2008



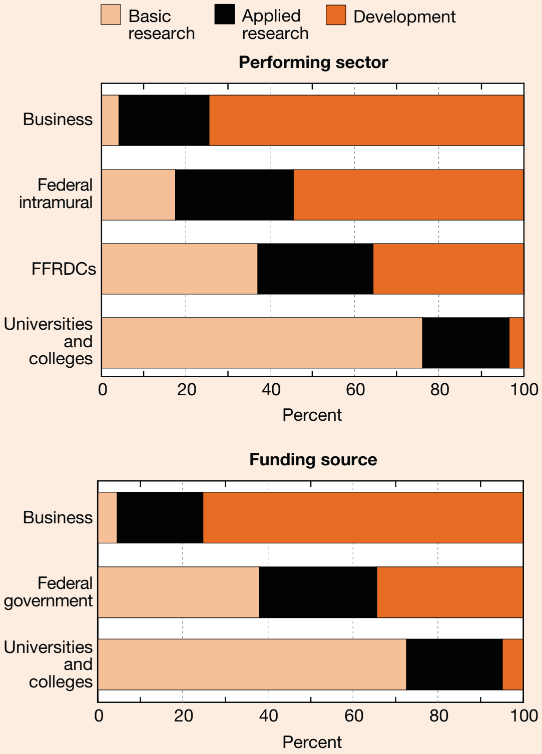
NOTES: Data for 2008 are preliminary. National R&D expenditures estimated at $398 billion in 2008. Federal performers include federal agencies and federally funded research and development centers. State and local government support to industry included in industry support for industry performance. State and local government support to universities and colleges included in universities and colleges support of universities and college performance. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3, 4-4, 4-5, 4-6, and 4-8.

Science and Engineering Indicators 2010

Figure 4-6

R&D performing sectors and funding sources, by character of work: 2008



FFRDCs = federally funded research and development centers.

NOTES: Data for 2008 are preliminary. State and local government support to industry included in industry support for industry performance. State and local government support to universities and colleges included in universities and colleges support for universities and colleges performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 to 4-10.

Science and Engineering Indicators 2010

Development expenditures totaled an estimated $239.9 billion in 2008, representing 60% of all U.S. R&D expenditures.[5] The development of new and improved goods, services, and processes is dominated by the business sector, which funded 84% (an estimated $201.8 billion) of all U.S. development in 2008. The federal government funded most of the remaining development, totaling 15%, or $35.7 billion. Most federal development spending is defense related; this spending includes military aircraft, for which the federal government is the main customer.

The business sector performs a higher share of development activities than it funds, having conducted about 90% of all U.S. development in 2008. Federal agencies and FFRDCs conducted 8%, and all other performers combined conducted just below 2%.

R&D expenditures by public and private organizations indicate the priority given to the creation of new science and technology (S&T)-based knowledge in support of their goals. As an input measure, however, R&D expenditures do not directly lead to subsequent economic and social outputs. For one approach to measuring the role of R&D in economic output and growth, see the sidebar "The BEA/NSF R&D Satellite Account: R&D and Economic Growth."

Location of R&D Performance

More than half of all U.S. R&D is performed in only a few states.[6] Nonetheless, patterns of expenditures for R&D activities vary among the top R&D-performing states. (For a broader range of indicators on state-level S&E activities, see chapter 8.)

Distribution of R&D Expenditures Among States

In 2007, the 10 states with the greatest R&D expenditure levels accounted for about 64% of U.S. R&D expenditures that can be allocated to the states. The top 20 states accounted for nearly 85% of the R&D total; the 20 lowest-ranking states, around 5%. California alone represented 22% of U.S. R&D, exceeding the next-highest state, Massachusetts, by more than three times. Appendix table 4-15 provides 2007 statistics on R&D performers and funders for all the states.

To some degree, state variations in the level of R&D expenditures reflect differences in economic scale. Reporting a state's R&D expenditures as a fraction of its GDP adjusts for these differences and is an indicator of R&D intensity at the state level.

States with the highest R&D/GDP ratios in 2007 included New Mexico, Massachusetts, and Maryland (table 4-3). New Mexico is the location of several major government research facilities. Massachusetts benefits from both leading research universities and thriving high-technology industries. Maryland is the site of many government research facilities and growing research universities. California ranks seventh in R&D intensity. See appendix table 4-16 for a complete list of states and their corresponding R&D intensities.

The BEA/NSF R&D Satellite Account: R&D and Economic Growth

Measuring R&D as capital investment rather than an expense (that is, capitalizing R&D) recognizes that R&D has long-term benefits, much as do investments in physical assets. Capitalized R&D has a direct impact on GDP because business R&D becomes part of economic output instead of an expense. International activities are underway to update systems of national accounts to recognize the investment nature of R&D (UNSC 2007). A first step in the statistical systems of the United States and other OECD countries is to develop R&D satellite accounts, that is, supplementary estimates of the GDP and related measures that provide greater detail or alternative measurement concepts without changing the core accounts. Future research topics include improving the price indexes used to produce inflation-adjusted R&D investment figures and measures of the depreciation of R&D as a capital asset.

Several U.S. interagency efforts are aimed at identifying improved measures of intangibles, such as R&D, and their economic role (Aizcorbe, Moylan, and Robbins 2009; Jorgenson, Landefeld, and Nordhaus 2006). NSF's Division of Science Resources Statistics, responsible for U.S. R&D statistics, and the Bureau of Economic Analysis (BEA), responsible for the U.S. national economic accounts, are jointly developing an R&D Satellite Account (Robbins and Moylan 2007). Current plans call for incorporation of R&D capital into the National Income and Product Accounts and other core accounts in 2013.

According to BEA preliminary estimates, capitalizing R&D increased the level of current-dollar GDP by an average of 2.9% per year between 1959 and 2006. Adjusted for inflation, R&D capital would account for about 5.1% of real GDP growth between 1959 and 2006. This figure compares with a 2.2% share for all business investment in commercial and all other types of buildings. During the more recent 1995–2006 period, R&D investment accounted for about 7% of real GDP growth, with the business sector's R&D contribution amounting to 4.6% percent.

From 1995–2006, the largest estimated contributions to real GDP growth came from the pharmaceutical and medicine manufacturing industry, which accounted for more than 1% of GDP growth. The software publishing industry accounted for an additional 0.5%.

Table 4-3
Top 10 states in R&D performance, by sector and intensity: 2007

	All R&D[a]		Sector ranking			R&D intensity (R&D/GDP ratio)		
Rank	State	Amount (current $millions)	Business	Universities and colleges	Federal intramural and FFRDC[b]	State	R&D/ GDP (%)	GDP (current $billions)
1	California	77,608	California	California	Maryland	New Mexico	7.53	75.2
2	Massachusetts	24,557	Massachusetts	New York	California	Massachusetts	6.97	352.2
3	New Jersey	19,552	New Jersey	Texas	New Mexico	Maryland	5.34	264.4
4	Texas	17,853	Michigan	Maryland	Virginia	Washington	4.85	310.3
5	Michigan	17,402	Texas	Pennsylvania	District of Columbia	Connecticut	4.82	212.3
6	New York	15,939	Washington	Massachusetts	Massachusetts	Michigan	4.58	379.9
7	Washington	15,061	Illinois	North Carolina	Tennessee	California	4.31	1,801.8
8	Illinois	14,287	New York	Illinois	Washington	New Jersey	4.24	461.3
9	Maryland	14,130	Pennsylvania	Ohio	Illinois	District of Columbia	4.17	92.5
10	Pennsylvania	13,510	Connecticut	Florida	Florida	New Hampshire	3.71	57.8

FFRDC = federally funded research and development center; GDP = gross domestic product

[a] Includes in-state total R&D performance of business, universities, federal agencies, FFRDCs, and federally financed nonprofit R&D.
[b] Includes costs associated with administration of intramural and extramural programs by federal personnel and actual intramural R&D performance.

NOTE: Small differences in parameters for state rankings may not be significant. Rankings do not account for the margin of error of the estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2007; Survey of Research and Development Expenditures at Universities and Colleges, FY 2008; Survey of Federal Funds for Research and Development, FY 2007-2009; Survey of State Research and Development Expenditures, FY 2007. State GDP data are from the U.S. Bureau of Economic Analysis, http://www.bea.gov/regional/gsp, accessed 29 July 2009. See also appendix tables 4-15 and 4-16.

Science and Engineering Indicators 2010

Sector Distribution of R&D Performance by State

The proportion of R&D performed in each of the major R&D-performing sectors (business, universities and colleges, federal intramural facilities and FFRDCs) varies across states. States that lead in total R&D tend to be well represented in each of these sectors (table 4-3).

In 2007, business-sector R&D accounted for about 74% of the U.S. R&D total that could be allocated to specific states. Of the top 10 states in total R&D performance, 9 are also in the top 10 in industry R&D. Connecticut, 10th in business-sector R&D and home to substantial pharmaceutical R&D activity, surpasses Maryland in the business R&D ranking.

University-performed R&D accounts for 14% of the U.S. total, and it also closely follows state total R&D performance. Among the top 10 states in total R&D, only Michigan, New Jersey, and Washington are not also among the university R&D top 10, being replaced by North Carolina, Ohio, and Florida.

Representing about 11% of the state-distributed U.S. total, federal R&D performance (both intramural and FFRDC) is more concentrated geographically than performance in other sectors—and the relationship between its geographical distribution and that of total R&D is less significant. The top four states (Maryland, California, New Mexico, and Virginia) and the District of Columbia represent 64% of all federal R&D performance.[7] This figure rises to 78% when the other five top 10 states (Massachusetts, Tennessee, Washington, Illinois, and Florida) are included.

Federal R&D accounts for 82% of all R&D in New Mexico, home of the nation's two largest FFRDCs (Los Alamos and Sandia National Laboratories). The high figures for Maryland (54%), Virginia (38%), and the District of Columbia (74%) reflect the concentration of federal facilities and administrative offices in the national capital area. The share for Tennessee (32%) reflects the presence of a large federal facility, Oak Ridge National Laboratory.

In California, Massachusetts, Washington, and Illinois, federal R&D performance accounts for no more than 6% to 7% of the state R&D totals, even though each state is among the top 10 in federal performance. The federal R&D share in Florida was 13% in 2007.

Business R&D in Top States

During 2007, companies in the 10 states with the highest business R&D performance reported aggregate R&D expenditures of $186.0 billion and accounted for 69% of the business R&D performed in the United States. Companies in California alone accounted for 24% of the nation's business R&D. The types of companies that carry out R&D vary considerably among these 10 leading states (table 4-4), reflecting regional specialization or clusters of business activity. For example, the automotive manufacturing industry accounted for 75% of Michigan's business R&D in 2007, although it accounted for only 6% of the nation's total business R&D.

Table 4-4

Top 10 states in business R&D performance and share of R&D, by selected industry: 2007

(Percent)

State	Business-performed R&D (current $millions)	Chemicals	Computer and electronic products	Computer-related services	R&D services	Motor vehicles	Companies with 5–499 employees
All states	269,267	20.6 L	21.8	5.4	8.4	6.0 L	18.7
California	64,187	13.9	33.0	14.6	9.5	D	20.2
Massachusetts	19,488	17.4	44.6	5.5	9.9	0.0	18.5
New Jersey	17,892	63.1	6.3	5.2	8.0	0.1	13.4
Michigan	15,736	6.7	1.3	1.9	2.8	74.8	8.5
Texas	13,889	5.6	32.3	17.8	7.4	0.4	18.6
Washington	12,687	5.2	5.3	2.6	6.5	0.4	12.3
Illinois	11,362	25.2	32.7	4.3	2.4	1.8	14.1
New York	10,916	30.1	7.8	15.6	4.1	3.0	22.7
Pennsylvania	10,387	55.0	7.3	6.2	5.2	0.8	17.5
Connecticut	9,444	59.0	2.3	2.5	3.2	0.2	8.2

L = lower-bound estimate; D = suppressed to avoid disclosure of confidential information

NOTES: Rankings do not account for margin of error of estimates from sample surveys. Detail does not add to total because not all industries shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

Science and Engineering Indicators 2010

The computer and electronic product manufacturing industries performed 22% of the nation's total business R&D, but the shares of this performance were larger in Massachusetts (45%), Illinois (33%), California (33%), and Texas (32%). These states have clearly defined regional centers of high-technology research and manufacturing, including Cambridge and Route 128 in Massachusetts; Champaign County, Illinois; Silicon Valley, California; and the Silicon Hills of Austin. About two-thirds of R&D performed in the United States by computer and electronic product companies in 2007 was located in these four states and accounted for 14% of all business R&D nationwide (table 4-4; appendix table 4-11).

R&D performed by chemical manufacturing companies remains prominent in New Jersey, Connecticut, and Pennsylvania, all home to the pharmaceuticals and the chemicals industries. According to the American Chemistry Council (ACC 2009), together these states are host to more than 2,000 chemical manufacturing establishments, an increase of about 500 since 2005, and rank among the top 18 in chemicals industry employment. In 2007, chemical manufacturers accounted for 63% of New Jersey's business R&D, 59% of Connecticut's, and 55% of Pennsylvania's (table 4-4). These three states represented more than 41% of the nation's R&D in this sector.

The R&D and related-services sector, which consists largely of biotechnology companies, contract research organizations, and early-stage technology firms, is also geographically concentrated, with California, Massachusetts, and New Jersey accounting for more than 42% of R&D. The companies in this sector maintain strong ties to the academic sector and are often located near large research universities (Stuart and Sorenson 2003).

Nationally, small companies (those that have from 5 to 499 employees[8]) performed 19% of total U.S. business R&D in 2007 (appendix table 4-11). Among the top 10 business R&D-performing states, New York and California had the highest totals of small companies performing business R&D, with 23% and 20%, respectively, in each state. Small companies in these two states performed 6% of the nation's total business R&D in 2007 (table 4-4).

Business R&D

Businesses perform R&D with a variety of objectives in mind, but most business R&D is aimed at developing new and improved goods, services, and processes. R&D expenditures, therefore, indicate the level of effort dedicated to producing future products and process improvements while maintaining current market share and increasing operating efficiency. By extension, such expenditures may reflect firms' perceptions of the market's demand for new and improved technology.

R&D performed by the business sector totaled $269.3 billion in 2007. The federal government funded 9.9% ($26.6 billion) of this total, and company funds and other private sources financed the remainder (appendix tables 4-11 to 4-13).[9]

In addition to absolute levels of R&D expenditures, another indicator in the business sector is R&D intensity—that is, R&D relative to production in a company, industry, or sector. The measure used most frequently is the ratio of company-funded R&D to net sales.[10] This statistic provides a way to gauge the relative importance of R&D across industries and among firms in the same industry. The company-funded R&D-to-sales ratio of companies in all industries performing R&D in the United States varied between 3.2% and 3.4% during 2003-06; in 2007 it was 3.5% (table 4-5; appendix table 4-14).

Largest R&D Industries

Benefits from advances in S&T may be broadly shared among industries; however, different industries perform different amounts of R&D.[11] Some industries, such as utility,[12] finance, insurance, and real estate, have relatively low R&D intensities (0.5% or less). Appendix table 4-14 provides data on ratios of company-funded R&D to net sales for an array of industries.[13] Six industry groups—four in manufacturing (chemicals, computer and electronic products, aerospace and defense manufacturing, and automotive manufacturing) and two in services (software and computer-related, and R&D services)—accounted for 78% of company-funded business R&D and 95% of federally funded business R&D in 2007 (table 4-5).[14]

Table 4-5
Business R&D and domestic net sales, by industry: 2006 and 2007
(Millions of current dollars)

Industry	Business-performed R&D		Federally funded R&D		Company-funded R&D	
	2006	2007	2006	2007	2006	2007
All	247,669	269,267	24,304	26,585	223,365	242,682
Highlighted industries	193,956 L	209,116 L	23,352 L	25,355 L	170,606	183,761
Chemicals	48,913	50,423	662	663	48,251	49,760
Computer and electronic products[a]	46,329	55,571 L	211	252 L	46,119	55,319
Software and computer-related services[b]	33,831 L	34,079 L	1,048 L	842	32,783	33,237
Aerospace and defense manufacturing[c]	27,217 L	30,278 L	15,222 L	16,882 L	11,995	13,397
R&D and related services[d]	21,104	22,731	6,209	6,716	14,896	16,014
Automotive manufacturing[e]	16,562 L	16,034 L	NA	NA	16,562	16,034
All other	53,713 L	60,151 L	952 L	1,230 L	52,759	58,921

Industry	Domestic net sales		Business-performed R&D/ sales ratio (%)		Company-funded R&D/ sales ratio (%)	
	2006	2007	2006	2007	2006	2007
All	6,642,500	7,027,049	3.7	3.8	3.4	3.5
Highlighted industries	2,530,579	2,602,127	7.7	8.0	6.7	7.1
Chemicals	524,160	589,918	9.3	8.5	9.2	8.4
Computer and electronic products[a]	612,885	699,520	7.6	7.9	7.5	7.9
Software and computer-related services[b]	376,638	304,952	9.0	11.2	8.7	10.9
Aerospace and defense manufacturing[c]	243,110	263,321	11.2	11.5	4.9	5.1
R&D and related services[d]	86,945	89,166	24.3	25.5	17.1	18.0
Automotive manufacturing[e]	686,841	655,250	2.4	2.4	2.4	2.4
All other	4,111,921	4,424,922	1.3	1.4	1.3	1.3

L = lower-bound estimate; NA = not available

[a] Includes all R&D and domestic net sales for the computer and electronics industry (NAICS 334), except for federal R&D for the navigational, measuring, electromedical, and control instruments industry (NAICS 3345), which is included in the aerospace and defense manufacturing sector.

[b] Includes R&D and domestic net sales for software (NAICS 5112) and computer systems design and related service industries (NAICS 5415).

[c] Includes all R&D for aerospace products and parts (NAICS 3364), plus all federal R&D for navigational, measuring, electromedical, and control instruments (NAICS 3345), automotive (NAICS 3361–3363), and other transportation manufacturing industries. Domestic net sales are not included for automotive and other transportation manufacturing industries.

[d] Includes R&D and domestic net sales for architectural, engineering, and related services (NAICS 5413) and scientific R&D services industries (NAICS 5417).

[e] Includes all R&D for transportation manufacturing equipment (NAICS 336), except federally funded components that are included in aerospace and defense manufacturing sector.

NOTE: Potential disclosure of individual company operations only allows lower-bound estimates for some sectors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development.

Science and Engineering Indicators 2010

Chemicals (Including Pharmaceuticals)

Among three-digit North American Industry Classification System (NAICS) codes, the chemicals industry accounted for the largest amount of R&D performed in the United States in 2007. Companies in this group performed $55.6 billion of R&D, with relatively little of it federally funded. Within the chemicals industry, the largest subsector is pharmaceuticals and medicines. In 2007, pharmaceutical companies performed $47.6 billion of company-funded R&D, representing 86% of nonfederal R&D funding in the chemicals sector (appendix table 4-12).

A related indicator is reported by the Pharmaceutical Research and Manufacturers of America (PhRMA), an industry association that represents the country's leading research-based pharmaceutical and biotechnology companies. This association conducts an annual survey of its members to gather information about R&D. In 2007, PhRMA estimated that its members invested $35.4 billion in R&D performed in the United States and $9.1 billion in R&D performed abroad. The total $44.5 billion investment represented 18.7% of domestic sales and 16.4% of global sales (PhRMA 2008a).[15] According to PhRMA, U.S. biopharmaceutical research companies obtained approval for 26 new medicines in 2007 from the U.S. Food and Drug Administration. About 75% of PhRMA members' domestic R&D investment supports R&D on projects that originate in their own laboratories, and 25% supports R&D on products licensed from other organizations, notably biotechnology companies, universities, or the government (PhRMA 2008b).[16]

Computer and Electronic Products

Companies in the computer and electronic product manufacturing industry include producers of computers, computer peripherals, communications equipment, and similar electronic products and producers of components for such products.[17] The design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production processes of the computer and electronic product sector.

In 2007, companies in this industry performed $50.4 billion of R&D, or 19% of all business R&D (table 4-5).[18] Company and other nonfederal sources funded almost all of this R&D. Two of the more R&D-intensive industries, communications equipment and semiconductor manufacturing, are included in this group. Both devoted more than 10% of sales to R&D in 2007 (appendix table 4-14).

Software and Computer-Related Services

Software and computer-related services industries, such as data processing and computer systems design, performed approximately $33.2 billion of company-funded R&D in 2007. The R&D of these industries (14% of the U.S. business sector total), combined with that of the computer and electronic product manufacturers, accounted for 34% of all industrial R&D in 2007. As computing and information technology has become more integrated with every sector of the economy, the demand for services associated with these technologies has increased.

Between 1987 and 2007, R&D expenditures of companies providing these services grew. In 1987, when an NSF survey estimate of software and other computer-related services R&D first became available, companies classified in the industry group—computer programming, data processing, other computer-related, engineering, architectural, and surveying services—performed $2.4 billion of company-funded R&D, or 3.8% of all company-funded industrial R&D. In 2007, the company-funded R&D of these industries (excluding engineering and architectural services) accounted for 13.7% of all company-funded industrial R&D, and these companies accounted for 4.3% of domestic sales of R&D-performing companies (table 4-6).[19]

Table 4-6
Estimated share of computer-related services in company-funded R&D and domestic net sales of R&D-performing companies: 1987–2007
(Percent)

Year	Company-funded R&D	Domestic net sales
1987	3.8	1.4
1988	3.6	1.5
1989	3.4	1.4
1990	3.7	1.5
1991	3.6	1.6
1992	4.0	1.6
1993	8.2	1.5
1994	6.6	2.2
1995	8.8	3.3
1996	8.8	2.6
1997	9.1	2.5
1998	9.5	2.2
1999	10.6	2.2
2000	10.9	2.8
2001	13.0	3.5
2002	14.6	5.4
2003	14.3	3.5
2004	14.7	3.0
2005	14.7	3.5
2006	14.7	5.7
2007	13.7	4.3

NOTES: Before 1998 companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). After 1998 companies classified in North American Industry Classification System (NAICS) industries 5112 (software) and 5415 (computer systems design and related services). With SIC classification, information technology services share of company-funded R&D was 10.4% for 1998, indicating SIC-based data may overestimate information technology services R&D and net sales relative to NAICS-based data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series), http://www.nsf.gov/statistics/srvyindustry/, accessed 6 May 2009.

Science and Engineering Indicators 2010

Aerospace and Defense Manufacturing

Although it is common to refer to the "defense industry," the NAICS industry classification system does not include this category. Thus, to approximate the cost of defense-related R&D, one can focus on aerospace products and parts, plus federally funded R&D in the following industries: navigational, measuring, electromedical, and control instruments; automotive manufacturing; and other transportation manufacturing industries. Companies in this sector perform the majority of DOD's extramural R&D. In 2007, these industries reported performing $16.9 billion of federally funded R&D (table 4-5), about 64% of all federally funded industrial R&D. This total accounts for more than half of the $30.3 billion that the defense industry as a whole spent on R&D, including both federal and nonfederal sources of funds. (See "Federal R&D" for further discussion of defense R&D.)

R&D and Related Services

The R&D and related-services category includes companies that provide scientific R&D, engineering, and architectural services to other firms. Also included are businesses that conduct R&D for their own use (e.g., biotechnology and other firms that conduct R&D in physical, engineering, and life sciences) but may not yet have sales. Companies in this sector performed $6.7 billion of federally funded R&D in 2007, the highest figure outside the aerospace and defense manufacturing category. Despite the significant amount of government-sponsored R&D performed by this sector, R&D and related-services companies increasingly rely on nonfederal sources of R&D financing. The R&D performed by companies in the R&D and related-services sector and funded by company and other nonfederal sources has grown from $5.8 billion in 1997 to $16 billion in 2007.[20] Because much of the R&D reported by these companies also appears in their reported sales figures, the R&D intensity of this sector is particularly high (26% in 2007).[21]

Automotive Manufacturing

The sixth-largest business sector in terms of R&D is automotive manufacturing. Companies in this industry reported performing $16 billion of company-funded R&D in 2007, accounting for 6% of all such R&D performed by businesses in the United States.

In 2007, 15 companies in the automotive manufacturing industry reported company-funded R&D expenditures of more than $100 million each, collectively representing 83% of the industry's R&D (NSF/SRS 2009). In most industries, large companies perform more R&D than small companies, but in the automotive manufacturing industry, the distribution of R&D is even more skewed toward large companies, with the R&D activities of General Motors, Ford, and DaimlerChrysler dominating the sector. In their reports to the Securities and Exchange Commission, these companies noted R&D expenses of $20.8 billion in 2006 (IEEE 2009). In addition to NSF statistics, other sources of indicators for business R&D include surveys conducted by the Industrial Research Institute (IRI) and companies' own annual reports. (See sidebar "Trends in R&D for Industrial Research Institute Members."[22])

Federal R&D

The government supports S&T through a number of policy measures, the most direct of which is the conduct and funding of R&D that would not or could not be conducted or financed in the private sector. This section presents data on federally funded R&D activities, on the government's contribution to the U.S. R&D infrastructure, and on federal R&D tax credits, which serve as an indirect means of stimulating R&D in the private sector.

Trends in R&D for Industrial Research Institute Members

For more than 20 years, the Industrial Research Institute (IRI), a nonprofit association of more than 200 leading, R&D-performing, manufacturing and service companies, has surveyed its U.S.-based members on their intentions for the coming year with respect to R&D expenditures, focus of R&D, R&D personnel, and other items. Because IRI member companies carry out a large amount of industrial R&D in the United States, the results of these surveys help identify broad trends in corporate R&D strategies.

The most recent survey, administered during the summer of 2008, suggests that many companies continue to shift the focus of their R&D spending away from directed basic research and the support of existing business to new business projects (IRI 2009). As reflected in IRI's Sea Change Index,* IRI survey respondents also reported the following plans and expectations for 2009:

- Increase outsourcing of R&D to other companies
- Increase outsourcing to universities and participation in academic consortia
- Increase outsourcing to federal laboratories
- Increase participation in alliances and joint R&D ventures
- Increase acquisition of technological capabilities through mergers and acquisitions
- Increase spin-offs based on developed technology
- Maintain total company expenditures for R&D
- Maintain level of technology licensing to others

Overall, these strategic moves are consistent with companies' expectations of flat R&D budgets.

---

*IRI states that its Sea Change Index likely "understates the absolute value of change," but the association believes it to be a "good indicator of the direction of change." See IRI (2009) for details.

R&D Funding in Current Federal Budget

The budget appropriations for federal spending on R&D in FY 2009 (signed into law in March 2009) totaled $147.1 billion (table 4-7), an increase of $3.3 billion, or 2.3%, over the enacted FY 2008 spending level of $143.7 billion. The president's proposed FY 2010 budget includes requests for spending on R&D of $147.6 billion, an increase of $0.6 billion, or 0.4%, over the appropriated FY 2009 level.

In addition, a one-time but sizable increase in budget authority for federal R&D was provided by the American Recovery and Reinvestment Act (ARRA) (Public Law 111-5) in early 2009. In a preliminary estimate (May 2009), the White House's Office of Science and Technology Policy placed the overall increase of federal R&D and R&D infrastructure funding from ARRA at about $18.3 billion in FY 2009 (table 4-7).

Adjusted for inflation, the enacted federal budget for FY 2009 represents a 0.8% increase in constant dollars. The increase proposed by the president for FY 2010 represents a constant-dollar decline of 0.6%. The ARRA funding is a sizable increase, whether in current-dollar or inflation-adjusted

Table 4-7
Federal budget authority for R&D and R&D plant: FY 2008–10
(Millions of current dollars)

Performer/character of work	FY 2008 Actual	FY 2009 Enacted	FY 2009 ARRA[a]	FY 2010 Requested	Annual change (%)[b] 2008–09	Annual change (%)[b] 2009–10
All R&D, R&D facilities and equipment	143,746	147,065	18,335	147,620	2.3	0.4
DOD (military)	82,278	81,616	300	79,687	–0.8	–2.4
HHS	29,265	30,415	11,103	30,936	3.9	1.7
NIH	28,547	29,748	10,400	30,184	4.2	1.5
All other HHS R&D	718	667	703	752	–7.1	12.7
NASA	11,182	10,401	925	11,439	–7.0	10.0
DOE	9,807	10,621	2,446	10,740	8.3	1.1
NSF	4,580	4,857	2,900	5,312	6.0	9.4
USDA	2,336	2,421	176	2,272	3.6	–6.2
DOC	1,160	1,292	411	1,330	11.4	2.9
NOAA	625	700	1	644	12.0	–8.0
NIST	498	550	410	637	10.4	15.8
VA	960	1,020	0	1,160	6.3	13.7
DHS	995	1,096	0	1,125	10.2	2.6
DOT	875	913	0	939	4.3	2.8
DOI	683	692	74	730	1.3	5.5
USGS	586	611	74	649	4.3	6.2
EPA	551	580	0	619	5.3	6.7
ED	313	323	0	384	3.2	18.9
All other	761	818	0	947	7.5	15.8
Research	56,026	58,647	13,285	59,023	4.7	0.6
Basic	28,613	29,881	11,365	30,884	4.4	3.4
Applied	27,413	28,766	1,920	28,139	4.9	–2.2
Development	83,254	83,887	1,408	84,054	0.8	0.2
R&D facilities and equipment	4,466	4,531	3,642	4,543	1.5	0.3
Defense R&D	84,337	85,426	300	83,760	1.3	–2.0
Nondefense R&D	59,409	61,639	18,035	63,860	3.8	3.6
All R&D, R&D facilities and equipment (2000 constant $millions)	117,286	118,267	14,745	117,532	0.8	–0.6

ARRA = American Recovery and Reinvestment Act; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NIST = National Institute of Standards and Technology; NOAA = National Oceanic and Atmospheric Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; USGS = U.S. Geological Survey; VA = Department of Veterans Affairs

[a] Based on preliminary allocations of ARRA. These figures may change.

[b] Excludes appropriations from ARRA. Change is FY 2008 actual appropriations to FY 2009 enacted appropriations; FY 2009 enacted appropriations to FY 2010 requested appropriations.

SOURCES: Office of Management and Budget, Budget of the United States Government for Fiscal Year 2010, 7 May 2009; and Office of Science and Technology Policy, Executive Office of the President, Federal R&D, Technology, and STEM Education in the 2010 Budget, 7 May 2009.

Science and Engineering Indicators 2010

terms. The overall effects on the growth of federal R&D funding in either year depends on whether added spending under ARRA occurs in FY 2009 or FY 2010.

The largest increases among the agencies in the FY 2009 budget for R&D go to the National Institutes of Health (NIH), with an increase of $1.2 billion; the Department of Energy (DOE), up $814 million; and NSF, up $277 million (table 4-7). These same agencies are also major recipients of ARRA funds (table 4-7): $10.4 billion to NIH for added biomedical research and laboratory renovation and construction; $2.9 billion to NSF for increased basic research, education and human resources, research facility construction, and research instrumentation; and $2.4 billion to DOE for new collaborations at the frontiers of energy research and infrastructure investments at the national laboratories. In addition, $925 million goes to the National Aeronautics and Space Administration (NASA) for accelerated activities in earth science climate research missions and the development of a next-generation air transport system. Another $410 million goes to the National Institute of Standards and Technology (NIST) for new standards research, advanced measurement equipment, and construction of research facilities.

The president's FY 2010 proposal for federal R&D notes investment priorities in four main areas, as follows:

- Sciences for a prosperous America—increased federal support for basic research. This focus recognizes that new fundamental knowledge and technology have often fueled the creation of new industries with associated high-technology and high-wage jobs.
- A clean energy future—expanded investment in research, development, demonstration, and deployment of clean energy technologies to help reduce U.S. dependence on oil, create green jobs, and limit the impact of climate change. (See sidebar "Public Investment in Energy R&D.")
- Healthy lives for all Americans—increased funding for biomedical and health research.
- A safe and secure America—development of better science and technology to improve the prediction and prevention of, and the reaction to, destabilizing or paralyzing natural and man-made threats; improve capabilities for biodefense; and monitor nuclear nonproliferation compliance and prevent the surreptitious entry of weapons of mass destruction (OSTP 2009).

Federal R&D Budget by National Objectives

To assist Congress and the president in evaluating and setting the federal budget and its components, the Office of Management and Budget classifies agency budget requests into specific categories called *budget functions*. Budget functions represent a wide range of national objectives that the government wants to advance, from defense to health to transportation.

Defense-Related R&D

In the FY 2008 budget, defense was the largest budget function, accounting for $81.1 billion (current dollars), or 59% of the federal R&D budget (appendix table 4-17). Nondefense functions totaled $56.9 billion. Defense R&D is supported by DOD, DOE, and the Department of Homeland Security (DHS), with DOD accounting for $78 billion in FY 2008.

The proportional split between defense and nondefense R&D has fluctuated over the past several decades (figure 4-7). In FY 1980, federal budget authority for defense-related R&D roughly equaled nondefense R&D. During the next several years, however, defense R&D expanded rapidly. By FY 1985, defense R&D budget authority more than doubled that of nondefense R&D. In contrast, between 1986 and 2001 nondefense surged, and the gap between defense and nondefense R&D budgets shrank almost every year. In FY 2001, the defense budget function represented 53% of the federal R&D budget. The trend reversed yet again after September 11, 2001, as defense R&D became more prominent, accounting for 59% of the federal R&D budget in FY 2008.

Civilian-Related R&D

The most dramatic change in federal R&D priorities over the past 25 years has been the increase in health-related R&D (figure 4-7), which rose from 25% of the federal nondefense R&D budget allocation in FY 1980 to 55% in FY 2005. Growth accelerated after 1998, when policymakers set the NIH budget on course to double by FY 2003. In FY 2008, health-related R&D represented 52% of nondefense R&D, even though recent increases have been below the level of inflation.

The budget allocation for space-related R&D peaked in the 1960s, during the height of the nation's efforts to surpass the Soviet Union in space exploration. The loss of the Space Shuttle *Columbia* and its entire crew in February 2003 prompted curtailment of manned space missions. In more recent years, NASA's nondefense R&D budget share has increased, growing from 14% in FY 2005 to 17% in FY 2008. Nearly 58% of NASA's $17 billion budget in FY 2008 was allocated for R&D; adjusted for inflation, the space-related R&D total was higher in FY 2008 than at any time since FY 1999.

Federal nondefense R&D classified as general science had about a 9% share in the mid 1990s, growing to 14% in FY 2008. However, this change reflected chiefly a reclassification of several DOE programs from energy to general science in FY 1998.

With respect to the federal budget for basic research, 94% of the funding in FY 2008 resided in nondefense budget functions (appendix table 4-18). In large part, this reflects the budgets of agencies with nondefense objectives such as general science (notably NSF), health (NIH), and space research and technology (NASA). Over the past several years, budget authority for basic research (which is not equivalent to general science R&D) has been flat after adjusting for inflation.

Public Investment in Energy R&D

International public investment in energy research, development, and demonstration (hereafter R&D) has grown by about 30% over the 1997–2007 period, from $8.6 billion to $11.3 billion in inflation-adjusted dollars (figure 4-A). The data reflect annual energy R&D reports, by technology type, submitted by member governments of the International Energy Agency (IEA). These data provide insight into governmental R&D priorities in this area. The data do not include industry-funded activities in the listed energy types, nor do they cover broader activities that seek energy savings or reductions in such areas as industrial production and automotive and aircraft design.

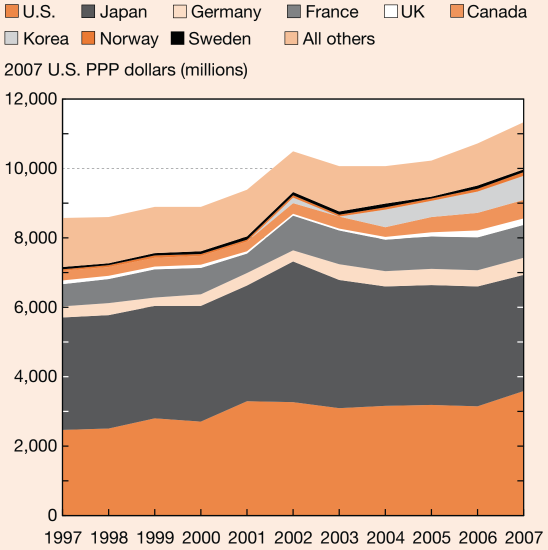
The U.S. and Japanese governments reported by far the largest energy R&D government funds, fluctuating around 30% of the reported IEA total for the United States and declining from 38% to 30% for Japan. France, Germany, and the United Kingdom, which are very broadly similar in overall R&D spending, committed very different public investments to energy R&D, with France's funding being much larger than expected relative to the other two countries. South Korea invested more than the combined total of the United Kingdom and Germany.

The biggest energy type is nuclear fission and fusion (figure 4-B), which consumed 38% of the 2007 amount—down from 48% in 1997—and showed share losses in many major countries: from 75% to 65% in Japan, from 92% to 60% in France, and from 56% to 33% in Germany. In the United States, the energy share of nuclear fission/fusion rose from a low of 10% in 2002 to 18% in 2007—still well below the level of most other major countries.

R&D in hydrogen and fuel cell energy is of most recent vintage. It represented about 7% of the IEA 2007 total; Canada stood out with 16% of its energy R&D funds in hydrogen and fuel cell technology. R&D in renewable energy has slowly risen to about 12% of the total, from 8% a decade ago; the United Kingdom led in renewable energy, with an increase from 9% to 36%; Sweden's level was high at 33%, as was Germany's at 22%.

The quest for energy efficiency received a fairly steady 13% of total energy R&D budgets, although the budget share was less in Germany, France, and the United Kingdom. All other technologies combined averaged about 20% but garnered twice that level in the United States and much less than the IEA average in Japan and France.

Figure 4-A
Energy R&D budgets of national governments of selected IEA members: 1997–2007

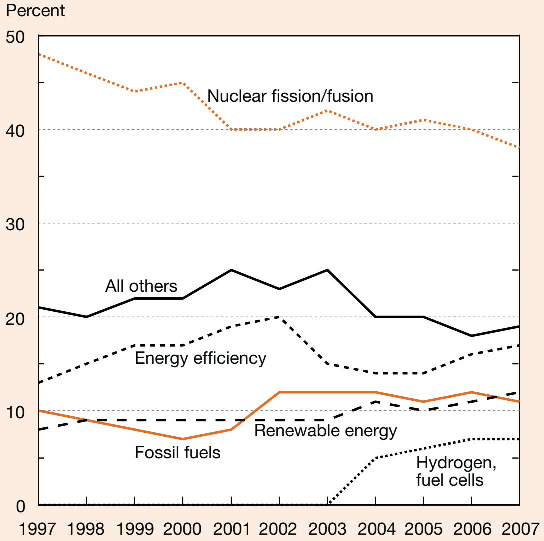


IEA = International Energy Agency; PPP = purchasing power parity; R&D = research, development, and demonstration

SOURCE: IEA, http://wds.iea.org, accessed 31 July 2009.

Science and Engineering Indicators 2010

Figure 4-B
Combined energy R&D budgets of IEA members, by technology type: 1997–2007



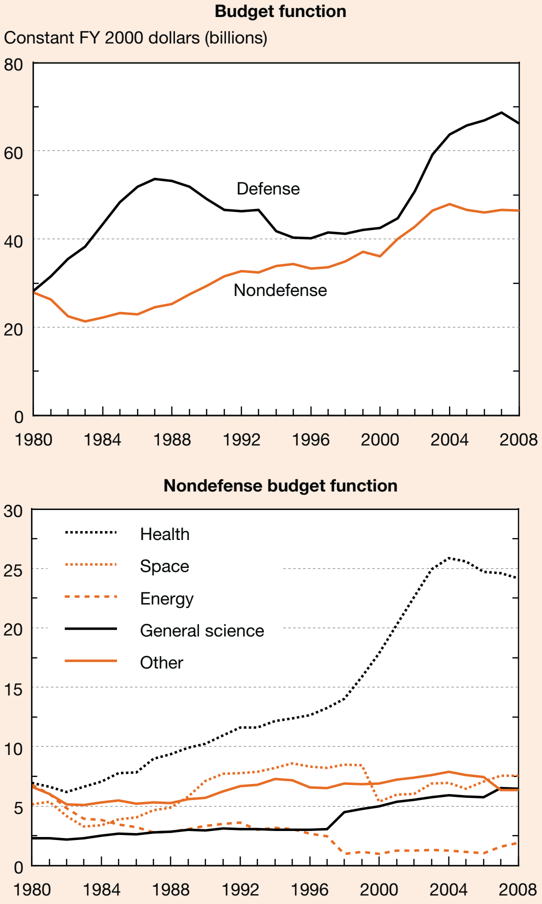
IEA = International Energy Agency; R&D = research, development, and demonstration

NOTE: Percentage of totals reported by all IEA members.

SOURCE: IEA, http://wds.iea.org, accessed 31 July 2009.

Science and Engineering Indicators 2010

Figure 4-7
Federal R&D budget authority, by budget function: FY 1980–2008



NOTES: Figures for FY 2008 are preliminary. Other includes all nondefense functions not separately graphed, such as agriculture and transportation. 1998 increase in general science and decrease in energy, and 2000 decrease in space were results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal R&D Funding by Budget Function: Fiscal Years 2007–09. See appendix table 4-17.

Science and Engineering Indicators 2010

In FY 2003, basic research budget authority was $23.8 billion (constant 2000 dollars); in FY 2008, $23.4 billion.

Federal Spending on R&D by Agency

Federal R&D obligations totaled an estimated $114.6 billion in FY 2008 (the most recent year for which complete data are available). An additional $1.8 billion was obligated for R&D plant (facilities and equipment). Federal obligations for R&D have increased annually on a current-dollar basis since the early 1990s, but when adjusted for inflation, the increases flatten out after FY 2005 (appendix table 4-19).

More than 20 federal agencies fund R&D in the United States. In FY 2008, seven agencies committed more than $1 billion each for R&D (figure 4-8; table 4-8; table 4-9; appendix table 4-20). These agencies accounted for about 96% of total federal R&D obligations that year.

Department of Defense

DOD funds more than half of all federal R&D, having provided an estimated $58.7 billion (51%) in FY 2008. Of this total, $51.8 billion, or 88%, went to development, the majority ($45.8 billion) being allocated for “major systems development,” which includes the primary activities for developing, testing, and evaluating combat systems.

Extramural performers received 71% of DOD’s R&D obligations ($41.8 billion), the bulk going to industrial firms ($38.6 billion). DOD accounted for about 84% of all federal R&D funding to industry in FY 2008. DOD intramural R&D accounted for 26%, and FFRDC R&D accounted for 3%.

Department of Health and Human Services

The Department of Health and Human Services (HHS) is the primary federal source of funding for health-related R&D. In FY 2008, it obligated an estimated $29.7 billion, or 26% of all federal R&D, most ($28.5 billion) being R&D funding by NIH. HHS R&D funding is almost entirely allocated for research (almost 54% for basic and 46% for applied). Development activities accounted for less than 1% of the HHS total.

Extramural performers accounted for 80% ($23.8 billion) of FY 2008 HHS R&D obligations. Universities and colleges received $17.1 billion; other nonprofit research organizations, $4.4 billion. HHS provided about 67% of all federal R&D funds distributed to universities and colleges in FY 2008 and 74% of federal R&D funds distributed to nonprofit institutions.

Department of Energy

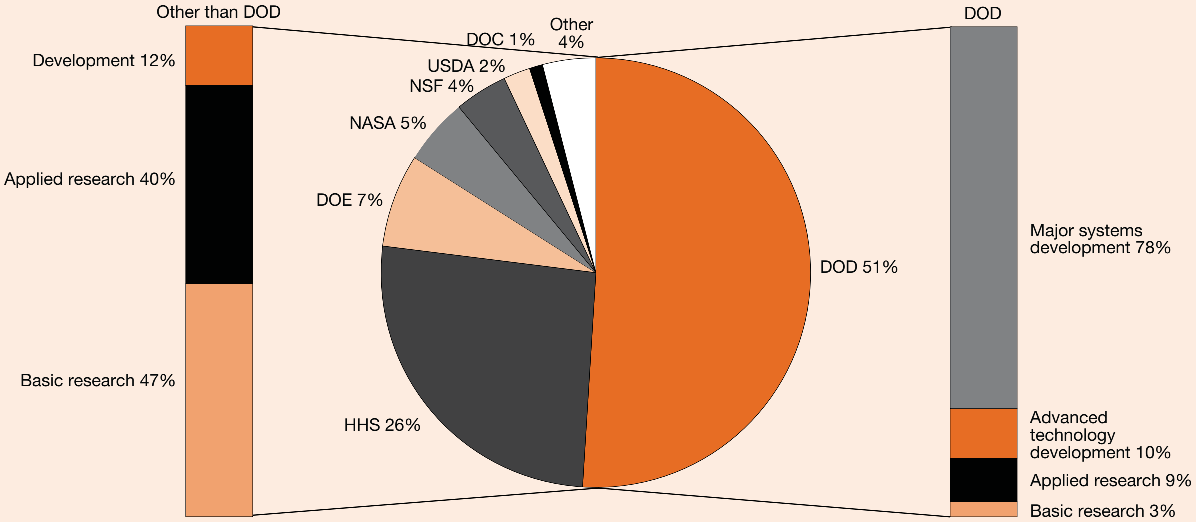
DOE obligated an estimated $8.2 billion to R&D in FY 2008, 7% of the federal R&D total. Research accounted for 76% of these obligations (40% for basic and 36% for applied). FFRDCs received about 66% of DOE R&D obligations. Many of DOE’s research activities require specialized equipment and facilities available only at its intramural laboratories and FFRDCs. Accordingly, DOE invests more resources in FFRDCs than other agencies. In FY 2008, DOE funds accounted for 59% of all federal R&D obligations to FFRDCs.

National Aeronautics and Space Administration

NASA obligated an estimated $6.2 billion to R&D in FY 2008, 5% of the federal R&D total. Of this R&D support, 66% funded development activities; 21%, basic research; and 13%, applied research. Extramural R&D (chiefly by industry performers) accounted for 64% of NASA’s R&D obligations in FY 2008. Agency intramural activities represented 19%—and FFRDC activities, another 17%—of the NASA R&D total.

Figure 4-8

Projected federal obligations for R&D, by agency and character of work: FY 2008



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTE: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–09. See appendix table 4-30.

Science and Engineering Indicators 2010

Table 4-8

Federal obligations for research and development, by agency and character of work: FY 2008

(Millions of current dollars)

Agency	Obligations for total R&D	Basic research	Applied research	Development	Basic research (%)	Applied research (%)	Development (%)
All federal government	114,625	27,559	27,538	59,528	24.0	24.0	51.9
DOD	58,676	1,510	5,345	51,821	2.6	9.1	88.3
HHS	29,657	15,989	13,594	74	53.9	45.8	0.2
DOE	8,212	3,243	2,917	2,052	39.5	35.5	25.0
NASA	6,243	1,298	829	4,117	20.8	13.3	65.9
NSF	4,031	3,692	340	0	91.6	8.4	0.0
USDA	2,357	990	1,197	170	42.0	50.8	7.2
DOC	1,062	108	861	93	10.2	81.1	8.8
DOT	885	3	638	245	0.3	72.0	27.7
DHS	847	191	77	579	22.5	9.1	68.3
DOI	625	43	513	68	6.9	82.1	10.9
EPA	557	97	379	81	17.4	68.1	14.5
VA	480	211	246	23	44.0	51.2	4.8
ED	325	4	202	119	1.3	62.0	36.7
Smithsonian Institution	148	148	0	0	100.0	0.0	0.0
AID	138	6	132	0	4.1	95.9	0.0
All other	382	26	270	86	6.9	70.6	22.5

AID = Agency for International Development; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; VA = Department of Veterans Affairs

NOTES: Table lists all agencies with R&D obligations greater than $100 million in FY 2008. Figures for FY 2008 are preliminary.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–09.

Science and Engineering Indicators 2010

Table 4-9

Federal obligations for research and development, by agency and performer: FY 2008

(Millions of dollars)

Agency	Obligations for total R&D	Agency intramural	FFRDCs	Extramural performers	Agency intramural (%)	FFRDCs (%)	Extramural performers (%)
All federal government	114,625	26,828	9,171	78,627	23.4	8.0	68.6
DOD	58,676	15,066	1,770	41,840	25.7	3.0	71.3
HHS	29,657	5,287	527	23,843	17.8	1.8	80.4
DOE	8,212	678	5,400	2,135	8.3	65.8	26.0
NASA	6,243	1,198	1,077	3,969	19.2	17.2	63.6
NSF	4,032	16	207	3,808	0.4	5.1	94.5
USDA	2,357	1,497	0	860	63.5	0.0	36.5
DOC	1,062	830	1	231	78.2	0.1	21.7
DOT	885	250	17	618	28.3	1.9	69.8
DHS	847	225	148	475	26.6	17.4	56.0
DOI	625	532	0	93	85.2	0.0	14.8
EPA	557	407	0	150	73.1	0.0	26.9
VA	480	480	0	0	100.0	0.0	0.0
ED	325	13	0	312	4.0	0.0	96.0
Smithsonian Institution	148	148	0	0	100.0	0.0	0.0
AID	138	17	0	121	12.5	0.0	87.5
All other	382	183	25	174	47.9	6.5	45.7

AID = Agency for International Development; DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; ED = Department of Education; EPA = Environmental Protection Agency; FFRDC = federally funded research and development center; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; VA = Department of Veterans Affairs

NOTES: Table lists all agencies with R&D obligations greater than $100 million in FY 2008. Figures for FY 2008 are preliminary. Total R&D is basic research, applied research, and development; does not include R&D plant. Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by federal personnel. Extramural performers includes federally funded R&D performed in the United States and U.S. territories by industry, universities and colleges, other nonprofit institutions, state and local governments, and foreign organizations.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–09.

Science and Engineering Indicators 2010

National Science Foundation

NSF obligated an estimated $4 billion for research in FY 2008. About 92% of NSF's support funded basic research, and 95% funded extramural performers, chiefly universities and colleges ($3.3 billion). NSF is the federal government's primary source of funding for academic, basic S&E research and the second-largest federal source (after HHS) of R&D funds for universities and colleges.

Department of Agriculture

The U.S. Department of Agriculture (USDA) obligated an estimated $2.4 billion for R&D in FY 2008, with the main focus on life sciences. The agency is also one of the largest research funders in the social sciences, particularly agricultural economics. Of USDA's total obligations for FY 2008, about 64% ($1.5 billion) funded intramural R&D, chiefly the Agricultural Research Service.

Department of Commerce

The Department of Commerce (DOC) obligated an estimated $1.1 billion for R&D in FY 2008, mainly for the R&D activities of the National Oceanic and Atmospheric Administration and NIST. Research accounted for 91% of the R&D for the department as a whole (10% for basic research and 81% for applied research); 78% of the total was for intramural R&D; and almost 22% supported extramural performers, primarily universities and colleges.

Other Agencies

Of the other R&D-funding agencies, eight obligated between $100 million and $1 billion for R&D in FY 2008 (table 4-8). This group included the Departments of Transportation, Homeland Security, the Interior, Veterans Affairs, and Education; the Environmental Protection Agency; the Smithsonian Institution; and the Agency for International Development. These agencies also varied with respect to the character of the research and the roles of intramural, FFRDC, and extramural performers.

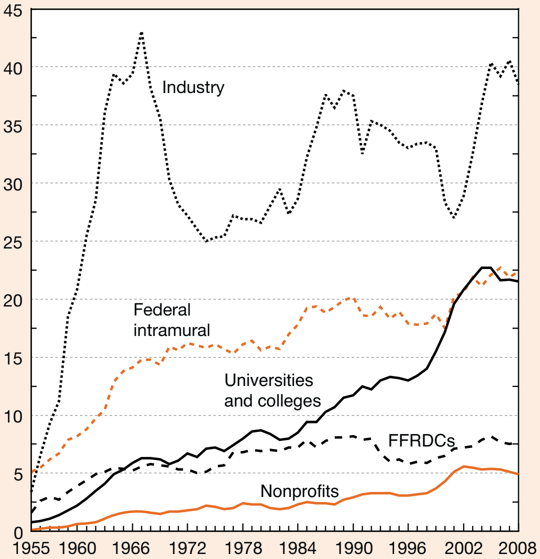
Federal Spending on R&D by Performer

Academia

The federal government has historically been the primary source of funding for R&D performed by universities and colleges. Federal obligations for academic R&D in FY

Figure 4-9
Federal obligations for R&D, by performing sector: FY 1955–2008

Constant FY 2000 dollars (billions)



FFRDC = federally funded research and development center

NOTE: Data for FY 2008 are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007-09.

Science and Engineering Indicators 2010

2008 totaled an estimated $25.7 billion (current dollars). As figure 4-9 illustrates, federal funding for academic R&D generally has increased over the long term. In FY 1955, federal obligations for academic R&D stood at $0.8 billion in constant 2000 dollars and accounted for 7% of all federal R&D funding. In FY 1985, federal obligations to this sector were $9.4 billion, 13% of all federal R&D funding. The corresponding figures for FY 2008 were $21.5 billion and 23%, respectively.

Federal funding of academic R&D grew rapidly after FY 1998, the result of a successful bipartisan effort to double the budget of NIH from its FY 1998 level over the following 5 years. Since FY 2004, however, federal R&D obligations to universities and colleges have failed to keep pace with inflation. (For additional details on academic R&D, see chapter 5.)

Business

Federal obligations for R&D performed by businesses totaled an estimated $46.0 billion in FY 2008. For decades, the business sector has consistently received the bulk of federal R&D funds (figure 4-9).

Space program investments in the 1960s fueled the growth of federal obligations for business R&D, but after the successful Apollo 11 mission to the moon, R&D obligations to industry declined. A decade later, Cold War investments in military technology resulted in a renewed period of growth. Similarly, military investment in the aftermath of September 11, 2001, has increased the flow of federal R&D funding to industry. Adjusting for inflation, federal R&D obligations to industry increased by 42% from FY 2001 to 2008.

The amount of federally funded R&D reported by industry began to diverge from the amount reported by the federal government beginning in FY 1989. For details on this discrepancy, see the sidebar "Tracking R&D: The Gap Between Performer- and Source-Reported Expenditures."

Federal Intramural R&D

Federal obligations for federal intramural R&D totaled an estimated $26.8 billion in FY 2008. These funds supported R&D performed at federal agencies' intramural laboratories, as well as the costs associated with the planning and administration of both intramural and extramural R&D projects.

Among individual agencies, DOD funds the most intramural R&D, having accounted for 56% of all federal obligations for intramural R&D in FY 2008 (table 4-9). DOD's intramural R&D obligations are almost three times those of HHS, the second-largest performer of federal intramural R&D. Only two other agencies reported intramural R&D obligations of more than $1 billion in FY 2008: NASA and USDA.

FFRDCs

Unique organizations in the federal R&D system, FFRDCs were established to help the U.S. government meet special long-term research or development needs that could not be met as effectively by existing in-house or contractor resources. They were first established during World War II to assist DOD and DOE with R&D on nuclear weapons. Today, FFRDCs perform R&D for both defense and civilian applications across a broad range of S&E fields. Of the 37 currently active FFRDCs (appendix table 4-22), 16 are sponsored by DOE, the most of any federal agency. These 16 organizations accounted for about 69% of the R&D obligations of all FFRDCs combined in FY 2007.

Five FFRDCs reported R&D obligations of more than $600 million in FY 2007: Los Alamos National Laboratory (DOE), Jet Propulsion Laboratory (NASA), Lawrence Livermore National Laboratory (DOE), Sandia National Laboratory (DOE), and Oak Ridge National Laboratory (DOE). These five accounted for 55% of the FFRDC total that year. Los Alamos National Laboratory and Lawrence Livermore National Laboratory are the only two laboratories in the United States where research on the nation's nuclear stockpile is conducted.

Federal Spending on Research by Field

Federal agencies fund research (that is, basic research plus applied research, excluding development) in a wide range of S&E fields, from physics and mathematics to aeronautical engineering to sociology. Furthermore, the share of funding for research differs by field, as do the trends in funding over time.

Tracking R&D: The Gap Between Performer- and Source-Reported Expenditures

In some OECD countries, including the United States, figures for total government R&D support reported by government agencies differ from those reported by performers of R&D work. In keeping with international guidance and standards, most countries' national R&D expenditure totals and time series are based primarily on data reported by performers (OECD 2002). Differences may be expected between funder and performer series for many reasons, such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year). Nonetheless, the gap between the two U.S. R&D series has widened over the past decade or more.

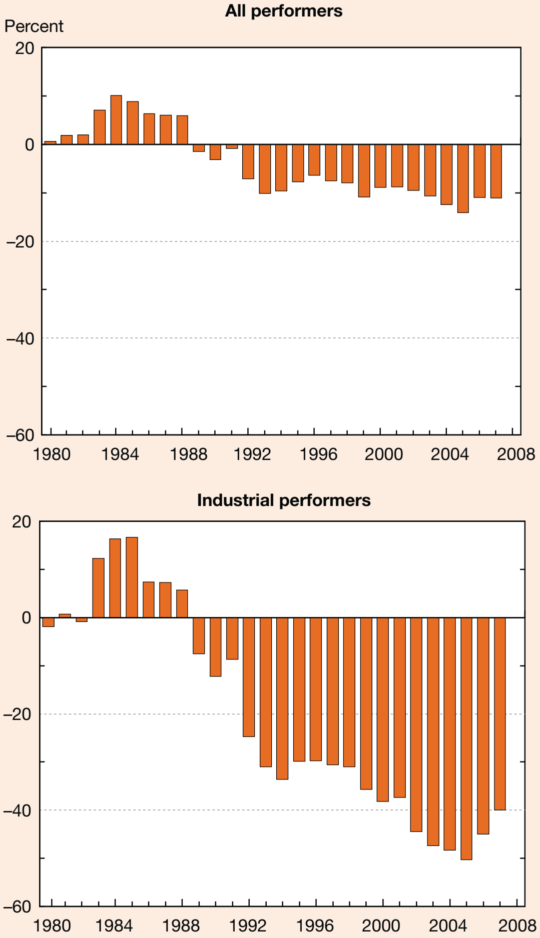
During the mid-1980s, performer-reported federal R&D in the United States exceeded federal reports of funding by $3 to $4 billion annually (5% to 10% of the government total). This pattern reversed itself toward the end of the decade; in 1989, the government-reported R&D total exceeded performer reports by $1 billion. For FY 2007, federal agencies reported obligating $114 billion in total R&D to all R&D performers ($44 billion to the business sector), compared with $101 billion in federal funding reported by the performers of R&D ($27 billion by businesses). In other words, the business-reported total was approximately 40% smaller than the federally reported R&D support to industry in FY 2007 (figure 4-C). The difference in federal R&D totals resided primarily in DOD funding of development activities by industry.

Several investigations into the possible causes for the data gap have produced insights but no conclusive explanation. According to a General Accounting Office investigation (GAO 2001):

> Because the gap is the result of comparing two dissimilar types of financial data [federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist.

Echoing this assessment, the National Research Council (2005a) noted that comparing federal outlays for R&D (as opposed to obligations) to performer expenditures results in a smaller discrepancy. In FY 2007, federal agencies reported total R&D outlays of $109 billion.

Figure 4-C
Discrepancy in U.S. performer-reported and agency-reported federal R&D: 1980–2007



NOTE: Difference defined as percentage of federally reported R&D, with positive difference indicating that performer-reported R&D exceeds agency-reported R&D.

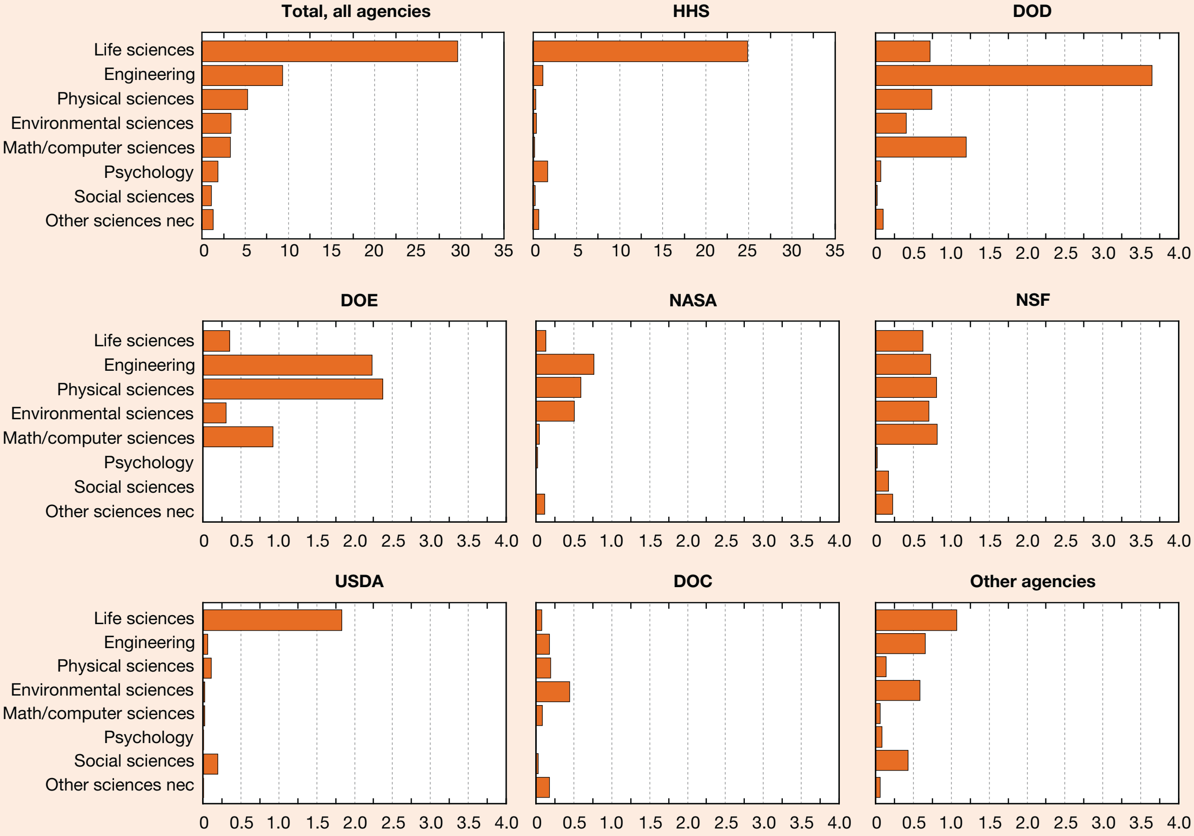
SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), National Patterns of R&D Resources (annual series); and NSF/SRS, Federal Funds for Research and Development: Fiscal Years 2007–09 (forthcoming). See appendix table 4-21.

Science and Engineering Indicators 2010

In FY 2008, an estimated $55.1 billion (48%) of the $114.6 billion for all R&D supported research. Of this total, $29.7 billion (54%) supported research in the life sciences (figure 4-10; appendix table 4-23). The fields with the next-largest amounts were engineering ($9.4 billion, 17%) and the physical sciences ($5.2 billion, 10%), followed by environmental sciences ($3.3 billion, 6%), and mathematics and computer sciences ($3.3 billion, 6%). The balance of

Figure 4-10
Federal obligations for research, by agency and major S&E field: FY 2008

(Billions of current dollars)



nec = not elsewhere classified; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

NOTES: Scale differs for total and HHS compared to the other agencies listed. Figures for FY 2008 are preliminary. Research includes basic and applied research.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2007–2009. See appendix table 4-23.

Science and Engineering Indicators 2010

federal obligations for research in FY 2008 supported the social sciences, psychology, and all other sciences ($4.2 billion overall, 8% of the total for research).

HHS, primarily through NIH, accounted for the largest share (54%) of federal obligations for research in FY 2008. Most of this amount funded research in medical and related life sciences. The five next-largest federal agencies for research funding that year were DOD (12%), DOE (11%), NSF (7%), USDA (4%), and NASA (4%).

DOD's research funding emphasized engineering ($3.7 billion), and mathematics and computer sciences ($1.2 billion). DOE provided substantial funding for research in the physical sciences ($2.4 billion) and engineering ($2.2 billion), whereas USDA's research funding was chiefly directed at the life sciences ($1.8 billion). NASA's research funding emphasized engineering ($0.8 billion), followed by the physical sciences ($0.6 billion) and environmental sciences ($0.5 billion). NSF, which has a mission to "promote the progress of science," had a relatively balanced research portfolio, contributing between $0.6 and $0.8 billion to researchers in each of the following fields: mathematics and computer sciences, physical sciences, engineering, environmental sciences, and life sciences.

From 1986 to 2008, real growth in federal obligations for research averaged 3.2% per year, increasing from $23.1 billion in 2000 dollars in FY 1986 to $45.0 billion in FY 2008 (appendix table 4-24). The fields that experienced higher-than-average growth during this period were mathematics and computer sciences (5.5% per year in real terms), life sciences (4.8%), and psychology (5.8%). Funding for the remaining fields also grew at a faster rate than inflation over this period: social sciences (1.9%), engineering (1.8%), and environmental sciences (1.3%).

Federal R&D Tax Credits

Background

Contributions of R&D to economic growth and social welfare, along with likely underinvestment by private performers, given the difficulty in fully appropriating R&D benefits, are often cited as reasons for justifying public support for R&D (NRC 2005b).[23] In addition to direct government funding discussed earlier in this chapter, fiscal policy tools used to provide such support include tax incentives.[24] The federal government offers several corporate tax incentives for qualified R&D expenditures including a deduction under Internal Revenue Code (IRC) section 174 (C.F.R. Title 26) and a tax credit under section 41. As of 2006, at least 32 states also offered credits for company-funded R&D (NSB 2008; Wilson forthcoming). This section focuses on business R&D tax credits at the federal level.

The research and experimentation (R&E) tax credit, established by the Economic Recovery Tax Act of 1981 (Public Law 97-34), covers R&D activities performed in the United States by domestic and foreign-owned firms but excludes R&D conducted abroad by U.S. companies. It is subject to periodic extensions and, at the time of writing, was last renewed by the Emergency Economic Stabilization Act of 2008[25] through 31 December 2009.

The R&E tax credit encompasses a regular credit, as well as credits for payments for basic research to qualified universities, scientific research organizations, or grant organizations, and for payments to energy research consortia. Under the regular credit, companies can take a 20% credit for qualified research above a base amount for activities undertaken in the United States (IRC section 41(a)(1)).[26] Thus, the regular credit is characterized as a fixed-base incremental credit. An incremental design is intended to encourage firms to spend more on R&D than they otherwise would by lowering after-tax costs. At the same time, the actual or effective credit rate for corporate taxpayers is lower than 20% because of limitations involving deductions under IRC section 174 (Guenther 2008).[27]

Federal Corporate Tax Credit Claims

According to the IRS Statistics of Income Division (SOI),[28] U.S. companies claimed an estimated $7.3 billion in federal R&E tax credits in 2006, involving close to 11,000 corporate tax returns, compared with $6.4 billion in 2005 (table 4-10).[29] The proportion of R&E credits going to corporations with business receipts of $250 million or more has fluctuated narrowly between 75% and 80% since 2003 and was 75% in 2006.[30]

For all industries, the size of R&E claims was about 3.3% relative to company-funded R&D in 2006, a proportion that has changed little in recent years (figure 4-11). Appendix tables 4-25 and 4-26 show data by NAICS industry up to 2005 (latest available year by detailed industry). Five industries accounted for about three-quarters of R&E credit claims in 2005. These industries had much higher ratios of R&E claims to industry-funded R&D: computer and electronic products (26%); chemicals, including pharmaceuticals and

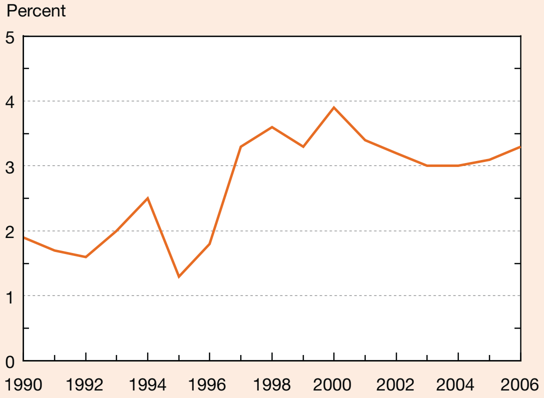
Table 4-10
Federal research and experimentation tax credit claims and corporate tax returns claiming credit: 1990–2006

Year	Tax credit claims ($millions)	Tax returns
1990	1,547	8,699
1991	1,585	9,001
1992	1,515	7,750
1993	1,857	9,933
1994	2,423	9,150
1995	1,422	7,877
1996	2,134	9,709
1997	4,398	10,668
1998	5,208	9,849
1999	5,281	10,019
2000	7,079	10,495
2001	6,356	10,389
2002	5,656	10,254
2003	5,488	10,369
2004	5,554	10,244
2005	6,363	11,290
2006	7,311	10,788

SOURCE: Internal Revenue Service, Statistics of Income, special tabulations (historical data), http://www.irs.gov/taxstats/article/0,,id=164402,00.html (2006), accessed 19 June 2009.

Science and Engineering Indicators 2010

Figure 4-11
Research and experimentation credit claims as percentage of industry-funded R&D: 1990–2006



SOURCES: Internal Revenue Service, Statistics of Income, special tabulations; and National Science Foundation, Survey of Industrial Research and Development (annual series).

Science and Engineering Indicators 2010

Comparing International R&D Expenditures

Comparisons of international R&D statistics are hampered by the lack of R&D-specific exchange rates. If countries do not share a common currency, some conversion must be made to compare their R&D expenditures. Two approaches are commonly used to facilitate international R&D comparisons: (1) normalize national R&D expenditures by dividing by GDP, thereby obviating the need for currency conversion altogether or (2) convert all foreign-denominated expenditures to a single currency, resulting in indicators of absolute effort. The first method is a straightforward calculation but permits only gross national comparisons of R&D intensity. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D, but it entails choosing an appropriate method of currency conversion.

Because no widely accepted R&D-specific exchange rates exist, the choice is between market exchange rates (MERs) and purchasing power parities (PPPs). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

MERs. At their best, MERs represent the relative value of currencies for goods and services that are traded across borders. That is, MERs measure a currency's relative international buying power. Nevertheless, MERs may not accurately reflect the true cost of goods or services that are not traded internationally. In addition, fluctuations in MERs as a result of currency speculation, political events (such as wars or boycotts), and official currency intervention greatly impair their statistical utility—despite the fact that such occurrences have little or nothing to do with changes in the relative prices of internationally traded goods.

PPPs. PPPs were developed because of the shortcomings of MERs (Ward 1985). PPPs take into account the cost differences across countries of buying a similar market basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is thereby assumed to be representative of total GDP across countries.

Although the goods and services included in the market basket used to calculate PPP rates differ from the major components of R&D costs (fixed assets, as well as wages of scientists, engineers, and support personnel), they still result in a more suitable domestic price converter than one based on foreign trade flows. Exchange-rate movements bear little relationship to changes in the cost of domestically performed R&D. The adoption of the euro as the common currency for many European countries provides a useful example: although Germany and Portugal now share a common currency, the real costs of most goods and services are substantially less in Portugal. PPPs are, therefore, the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official R&D tabulations of the OECD.*

Because MERs tend to understate the domestic purchasing power of developing countries' currencies, PPPs can produce substantially larger R&D estimates than MERs for these countries. For example, China's 2006 R&D expenditures (as reported to the OECD) are $38 billion using MERs but $87 billion using PPPs. (Appendix table 4-2 lists the relative difference between MERs and PPPs for a number of countries.)

Although PPPs are available for developing countries, such as India and China, they may be less useful for converting R&D expenditures in such countries than in more developed countries for a number of reasons:

- It is difficult or impossible to assess the quality of PPPs for some countries, most notably China. Although PPP estimates for OECD countries are quite reliable, PPP estimates for developing countries are often rough approximations. The latter estimates are based on extrapolations of numbers published by the United Nations International Comparison Program and by Professors Robert Summers and Alan Heston of the University of Pennsylvania and their colleagues.
- The composition of the market basket used to calculate PPPs likely differs substantially between developing and developed countries. The structural differences in the economies of developing and developed countries, as well as disparities in income, may result in a market basket of goods and services in a developing country that is quite different from that of a developed country, particularly as far as these baskets relate to the various costs of R&D.
- R&D performance in developing countries often is concentrated geographically in the most advanced cities and regions in terms of infrastructure and level of educated workforce. The costs of goods and services in these areas can be substantially greater than for the country as a whole.

---

*Recent research raises some questions about the use of GDP PPPs for deflating R&D expenditures. In analyzing the manufacturing R&D inputs and outputs of six industrialized OECD countries, Dougherty et al. (2007) conclude that "the use of an R&D PPP will yield comparative costs and R&D intensities that vary substantially from the current practice of using GDP PPPs, likely increasing the real R&D performance of the comparison countries relative to the United States."

medicines (18%); transportation equipment, including motor vehicles and aerospace (13%); information, including software (10%); and professional, scientific, and technical services, including computer and R&D services (10%). The same five industries accounted for 80% of 2005 company-funded R&D from the NSF/Census Survey of Industrial Research and Development.[31]

International R&D Comparisons

Data on R&D expenditures can provide a broad picture of the changing distribution of R&D activities around the world. R&D data available from the OECD cover the organization's 30 member countries and 9 nonmembers. Data from the United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) Institute for Statistics are used here to supplement OECD statistics in order to cover a larger set of countries. Increasingly, these data are collected following OECD standards, but the reader should treat them as broad indicators of trends and patterns rather than as precise measures.

International comparisons involve currency conversions. The discussion here follows the international convention to convert foreign currencies into U.S. dollars via purchasing power parity (PPP) exchange rates. (See sidebar "Comparing International R&D Expenditures.")

Global Patterns of R&D Expenditures

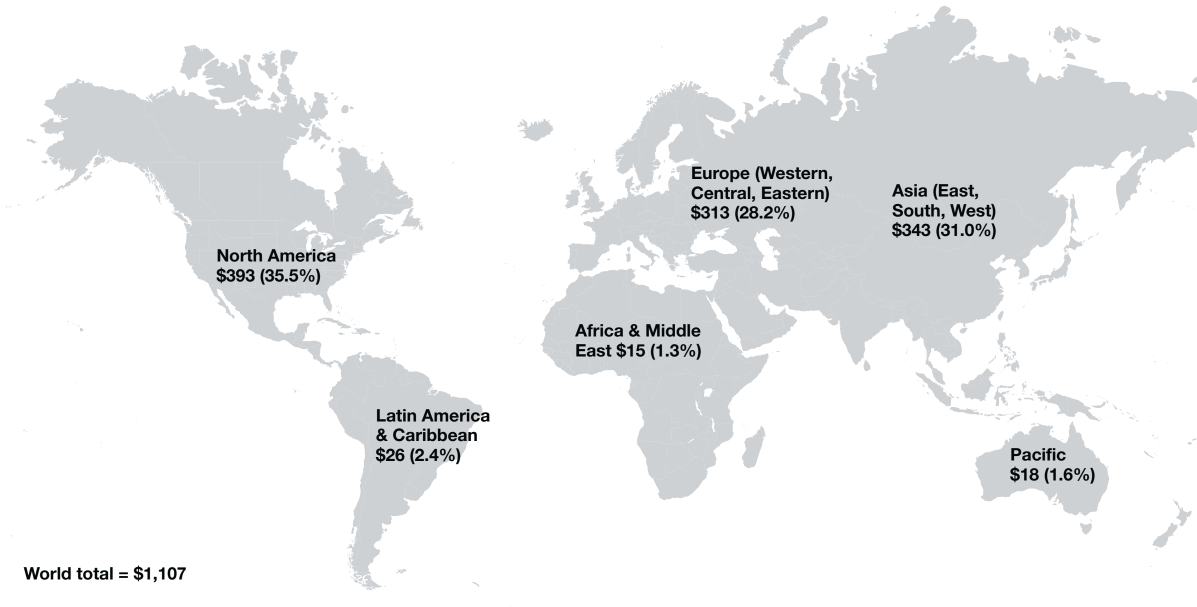
Worldwide R&D expenditures in 2007 totaled an estimated $1,107 billion. Although many countries conduct R&D, much of global R&D performance continues to be concentrated in a few high-income countries and regions.

Three regions predominate (figure 4-12). North America accounts for 35% ($393 billion) of worldwide R&D performance; Asia, 31% ($343 billion); and Europe, 28% ($313 billion). The small remainder, approximately 5%, reflects the R&D of countries in the Latin America/Caribbean, Pacific, and Africa/Middle East regions.

The concentration is more apparent when reviewing the data of specific countries (table 4-11). By itself, the United States accounts for about 33% of the current global R&D total. Japan, the second-largest performer, accounts for about 13%. China (9%) comes next, followed by Germany (6%) and France (4%).

The top two countries thus account for 47% of the global R&D total, whereas the top five countries represent about 66%. Adding the next 5 countries—South Korea,

Figure 4-12
National R&D expenditures and share of world total, by region: 2007
(Billions of U.S. PPP dollars)



PPP = purchasing power parity

NOTES: Foreign currencies converted to dollars through purchasing power parities. Sources track R&D for 126 countries. Some country figures are estimated.

SOURCES: United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org, accessed October 2009; and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

Table 4-11
International comparisons of gross domestic expenditures on R&D and R&D share of gross domestic product, by country/economy/region: Most recent year

Country/economy	GERD (millions PPP$)	GERD/ GDP (%)
Regions/selected countries:		
North America		
United States (2007)	368,799.0	2.68
Canada (2008)	23,781.0	1.82
Latin America and Caribbean		
Mexico (2005)	5,919.0	0.46
Argentina (2007)	2,656.2	0.51
Western Europe		
Germany (2007)	71,860.8	2.54
France (2007)	43,232.6	2.08
United Kingdom (2007)	38,892.8	1.79
Italy (2006)	19,678.1	1.13
Spain (2007)	18,000.3	1.27
Sweden (2007)	12,076.3	3.60
Netherlands (2007)	10,949.8	1.70
Austria (2008)	8,530.1	2.66
Switzerland (2004)	7,474.3	2.90
Belgium (2007)	7,028.3	1.87
Finland (2008)	6,519.7	3.46
Denmark (2007)	5,008.4	2.55
Norway (2007)	4,133.0	1.64
Ireland (2008)	2,855.1	1.45
Portugal (2007)	2,849.7	1.18
Greece (2007)	1,828.4	0.58
Luxembourg (2007)	624.0	1.63
Iceland (2008)	318.2	2.76
Central and Eastern Europe		
Russian Federation (2007)	23,482.0	1.12
Turkey (2007)	6,830.0	0.71
Czech Republic (2007)	3,813.8	1.54
Poland (2007)	3,482.3	0.57
Hungary (2007)	1,822.9	0.97
Romania (2007)	1,433.9	0.53
Slovenia (2007)	828.3	1.53
Slovak Republic (2007)	497.9	0.46
East, South, West Asia		
Japan (2007)	147,800.8	3.44
China (2007)	102,331.0	1.49
South Korea (2007)	41,741.6	3.47
Taiwan (2007)	18,324.8	2.63
Singapore (2007)	5,945.5	2.61
Pacific		
Australia (2006)	14,914.4	2.01
New Zealand (2007)	1,383.7	1.20
Africa and Middle East		
Israel (2007)	8,845.8	4.68
South Africa (2005)	3,654.3	0.92
Selected country groups:		
OECD (2007)	886,347.1	2.29
European Union-27 (2007)	262,985.0	1.77
G-7 countries (2007)	715,329.6	2.53

EU = European Union; GDP = gross domestic product; GERD = gross domestic expenditure on R&D; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTE: Data for Israel is civilian R&D only.

SOURCE: OECD, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

the United Kingdom, the Russian Federation, Canada, and Italy—increases the total to just below 80%, meaning that four-fifths of the world's R&D is concentrated in just 10 countries.

With respect to major geopolitical groupings, the R&D performance of the 27 nations of the European Union (EU-27) currently accounts for about 24% of the global total. The Group of Seven (G-7) industrialized countries, of which the United States is a member (along with Canada, France, Germany, Italy, Japan, and the United Kingdom), account for about 65%. The 30 countries constituting the OECD account for about 80% of worldwide R&D. (Among the current major R&D-performing nations, only China is not an OECD member.)

U.S. dominance of global R&D performance is notable as well with respect to these country groupings. U.S. R&D expenditures are currently 40% greater than the total for all of the EU-27 countries together. Within the G-7, the United States currently accounts for more than half (52%) of the R&D total. (The U.S. share was 48% in 1990. It has exceeded 50% since 1997.) Within the OECD, U.S. R&D is about 42% of the total.

According to OECD statistics (figure 4-13), total R&D by the EU-27 nations has been growing in real dollars over the past 10 years at an average annual rate of 3.3%. The pace of real growth during the same period for Germany, France, and the United Kingdom has been slower: averaging 2.9%, 1.8%, and 3.0%, respectively. By comparison, the U.S. pace of growth, on the same basis, has averaged 3.3%. Growth in Japan has been slower, at an annual average rate of 3.0%. For the OECD as a whole, real growth in R&D expenditures has also expanded on average at a rate of 3.6% annually over the past 10 years.

China continues to show the most dramatic growth pattern. The World Bank revised China's PPP exchange rate in late 2007, significantly lowering the dollar value of its R&D

expenditures. Nonetheless, the pace of real annual growth over the past 10 years in China remains exceptionally high at just above 19%.

Finally, both India and Brazil are among the world's larger R&D performers, although neither has yet become part of OECD's statistical system. According to the UNESCO statistics, India performed $15 billion of R&D in 2004 (current U.S. dollars, PPP) and Brazil performed $13 billion in 2005. Both figures are about double the levels of R&D performance that each country reported in the mid-1990s. These levels of R&D expenditures would put both India and Brazil in the world's top 15 R&D performers.

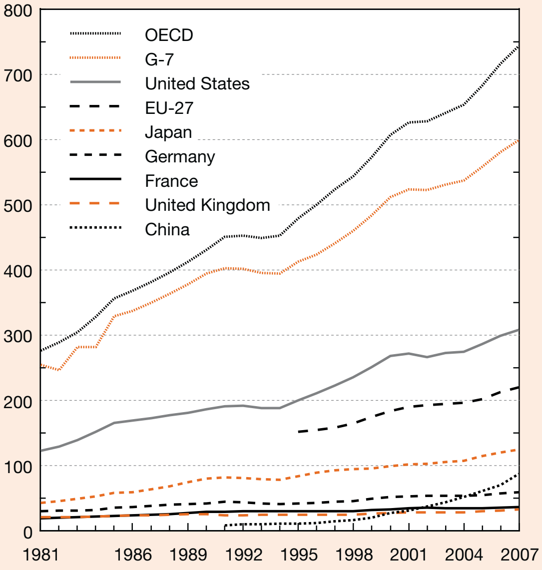
Comparison of Country R&D Intensities

R&D intensity—typically measured as the ratio of a country's national R&D expenditures to GDP for a given year—provides another basis for international comparisons of R&D performance. This approach does not require conversion of a country's currency to a standard international benchmark yet still provides a way to adjust for differences in the sizes of national economies.

Figure 4-13

Gross domestic expenditures on R&D by United States, EU-27, OECD, and selected other countries: 1981–2007

Constant 2000 PPP dollars (billions)



EU = European Union; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTES: Data not available for all countries for all years. U.S. data reflect OECD methodology for calculating gross expenditures on R&D. Japan data for 1996 onward may not be comparable with earlier years because of changes in methodology.

SOURCE: OECD, Main Science and Technology Indicators (2009/1). See appendix table 4-27.

Science and Engineering Indicators 2010

The structure of a national economy—that is, the relative prominence of agriculture, manufacturing, services, and so on—influences the interpretation of R&D intensity statistics. Businesses and organizations differ widely in their relative need for investment in the latest science and technology, and countries whose overall GDP depends considerably on industries in the high-technology sector will exhibit higher R&D/GDP ratios than other countries.

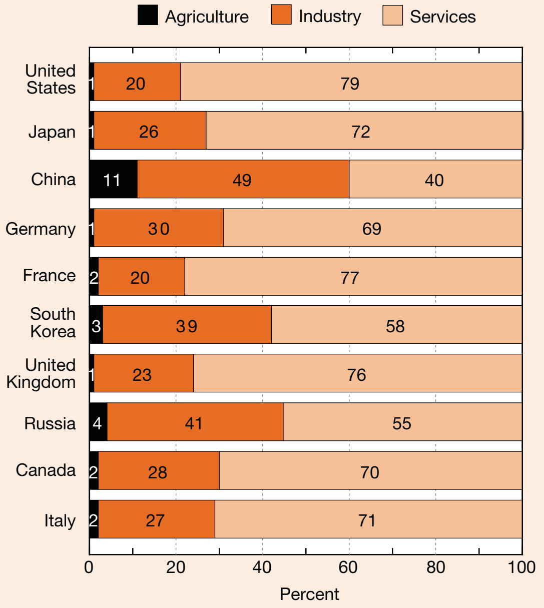
Figure 4-14 provides background information on the GDP composition of the current top 10 R&D-performing countries. Agriculture is a comparatively small component (4% or less) for 9 of these 10 countries; only China is an exception, where agriculture is currently about 11%. For all but four of the countries, services account for 70% or more of current GDP. In China (49%), South Korea (39%), and Russia (41%), industry accounts for a more sizable fraction of GDP.

Total R&D/GDP Ratios

The U.S. R&D/GDP ratio was about 2.7% in 2007 (table 4-11). At this level, the United States is eighth among the economies tracked by the OECD. Israel has the highest ratio at 4.7%, with Sweden, Finland, Japan, and South Korea all above 3%.

Figure 4-14

Composition of gross domestic product for selected countries, by sector: 2008



NOTES: Data for Russia are 2007. Data cover the 10 largest R&D performing countries.

SOURCE: Central Intelligence Agency, *The World Factbook*, http://www.cia.gov/library/publications/the-world-factbook/index.html, accessed 25 February 2009.

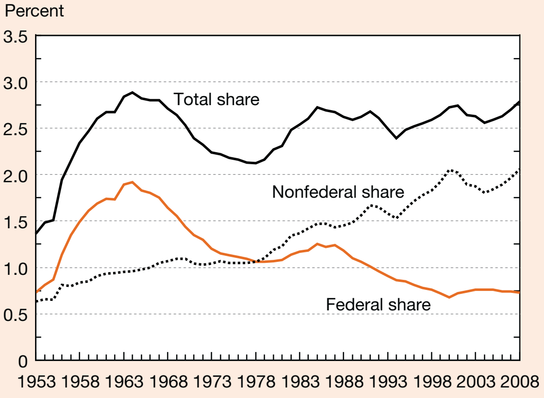
Science and Engineering Indicators 2010

The R&D/GDP ratio in the United States has ranged from 1.4% in 1953 to a high of 2.9% in 1964 and has fluctuated in the range of 2.6% to 2.7% in recent years (figure 4-15). Most of the growth over time in the U.S. R&D/GDP ratio can be attributed to increases in nonfederal R&D spending, financed primarily by business. Non-federally financed R&D increased from about 0.6% of GDP in 1953 to 2.0% of GDP in 2007. This increase in the nonfederal R&D/GDP ratio reflects the growing role of business R&D in the national R&D system and, more broadly, the growing prominence of R&D-derived products and services in the national and global economies.

Historically, the many peaks and valleys in the U.S. R&D/GDP ratio reflect changing federal R&D priorities. The ratio's drop from its peak in 1964 largely resulted from federal cutbacks in defense and space R&D programs; from 1975 to 1979, gains in energy R&D activities kept the ratio stable. Beginning in the late 1980s, cuts in defense-related R&D kept growth in federal R&D spending below GDP growth, while nonfederal growth kept pace with or exceeded that of GDP. Since 2000, defense-related R&D spending has helped federal R&D spending growth outpace the growth of GDP.

Among other top 10 R&D-performing countries, total R&D/GDP ratios over the past 10 years show mixed trends (figure 4-16). Compared with 1996 R&D/GDP ratios, 2007 (or 2006) ratios were substantially higher in Japan, China, and South Korea; modestly higher for Germany and Canada; somewhat higher for Italy and the United Kingdom; and lower for France. Russia's R&D/GDP ratio grew consistently from the late 1990s but has fallen back to only somewhat above its 1996 level in recent years.

Figure 4-15
U.S. R&D share of gross domestic product: 1953–2008



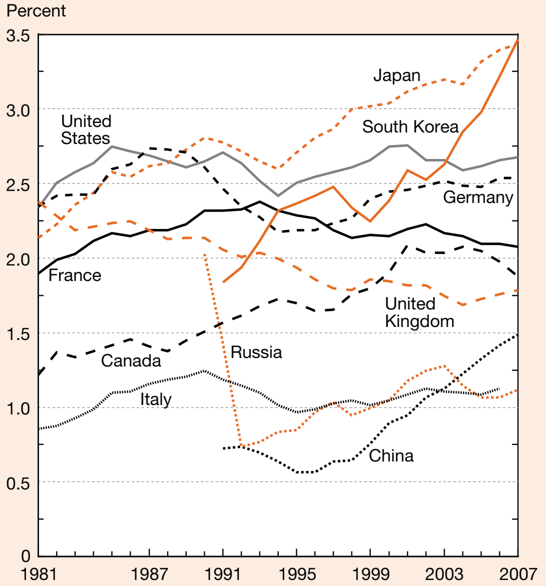
NOTE: Data for 2008 are preliminary.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series).

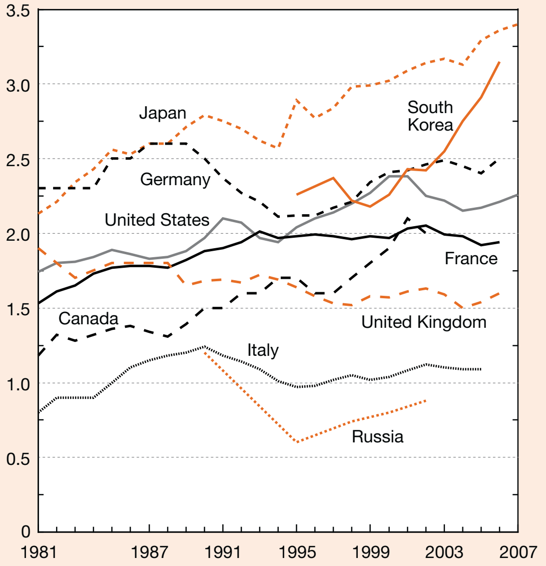
Science and Engineering Indicators 2010

Figure 4-16
Gross expenditures on R&D as share of gross domestic product, for selected countries: 1981–2007

Total R&D/GDP



Nondefense R&D/GDP



GDP = gross domestic product; OECD = Organisation for Economic Co-operation and Development

NOTES: Top 10 R&D performing countries. Data not available for all countries for all years. U.S. data reflect OECD methodology for calculating gross expenditures on R&D. Japan data for 1996 onward may not be comparable with earlier years because of changes in methodology.

SOURCE: OECD, Main Science and Technology Indicators (2009/1). See appendix tables 4-27 and 4-28.

Science and Engineering Indicators 2010

In addition to the United States, countries in Nordic and Western Europe and the most advanced areas of Asia have R&D/GDP ratios above 1.5%. This pattern broadly reflects the global distribution of wealth and level of economic development. Countries with high incomes tend to emphasize the production of high-technology goods and services and are also those that invest heavily in R&D activities. Private sectors in low-income countries often have a low concentration of high-technology industries, resulting in low overall R&D spending and, therefore, low R&D/GDP ratios.

Nondefense R&D and Basic Research

Further perspective is provided by the ratio of nondefense R&D expenditures to GDP. This ratio more directly measures civilian R&D intensity and is useful when comparing nations with substantially different financial commitments to national defense. Figure 4-16 shows the trends since the early 1980s in the nondefense R&D/GDP ratios for 7 of the top 10 R&D-performing nations (for which data are available). Although the U.S. ratio (2.3% in 2007) ranks ahead of that for the United Kingdom, it lags behind Japan, South Korea, and Germany.

Another perspective comes from the extent to which spending on basic research accounts for a country's total R&D/GDP ratio. Estimates of the relative volume of basic research spending can provide a glimpse of the extent to which R&D resources are directed toward advancing the scientific knowledge base.

Based on the most recent data available, the U.S. basic research/R&D ratio is about 0.5% and accounts for less than a fifth of the total R&D/GDP ratio (table 4-12). France's basic research ratio is slightly above the U.S. figure but accounts for nearly a quarter of its total ratio. South Korea's basic research ratio is close to the U.S. and French figures but accounts for less of the total ratio. The basic research ratios for Japan, Italy, and especially China are below the U.S. figure.

The following countries have basic research-to-GDP ratios at or above the U.S. level: Switzerland (0.83%), Israel (0.78%), Singapore (0.48%), Australia (0.45%), and Denmark (0.44%).

R&D by Performing Sector and Source of Funds

In all top 10 countries ranked by R&D expenditures, the business sector is currently the largest performer, ranging from 77% for South Korea and Japan to 49% for Italy (table 4-13). Countries with relatively lower business-sector R&D

Table 4-12

Gross expenditures on R&D as share of gross domestic product, for selected countries: Most recent year

(Percent)

Country	All R&D/GDP	Nondefense R&D/GDP	Share	Basic R&D/GDP	Share
United States (2007)	2.68	2.26	84	0.47	18
Japan (2007)	3.44	3.40	99	0.40	12
China (2007)	1.49	NA	NA	0.05	3
Germany (2006)	2.54	2.50	98	NA	NA
France (2006)	2.10	1.94	92	0.50	24
South Korea (2006)	3.22	3.15	98	0.49	15
United Kingdom (2006)	1.76	1.60	91	NA	NA
Russian Federation (2002)	1.25	0.88	70	0.17	14
Canada (2008)	1.82	NA	NA	NA	NA
Italy(2005)	1.09	1.09	100	0.30	28
Taiwan (2007)	2.63	2.60	99	0.26	10
Spain (2003)	1.05	1.02	97	0.20	19
Australia (2006)	2.01	1.93	96	0.45	22
Sweden (2006)	3.74	3.50	94	NA	NA
Israel (2007)	NA	4.68	NA	0.78	NA
Switzerland (2004)	2.90	2.88	99	0.83	29
Finland (2007)	3.48	3.48	100	NA	NA
Denmark (2005)	2.54	NA	NA	0.44	17
Singapore (2007)	2.61	NA	NA	0.45	17
Ireland (2006)	1.30	1.30	100	0.31	24

NA = not available

GDP = gross domestic product

NOTES: Top 10 R&D performing countries (United States to Italy) and selected other countries. Figures for Israel are civilian R&D only.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

tend to have greater higher education R&D; these countries include Canada, Italy, the United Kingdom, and France. The government sector is particularly prominent in the Russian Federation, Italy, China, and France.

China's business R&D sector has spurred much recent growth in national R&D expenditures, which rose from 60% of the total in 2000 to 72% in 2007. This increase reflects activities by private domestic companies and by multinational companies as well as the conversion of government-owned enterprises to the private sector.

With respect to R&D funding, the business sector supplies 66% of total R&D funds in the United States (table 4-14). In Japan and South Korea, the business sector supplies higher fractions of the total R&D funding than in the United States. Germany's and China's business sectors provide funding shares broadly similar to that of the United States. In France, Canada, the United Kingdom, Italy, and the Russian Federation, the business sector provides smaller shares of total R&D funding, but the government shares are relatively high. Government support for R&D is particularly low in Japan.

More precise analysis is impeded by the lack of comparable data for foreign-funded R&D in the United States (figure 4-17). Russia, the United Kingdom, and Canada had the strongest growth in foreign R&D funds during the 1990s but have recently experienced sharp drops. Foreign R&D funding largely comes from foreign companies but also includes resources from foreign governments and other overseas organizations. For European countries, growth

Table 4-13
Gross expenditures on R&D by performing sector, for selected countries: Most recent year
(Percent)

Country	Business	Government	Higher education	Private nonprofit
United States (2007)	71.9	10.7	13.3	4.2
Japan (2007)	77.9	7.8	12.6	1.7
China (2007)	72.3	19.2	8.5	0.0
Germany (2007)	69.9	13.9	16.2	0.0
France (2007)	63.2	16.5	19.2	1.1
South Korea (2007)	76.2	11.7	10.7	1.4
United Kingdom (2007)	64.1	9.2	24.5	2.1
Russian Federation (2007)	64.2	29.1	6.3	0.3
Canada (2008)	56.1	9.6	33.8	0.5
Italy (2006)	48.8	17.2	30.3	3.7

NOTE: Top 10 R&D performing countries.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

Table 4-14
Gross expenditures on R&D by funding source, for selected countries: Most recent year
(Percent)

Country	Business	Government	Other domestic	Abroad
United States (2007)	66.4	27.7	5.8	NA
Japan (2007)	77.7	15.6	6.3	0.3
China (2007)	70.4	24.6	NA	1.3
Germany (2006)	68.1	27.8	0.4	3.8
France (2006)	52.4	38.4	2.2	7.0
South Korea (2007)	73.7	24.8	1.3	0.2
United Kingdom (2007)	47.2	29.3	5.8	17.7
Russian Federation (2007)	29.4	62.6	0.7	7.2
Canada (2008)	49.5	31.3	10.3	9.0
Italy (2006)	40.4	48.3	3.0	8.3

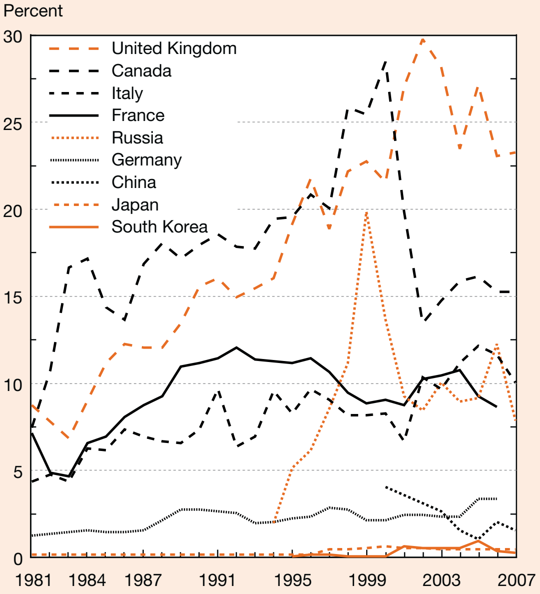
NA = not available

NOTES: Top 10 R&D performing countries. U.S. data on R&D funding from abroad not separately identified but included in sector totals.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

Figure 4-17
Business R&D financed by foreign sources, for selected countries: 1981–2007



NOTES: Top 10 R&D performing countries. Data not available for all countries for all years. Similar U.S. data not separately reported.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

in foreign-funded R&D may reflect coordinated European Community (EC) efforts to foster cooperative shared-cost research through its European Framework Programmes.

Businesses in the United States also receive R&D funding from abroad. However, this funding is not separately reported in U.S. R&D statistics; instead, it is included in the figures reported for the business sector.[32]

Business Sector

The structure of business R&D varies substantially among countries in terms of both sector concentration and sources of funding. Because businesses account for the largest share of total R&D performance in the United States and most OECD countries, differences in business structure can help explain international differences in more aggregated statistics such as R&D/GDP. For example, countries with higher concentrations of R&D-intensive industries (such as pharmaceuticals or automotive manufacturing) are likely to also have higher R&D/GDP ratios than countries whose business structures are weighted more heavily toward less R&D-intensive industries.

Sector Focus for the United States and OECD Countries

Using internationally comparable data, no one industry accounted for more than 18% of total business R&D in the United States in 2007 (figure 4-18; appendix table 4-31) (OECD 2009c). This circumstance stems largely from the fact that total business R&D expenditures are so large in the United States that it is difficult for any one sector to dominate. However, the diversity of R&D investment by industry in the United States is also an indicator of how the nation's accumulated stock of knowledge and well-developed S&T infrastructure have made it a popular location for R&D performance for a broad range of industries.[33]

Compared with the United States, many of the other countries shown in figure 4-18 display much higher industry sector concentrations. In countries with less business R&D, high sector concentrations can result from the activities of one or two large companies. This pattern is notable in Finland, where the communication, television, and radio equipment industry accounted for more than half of business R&D in 2007. This high concentration most likely reflects the activities of one company, Nokia, a major manufacturer of mobile phones at the forefront of the convergence of communications and the Internet. In contrast, South Korea's high concentration of R&D (48% of all business R&D in 2006) in this industry is not the result of any one or two companies, but reflects the structure of its export-oriented economy. South Korea is one of the world's top producers of electronic goods, and among its top export commodities are semiconductors, cellular phones, and computers. In the United States, the communication, television, and radio equipment industry accounted for 11% of all business R&D in 2007.

Other industries also exhibit relatively high concentrations of R&D by country. Automotive manufacturers ranked among the largest R&D-performing companies in the world in 2006. (See table 4-15 and sidebar "Global R&D Expenses of Public Corporations.") Hence, countries that are home to the world's major automakers also boast the highest concentration of R&D in the automotive manufacturing industry. This industry accounts for 30% of Germany's business R&D, 23% of the Czech Republic's, and 19% of Sweden's (figure 4-18), reflecting the operations of automakers such as Daimler AG and Volkswagen in Germany, Skoda in the Czech Republic, and Volvo and Saab in Sweden. Also home to large R&D-performing firms in this industry are France (18% of all business R&D; PSA Peugeot Citroën, Renault), Japan (17%; Toyota, Honda, Nissan), South Korea (15%; Hyundai, Kia), and Italy (12%; Fiat). In the United States, the automotive manufacturing industry accounted for 6% of all business R&D in 2007.

The pharmaceuticals industry is less geographically concentrated than the automotive manufacturing industry but is still prominent in several countries. The pharmaceuticals industry accounts for more than 27% of business R&D in Denmark and the United Kingdom, and more than 20% in

Figure 4-18
Share of industrial R&D, by industry sector and selected country: 2005–2007

(Percent)

UK = United Kingdom

NOTES: Countries listed in descending order by amount of total industrial R&D. Data are for years in parentheses.

SOURCES: Organisation for Economic Co-operation and Development, ANBERD database (2009), http://www.oecd.org/document/17/0,3343,en_2649_34445_1822033_1_1_1_1,00.html, accessed 15 June 2009; and National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (2007).

Science and Engineering Indicators 2010

Table 4-15
Global R&D spending by top 25 corporations: 2006

	R&D rank		R&D expense ($millions)			Sales ($millions)			R&D/sales ratio (%)	
Company (country)	2006	2005	2006	2005	Change (%)	2006	2005	Change (%)	2006	2005
Toyota Motor (Japan)	1	4	7,486	6,829	9.6	201,254	176,789	13.8	3.7	3.9
Pfizer (United States)	2	2	7,423	7,442	–0.3	48,201	51,298	–6.0	15.4	14.5
Ford Motor (United States)	3	1	7,200	8,000	–10.0	160,123	176,896	–9.5	4.5	4.5
Johnson & Johnson (United States)	4	8	7,125	6,312	12.9	53,194	50,434	5.5	13.4	12.5
Microsoft (United States)	5	7	7,121	6,584	8.2	51,122	44,282	15.4	13.9	14.9
DaimlerChrysler (Germany)	6	3	7,007	7,425	–5.6	199,246	196,863	1.2	3.5	3.8
GlaxoSmithKline (United Kingdom)	7	9	6,611	6,108	8.2	45,263	42,213	7.2	14.6	14.5
Siemens (Germany)	8	5	6,604	6,776	–2.5	114,779	99,164	15.7	5.8	6.8
General Motors (United States)	9	6	6,600	6,700	–1.5	207,349	190,215	9.0	3.2	3.5
Volkswagen (Germany)	10	12	6,030	5,364	12.4	137,846	125,219	10.1	4.4	4.3
Samsung Electronics (South Korea)	11	10	5,943	5,765	3.1	91,038	85,927	5.9	6.5	6.7
Intel (United States)	12	14	5,873	5,145	14.1	35,382	38,826	–8.9	16.6	13.3
Sanofi-Aventis (France)	13	13	5,823	5,315	9.6	37,293	35,897	3.9	15.6	14.8
International Business Machines (United States)	14	11	5,682	5,378	5.7	91,424	91,134	0.3	6.2	5.9
Roche Holding (Switzerland)	15	17	5,359	4,640	15.5	34,192	28,882	18.4	15.7	16.1
Novartis (Switzerland)	16	18	5,349	4,514	18.5	36,031	32,212	11.9	14.8	14.0
Nokia (Finland)	17	15	5,122	5,008	2.3	54,049	44,940	20.3	9.5	11.1
Matsushita Electric (Japan)	18	16	4,858	4,746	2.4	76,543	74,746	2.4	6.3	6.3
Honda Motor (Japan)	19	20	4,638	4,289	8.1	93,174	83,264	11.9	5.0	5.2
Sony (Japan)	20	19	4,571	4,469	2.3	69,715	62,822	11.0	6.6	7.1
Robert Bosch GmbH (Germany)	21	21	4,401	4,039	9.0	57,418	54,496	5.4	7.7	7.4
Motorola (United States)	22	24	4,106	3,680	11.6	42,879	36,843	16.4	9.6	10.0
Cisco Systems (United States)	23	30	4,067	3,322	22.4	28,484	24,801	14.9	14.3	13.4
Merck (United States)	24	22	4,020	3,848	4.5	22,636	22,012	2.8	17.8	17.5
Telefonaktiebolaget LM Ericsson (Sweden)	25	25	3,990	3,494	14.2	25,403	21,693	17.1	15.7	16.1

SOURCE: Institute of Electrical and Electronics Engineers (IEEE), IEEE Spectrum Top 100 R&D Spenders, Standard & Poor's data (2006), http://www.spectrum.ieee.org/images/dec07/images/12.RDchart.pdf, accessed 5 May 2009.

Science and Engineering Indicators 2010

Global R&D Expenses of Public Corporations

Most firms that make significant investments in R&D track their R&D expenses separately in their accounting records and financial statements. The annual reports of public corporations often include data on these R&D expenses. According to information gleaned from public reports, the 25 public corporations with the largest reported worldwide R&D expenses spent $143 billion on R&D in 2006. The six companies with the largest reported R&D expenses—Toyota, Pfizer, Ford Motor Company, Johnson & Johnson, Microsoft, and DaimlerChrysler—each spent between $7 billion and $7.5 billion. The six automobile manufacturers on the list reported combined spending of $39 billion on R&D (27.3% of the total for the top 25) (table 4-15). Eleven companies in the information and communications technologies (ICT) sector spent a total of $57.9 billion (40.5% of the total). The remaining eight companies include six pharmaceutical manufacturers and two diversified consumer product–oriented manufacturers. The top 25 companies are headquartered in 9 countries, with 10 headquartered in the United States. The location of a company's headquarters, however, is not necessarily the location of all its R&D activities. Most of the companies on this list have manufacturing and research facilities in multiple countries. (For more information, see section "R&D by Multinational Companies.")

Overall, R&D spending for the top 25 public corporations increased 5.8% in 2006. (The top 25 list was the same for 2006 as it was for 2005 except for the addition of Cisco Systems, Inc., and the deletion of Nissan Motor Company.) Sales for the group as a whole increased 6.5%; sales increased 5.2% for the automobile and pharmaceutical manufacturers, 8.9% for the ICT companies in the group, and 5.4% for the consumer product manufacturers. R&D expenses increased for the manufacturers (pharmaceuticals, 8.5%; automobiles, 0.9%; and consumer products, 11.4%). The ICT companies, representing the sector that has historically had the highest R&D intensity, reported a 6.6% increase.

Belgium and Ireland. Denmark, the largest performer of pharmaceutical R&D in Europe, is home to Novo Nordisk, a world leader in the manufacture and marketing of diabetes-related drugs, and H. Lundbeck, a research-based company specializing in psychiatric and neurological pharmaceuticals. The United Kingdom is the second-largest performer of pharmaceutical R&D in Europe and is home to GlaxoSmithKline, which manufacturers medicines and vaccines for the World Health Organization's three priority diseases—HIV/AIDS, tuberculosis, and malaria. GlaxoSmithKline was the third-largest pharmaceuticals company in the world in terms of R&D expenditures in 2005 and 2006 (table 4-15). In the United States, the pharmaceuticals industry accounted for 18% of all business R&D in 2007. U.S.-headquartered pharmaceutical companies include Abbott Laboratories, Bristol-Myers Squibb, Eli Lilly, Johnson & Johnson, Merck, Pfizer, Schering-Plough, and Wyeth.

The computers, office and accounting machines industry represents only a small share of business R&D in most countries. Among the OECD countries shown in figure 4-18 and appendix table 4-31, only Japan reports a double-digit concentration of business R&D in this industry, 13% (2006). Japan is the home of Fujitsu, Hitachi, and NEC. In the United States, the computers, office and accounting machines industry accounted for 3% of all business R&D in 2007. The United States is home to Apple, Dell, Hewlett-Packard, Sun Microsystems and other companies in this industry.

A significant trend in both U.S. and international business R&D activity has been the growth of R&D in the service sector. According to national statistics for recent years, the service sector accounted for 30% or more of all business R&D in 9 of the 19 OECD countries shown in figure 4-18 and less than 10% in only 4 of the countries. In the United States, service industries accounted for 30% of all business R&D in 2007.

Other Countries

Internationally comparable data for seven non-OECD countries have recently been made available in OECD's Analytical Business Enterprise R&D (ANBERD) database (OECD 2009c). Percentage shares of total business R&D by industry for Chile, China, Israel, the Russian Federation, Singapore, South Africa, and Taiwan are detailed in appendix table 4-31.

Among these countries, the new data show that the communication, television, and radio equipment industry accounts for more than 40% of all business R&D in Singapore and Taiwan and more than 15% in Israel and China. Motor vehicle and pharmaceutical R&D account for smaller percentages of business R&D than in most of the OECD countries. Motor vehicle R&D accounts for 5% or more of business R&D in South Africa and China, and the two countries with the highest percentages of pharmaceutical R&D are Singapore (8%) and China (4%). R&D in the computer, office and accounting machines industry accounts for 15% of the business R&D performed in Taiwan, the highest percentage among the seven nations.

Among the OECD countries shown in figure 4-18, the service sector accounts for as little as 7% of business R&D in South Korea to as much as 41% in Australia. The newly available data show a similar range among the seven nations. The percentage of business R&D accounted for by the service sector ranges from 7% in China to more than 60% in Israel and the Russian Federation.

Academic Sector

The academic sector's share of R&D is largest in Canada, where it accounted for 36% of national R&D performance in 2007 (table 4-13). It is lowest in the Russian Federation at 6%. The academic share in the United States and Japan is in the middle at 13%, whereas China is 9%.

Source of Funds

For most countries, the government is (and has long been) the largest source of academic research funding. (See sidebar "Government Funding Mechanisms for Academic Research.") Business support for academic R&D has increased over the past 25 years among the OECD countries as a whole. It was around 3% in the early 1980s, nearly 6% in 1990, and almost 7% in 2000 but then fell back to around 6% in 2006.

In the United States, business support for academic R&D was about 4% in the early 1980s and rose to about 7% later in that decade and through the 1990s but has dropped under 6% since 2000. Some commentators note with concern this recent trend of decline, in light of the significant role that academic basic research plays in providing a foundation for technological innovation important to the national economy.

The proportion of academic R&D financed by business is more varied among the other top R&D-performing countries (figure 4-19). The highest figures for business support of academic R&D are currently in China (35%) and Russia (31%). The figures are also high in Germany (14%) and South Korea (14%), whereas Japan, France, and Italy occupy the low end, with figures in the 1% to 3% range.

S&E Fields

Many countries that support a substantial level of academic R&D devote proportionately more of their R&D spending to engineering and social science than does the United States (table 4-16). The thrust of U.S. academic R&D support is more directed at the natural and medical sciences. (For a more detailed discussion of S&E field patterns of academic research in the United States and other countries, see chapter 5, "Outputs of S&E Research.")

Government R&D Priorities

Public R&D budget directed toward specific socioeconomic objectives gives insight into government priorities. Statistics compiled by the OECD on annual government

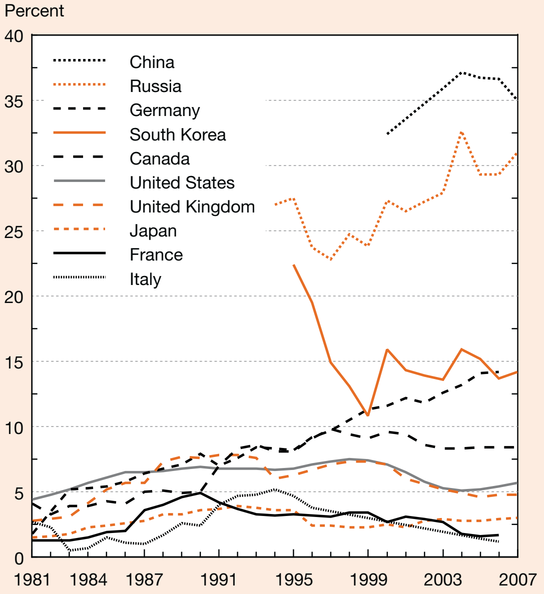
Government Funding Mechanisms for Academic Research

U.S. universities generally do not maintain data on departmental research (i.e., research which is not separately budgeted and accounted). As such, U.S. R&D totals are understated relative to the R&D effort reported for other countries. The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants provided by all levels of government to the academic sector. These funds can support departmental R&D programs that are not separately budgeted. GUF is not equivalent to basic research. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects, usually to address the objectives of the federal agencies that provide the R&D funds. However, some state government funding probably does support departmental research at U.S. public universities.

The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Moreover, government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds that can be assigned to specific socioeconomic categories).

In the United States, the federal government is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere—although this is not necessarily the case with state governments. In several European G-7 countries (France, Germany, Italy, and the United Kingdom), GUF accounts for 50% or more of total government R&D funding to universities. In Canada, GUF accounts for about 38% of government academic R&D support. These data reflect not only the relative international funding priorities but also the funding mechanisms and philosophies regarded as the best methods for financing academic research.

Figure 4-19
Academic R&D financed by business for selected countries: 1981–2007



NOTES: Data for top 10 R&D performing countries. Data not available for all countries for all years. Japan data for 1996 onward may not be comparable with earlier years because of changes in methodology.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2009/1).

Science and Engineering Indicators 2010

budget appropriations or outlays for R&D (GBAORD) for its members and selected other countries provide a basis for such a comparison (table 4-17).

Defense is an objective for government funding of R&D for all the top R&D-performing countries, but the share varies widely. Defense accounted for 58% of U.S. federal R&D support in 2007 but was markedly lower elsewhere: a smaller but still significant 29% in France and 28% in the United Kingdom, 17% in South Korea, and below 10% in both Germany and Japan.

Defense has remained the focus of more than 50% of the federal R&D budget in the United States for much of the past 25 years. It was 63% in 1990 as the long Cold War period drew to a close. It dropped to 52% in 2000 but has risen again in the wake of events stemming from September 11, 2001. The defense share of government R&D funding for the other countries over the past 25 years has generally declined or remained at a stable, low level.

The health and environment objective now accounts for 55% of nondefense federal R&D budget support in the United States and 26% in the United Kingdom. For both countries, the share has expanded dramatically over the prevailing levels several decades ago. The health and environment share is currently 17% in South Korea, 13% in France, and 10% or less in Germany and Japan. The funding under this objective goes primarily into the health arena in the United States and the United Kingdom. In the other countries, it is more balanced between health and the environment.

The economic development objective encompasses agriculture, fisheries and forestry, industry, infrastructure, and energy. The share of nondefense government R&D support

Table 4-16

Share of academic R&D expenditures, by country and S&E field: Most recent year

(Percent distribution)

Field	U.S. (2007)	Japan (2006)	Germany (2002)	Russia (2007)	Canada (2005)	Taiwan (2006)	Spain (2006)	Australia (2006)	Sweden (2005)
Academic R&D expenditure (PPP $billions)	50.24	17.62	9.64	1.59	8.16	2.03	4.31	3.83	2.34
Academic R&D	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NS&E	91.2	67.4	78.8	81.4	80.3	86.3	63.1	74.0	78.9
Natural sciences	37.6	11.6	29.2	29.4	NA	17.9	23.1	29.9	19.2
Engineering	15.0	24.5	20.3	46.8	NA	40.9	23.4	11.7	22.8
Medical sciences	32.9	26.8	25.2	3.0	NA	19.9	14.1	26.9	31.8
Agricultural sciences	5.8	4.6	4.1	2.2	NA	7.6	2.5	5.4	5.1
Social sciences and humanities	6.7	32.6	20.7	18.6	19.7	13.7	36.9	26.0	19.5
Social sciences	6.5	NA	8.4	13.5	NA	10.8	22.3	20.5	13.1
Humanities	0.1	NA	12.4	5.1	NA	2.9	14.6	5.5	6.3
Academic R&D nec	2.1	NA	0.4	NA	NA	NA	NA	NA	1.6
Academic NS&E									
NS&E	100.0	100.0	100.0	100.0	NA	100.0	100.0	100.0	100.0
Natural sciences	41.2	17.2	37.0	36.2	NA	20.8	36.6	40.5	24.3
Engineering	16.4	36.3	25.8	57.5	NA	47.4	37.2	15.8	28.9
Medical sciences	36.0	39.7	32.0	3.6	NA	23.0	22.3	36.4	40.3
Agricultural sciences	6.3	6.8	5.2	2.7	NA	8.9	3.9	7.3	6.5

NA = not available

nec = not elsewhere classified; NS&E = natural sciences and engineering; PPP = purchasing power parity

NOTES: Data for following top 10 R&D-performing countries not available: China, France, South Korea, United Kingdom, and Italy. Additional countries included in top 15 of R&D-performance. Detail may not add to total because of rounding.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: FY 2007 (2009); and Organisation for Economic Co-operation and Development (OECD), OECD.Stat database, accessed 6 March 2009.

Science and Engineering Indicators 2010

allocated to economic development has generally declined over the past 25 years across the OECD countries. In the United States, it was 36% of all nondefense federal support for R&D in 1981, dropping to 10% in 2007.[34] In the United Kingdom, it was 39% in 1981, declining to 7% in 2006. Despite a decline, support for this objective remains substantial in some countries: 22% in Germany and France (both with particular attention to industrial production and technology) and 31% in Japan (notably in energy and industrial production and technology). South Korea currently has by far the largest share for this objective, 52%, with a particularly strong emphasis in recent years on industrial production and technology.

The civil space objective accounts for 18% of nondefense federal R&D funding in the United States. The share has been around 20% in the United States for much of the past 25 years. The share in France is currently about 13%—and has been around that level for almost 20 years. The share has been below 10% for the rest of the OECD countries.

The *other purposes* objective includes the general advance of knowledge (university research and nonoriented government research), education, and other activities directed toward cultural and socioeconomic system purposes. This objective accounts for 17% of nondefense federal R&D funding in the United States (table 4-17). The share is substantially greater elsewhere: 64% in Germany and the United Kingdom, 55% in Japan, and 52% in France. For all OECD countries, university research and nonoriented government research constitute the vast majority of the funding under this objective.

R&D by Multinational Companies

Foreign direct investment (FDI) refers to the ownership of productive assets outside the home country by MNCs. (See sidebar "Foreign Direct Investment in R&D.") FDI and international trade are key channels for international knowledge and technology diffusion, which in turn contribute to productivity growth (Keller 2004; OECD 2008a). Globalization of R&D through FDI activities by MNCs reflects a decentralized model of innovation that takes advantage of location-specific skills while seeking to retain the benefits

Table 4-17

Government R&D support by major socioeconomic objectives, for selected countries: 1981–most recent year

(Percent)

		GBAORD budget shares		Nondefense R&D budget shares			
Country/economy and year	GBAORD (current US$millions, PPP)	Defense	Nondefense	Health and environment	Economic development programs	Civil space	Other purposes
OECD							
1981	68,423.0	37.7	62.3	17.8	37.7	10.2	34.3
1990	135,732.9	39.3	60.7	18.8	28.9	11.8	40.5
2000	196,850.7	28.2	71.8	22.3	23.0	10.0	44.7
Most recent (2006)	287,197.0	33.2	66.8	25.3	21.6	9.3	43.8
United States							
1981	33,735.0	56.4	45.4	31.2	36.1	20.3	12.4
1990	63,781.0	62.6	37.4	40.2	22.2	24.2	13.4
2000	83,612.5	51.6	48.4	49.9	13.4	20.9	15.8
Most recent (2007)	141,890.3	57.8	42.2	54.7	10.3	18.4	16.6
European Union-27							
1981	na	na	na	na	na	na	na
1990	na	na	na	na	na	na	na
2000	75,267.4	13.1	86.9	11.6	22.7	6.1	59.6
Most recent (2006)	96,995.8	13.3	86.7	13.7	22.3	5.4	58.6
Germany							
1981	8,572.5	8.9	91.1	9.6	34.9	4.6	50.9
1990	13,269.1	13.5	86.5	10.8	25.9	6.8	56.5
2000	16,787.5	7.8	92.2	9.4	21.6	4.9	64.1
Most recent (2007)	20,837.7	6.1	93.9	9.7	21.6	5.0	63.7
France							
1981	7,211.8	38.4	61.6	13.3	37.9	6.7	42.1
1990	13,738.9	40.1	60.0	9.3	32.8	13	44.9
2000	14,721.6	21.4	78.6	9.7	17.7	14.2	58.4
Most recent (2007)	15,538.5	28.8	71.2	13.2	21.9	12.6	52.3
United Kingdom							
1981	6,791.4	46.3	53.7	13.1	38.5	3.8	44.6
1990	8,154.7	43.5	56.5	18.1	31.9	5.5	44.5
2000	10,346.0	36.2	63.8	28.3	12.1	3.7	55.9
Most recent (2006)	14,768.8	28.3	71.7	25.8	7.1	3.0	64.1
Japan							
1981	NA	NA	NA	NA	NA	NA	NA
1990	10,255.4	5.4	94.6	4.5	33.9	6.9	54.7
2000	21,196.9	4.1	95.9	6.6	33.4	5.8	54.2
Most recent (2007)	29,184.8	4.5	95.5	7.1	30.6	7.3	55.0
South Korea							
1981	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA
2000	5,007.2	20.5	79.5	14.8	53.4	3.1	28.7
Most recent (2007)	10,831.9	16.6	83.4	17.1	52.4	4.6	25.9

na = not applicable; NA = not available

GBAORD = government budget appropriations or outlays for R&D; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTES: Nondefense R&D classified as other purposes consists primarily of general advancement of knowledge (university funds and nonoriented research programs). GBAORD figures not currently available for China and incomplete for Russian Federation. See appendix table 4-30.

SOURCE: OECD, Main Science and Technology Indicators (2008/2).

Science and Engineering Indicators 2010

of common ownership and control.[35] Overseas locations may also facilitate networking opportunities with foreign companies, research centers, and universities. Thus, R&D by MNCs complements activities with external parties, such as R&D contracting, technology alliances, and international exchanges of R&D services, discussed later in this chapter. As a whole, these activities reflect a collaborative and global framework for creating and exploiting new knowledge by leveraging internal and external capabilities (OECD 2008a).

As described below, according to Bureau of Economic Analysis (BEA) data, the majority of R&D by U.S. MNCs continues to be performed in the United States. Western Europe has attracted the majority of U.S.-owned overseas R&D, followed by the Asia-Pacific region.[36] Likewise, foreign-owned companies continue to invest in R&D in the United States.

Foreign Direct Investment in R&D

Direct investment is defined as ownership or control of 10% or more of the voting securities of a business (affiliate) in another country. As with other overseas activity, the geographic distribution of affiliates' R&D varies by investing country and industry (OECD 2007). FDI in R&D is driven by factors ranging from costs and long-term market and technological opportunities to infrastructure and policy considerations, such as availability of appropriately trained human resources and intellectual property protection (Niosi 1999; Thursby and Thursby 2006; von Zedtwitz and Gassmann 2002).

Statistics on R&D by affiliates of foreign companies located in the United States, and by foreign affiliates of U.S. MNCs and their parent companies, can be obtained from BEA's Survey of Foreign Direct Investment in the United States (FDIUS) and BEA's Survey of U.S. Direct Investment Abroad (USDIA). BEA data used in this section cover nonbank companies.* Affiliate data cover majority-owned affiliates, that is, those in which the ownership stake of parent companies totals more than 50%. Annual changes in FDI R&D reflect a combination of mergers and acquisitions; newly built factories, service centers, or laboratories; and activities in existing facilities. Available data do not, however, allow for distinguishing among these alternative investments.[†]

---

*Nonbank data exclude activities by companies classified in depository credit intermediation, which comprises commercial banks, savings institutions, credit unions, bank holding companies, and financial holding companies.

[†] For detailed methodology, see http://www.bea.gov/international/usdia2004f.html (USDIA) and http://www.bea.gov/scb/pdf/internat/fdinvest/meth/FDIUS2002Benchmark.pdf (FDIUS).

Linking MNC Data From International Investment and Industrial R&D Surveys

An ongoing data development project aims to integrate the statistical information from BEA's international investment surveys with the NSF/Census Survey of Industrial Research and Development. Combining technological and investment data from these complementary sources will facilitate a better assessment of globalization trends in R&D and technological innovation. The initial methodological study demonstrated the feasibility and utility of such a linkage.

A combined preliminary data set provided information for the first time on R&D expenditures by U.S. and foreign MNCs by character of work (basic research, applied research, and development). The study has also produced tangible benefits for the participating agencies, including improvements in survey sampling and the quality of reported data. These promising initial results have prompted the three participating agencies to continue work in this area. For more information, see NSF/SRS (2007b) and Census Bureau et al. (2005).

U.S. Affiliates of Foreign Companies

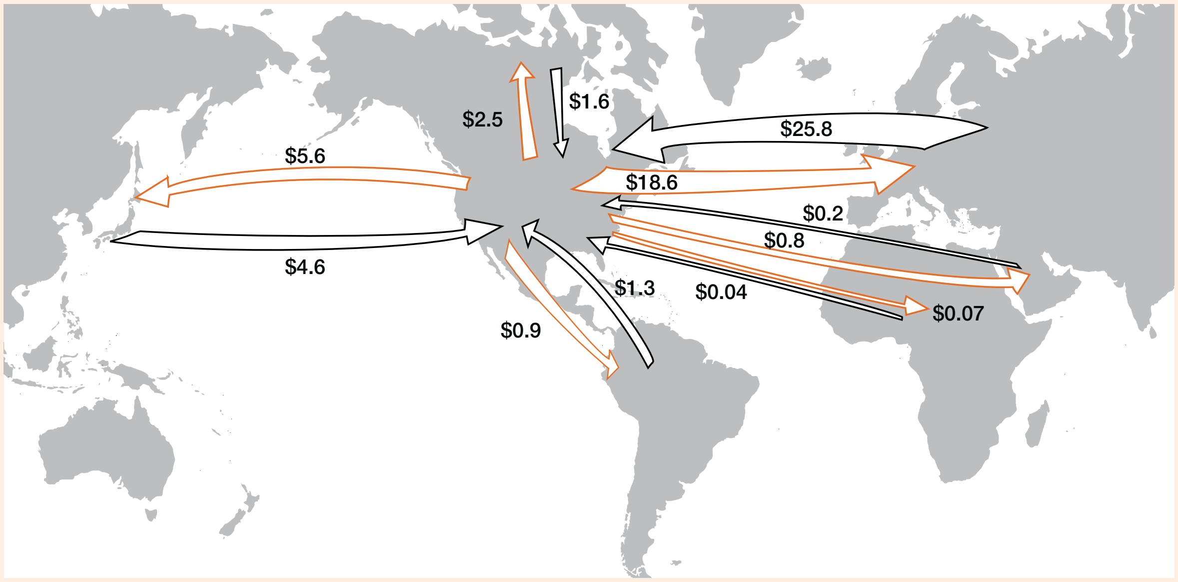
R&D performed by majority-owned affiliates of foreign companies located in the United States (U.S. affiliates) reached $34.3 billion in 2006, compared with $31.1 billion in 2005 (appendix table 4-32).[37] R&D expenditures by these companies grew at an annual average rate of 11.3% (8.6% after adjusting for inflation) from 1987 to 2006, more than double the 5.3% (2.8%) rate for total business R&D performed in the United States. This faster growth rate increased their share in total business R&D from the single digits in the early 1990s to 14.8% in 2003; their share has hovered near 14% since then. Details on the R&D character of work for MNCs are under development. (See sidebar "Linking MNC Data From International Investment and Industrial R&D Surveys.")

Since the late 1980s, European subsidiaries have performed about three-fourths of all U.S. affiliates' R&D ($25.8 billion in 2006) (figure 4-20). The share of Japanese-owned companies grew from the single digits in the late 1980s to between 10% and 12% since 1996. European and Japanese subsidiaries combined have accounted for more than 85% of these expenditures since 2001.

In 2006, manufacturing accounted for about three-quarters of U.S. affiliates' R&D, including 37% in chemicals (of which pharmaceuticals was 90%), 12% in transportation equipment, and 9% in computer and electronic products (table 4-18; appendix table 4-33). These three industries also topped overall U.S. business R&D.

Figure 4-20
R&D performed by U.S. affiliates of foreign companies in United States, by investing region, and performed by foreign affiliates of U.S. multinational corporations, by host region: 2006

(Billions of current U.S. dollars)



NOTES: Preliminary estimates.

SOURCES: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series); and Survey of U.S. Direct Investment Abroad (annual series). See appendix tables 4-32 and 4-34.

Science and Engineering Indicators 2010

Table 4-18
R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and country/region: 2006
(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Country/region	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Transportation equipment	Information	Professional, technical, scientific services
All countries	34,257	25,035	12,750	789	3,072	1,329	4,198	967	1,879
Canada	1,586	295	D	11	D	D	D	D	83 e
Europe	25,803	22,121	12,168	637	2,568	1,226	3,697	592	729
France	3,335	2,978	D	D	575	D	180 e	165	D
Germany	6,742	5,880	1,761	99	121	D	2,812	D	D
Netherlands	1,562	D	D	D	D	2	D	0	4
Switzerland	5,039	4,483	4,248	44	D	D	5	2	D
United Kingdom	6,801	6,357	3,836	45 e	1,682	28	491	D	110 e
Asia/Pacific	4,589	1,475	409	D	380	39 e	D	D	986
Japan	3,995	1,258	396	58	295	38 e	262	18 e	819
Latin America/OWH	D	920	2 e	D	D	D	4 e	3	D
Middle East	D	161	D	1	D	0	9	D	0
Africa	35	D	D	0	0	0	0	D	0

D = suppressed to avoid disclosure of confidential information; e = >50% of value for data cell estimated to account for data not reported by respondents

NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2006 estimates for majority-owned (>50%) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Expenditures included for R&D conducted by foreign affiliates, whether for themselves or others under contract. Expenditures excluded for R&D conducted by others for affiliates under contract.

SOURCE: Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/international/index.htm#omc, accessed 6 May 2009.

Science and Engineering Indicators 2010

Statistics from 2006 indicate that affiliates from different countries emphasized R&D in different industries. German-owned affiliates located in the United States spent more than 40% of their $6.7 billion R&D in transportation equipment (table 4-18). British-owned companies accounted for more than half of affiliates' R&D in computers and electronic products. Japanese-owned firms accounted for 44% of affiliates' R&D expenditures in professional, scientific, and technical services. Swiss-owned firms performed a third of affiliates' R&D in pharmaceuticals.

U.S. MNCs and Their Overseas R&D

U.S. MNCs (parent companies and their foreign affiliates) performed $216.3 billion in R&D worldwide in 2006 (table 4-19). Parents of U.S. MNCs performed $187.8 billion in R&D, compared with $177.6 billion in 2005, a 2.5% increase on an inflation-adjusted basis.[38] The 2006 R&D by MNC parents represented 87% of global R&D by U.S. MNCs and about 76% of U.S. business R&D. Both shares have changed little since 2004.[39]

Overseas R&D performed by majority-owned foreign affiliates (henceforth, foreign affiliates) reached $28.5 billion in 2006, compared with $27.7 billion in 2005 (essentially unchanged on an inflation-adjusted basis). However, since 1999 foreign affiliates' R&D expenditures increased at a 4.0% annual average rate after adjusting for inflation, and have increased at a 5.0% annual average rate since 1994.

In 2006, affiliates located in Europe accounted for 65% ($18.6 billion of $28.5 billion) of overseas affiliates' R&D, of which the United Kingdom and Germany combined represented more than half ($10.3 billion) (appendix table 4-34).[40] Europe's share, however, is down from 73% in 1994 (figure 4-21).

Indeed, the geographic distribution of R&D by overseas affiliates of U.S. MNCs is gradually reflecting the role of emerging markets in global R&D (figure 4-21).[41] In particular, major developed economies or regions (Canada, Europe, and Japan) account for a decreasing share of the overseas R&D investments of U.S. MNCs, declining from 90% in 1994 to 80% in 2006. Over the same period, the share of the region termed *Asia except Japan* more than doubled, from

Table 4-19
R&D performed by U.S. multinational companies: 2004–06

Year	R&D performed (current US$millions) U.S. parents	MOFAs	Total MNCs	Shares of MNC (%) U.S. parents	MOFAs
2004.....	164,189	25,840	190,029	86.4	13.6
2005.....	177,598	27,653	205,251	86.5	13.5
2006.....	187,813	28,484	216,297	86.8	13.2

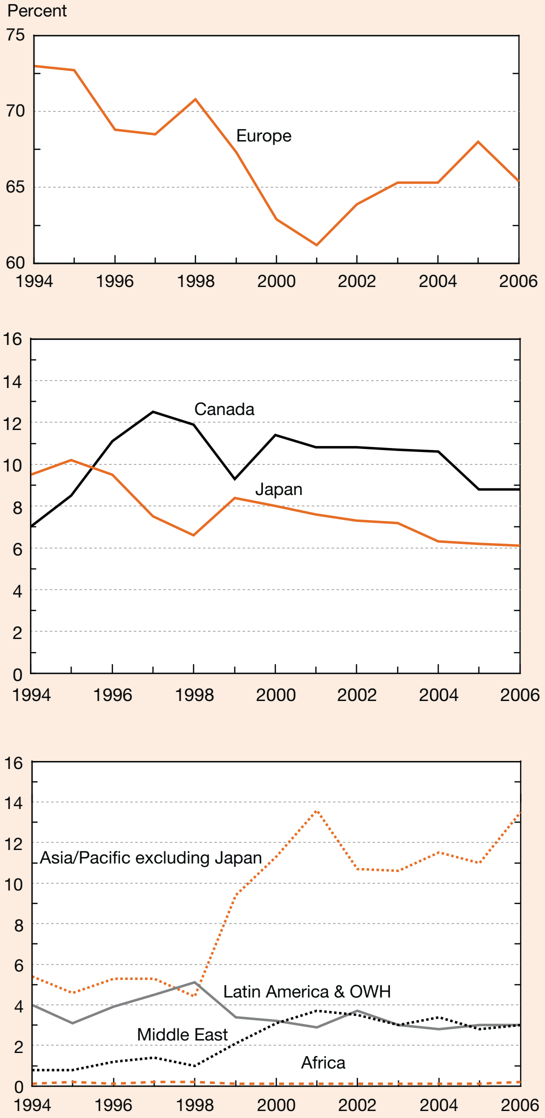
MNC = multinational company; MOFA = majority-owned foreign affiliate

NOTE: MOFAs are affiliates in which combined ownership of all U.S. parents is >50%.

SOURCE: Bureau of Economic Analysis. Survey of Foreign Direct Investment in the United States (annual series). See appendix tables 4-34 and 4-36.

Science and Engineering Indicators 2010

Figure 4-21
Regional shares of R&D performed abroad by foreign affiliates of U.S. MNCs: 1994–2006



MNC = multinational company; OWH = other Western Hemisphere

NOTES: Data for majority-owned affiliates. Preliminary estimates for 2006.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series).

Science and Engineering Indicators 2010

5.4% to 13.5%, driven by the R&D spending of U.S.-owned affiliates in China, Singapore, and South Korea.

On an individual country basis, changes proved more modest in terms of global shares, although funding levels in some lower-cost locations may still be significant from the perspective of purchasing power. R&D performed by U.S.-owned affiliates in China and India increased from less than $10 million in each country in 1994 to $804 million in China and $310 million in India in 2006, but these levels represented only about 3% and 1%, respectively, of total overseas R&D by U.S. MNCs. In the Middle East, Israel accounted for virtually all R&D by affiliates of U.S. MNCs, with about 3% of the global share. Brazil represented two-thirds of Latin America's U.S.-owned affiliates' R&D and a 2% global share.

In 2006, manufacturing affiliates accounted for 83% of overseas affiliates' R&D, including 68% by three manufacturing industries: transportation equipment (29%), chemicals (including pharmaceuticals) (22%), and computer and electronic products (17%) (table 4-20). More than half of R&D by U.S.-owned affiliates in Europe was performed by affiliates classified in transportation equipment (35%) and chemicals (21%). Affiliates classified in transportation equipment also performed half of U.S.-owned R&D in

Table 4-20

R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and country/region: 2006

(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing	
Country/region	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Information	Professional, technical, scientific services
All countries	28,484	23,638	6,166	1,128	4,874	651	8,342	1,014	2,688
Canada	2,503	1,766	759	37	260	14	587	271	415
Europe	18,628	15,635	3,882	830	1,976	503	6,460	374	1,790
Belgium	948	699	D	15	D	D	26	3	226
France	1,447	1,287	313	110	206	28	392	29	78
Germany	4,919	4,754	253	279	609	245	2,888	22	100
Ireland	848	538	234	0	225	4	5	204	D
Italy	689	587	274	84	21	42	86	*	84
Netherlands	486	426	184	26	35	D	D	8	38
Sweden	1,536	1,512	72	8	68	20	D	1	19
Switzerland	933	501	254	52	61	4	6	D	D
United Kingdom	5,378	4,296	1,412	200	632	71	1,582	77	862
Asia and Pacific	5,575	4,680	1,233	D	2,105	129	849	D	D
Australia	596	536	162	D	D	1	D	1	28
China	804	675	30	15	541	35	30	D	D
Hong Kong	105	47	D	0	16	D	0	4	50
India	310	106	8	13	D	*	20	D	108
Japan	1,739	1,560	893	10	397	D	92	111	16
Korea	729	704	34	15	201	D	D	D	1
Malaysia	249	248	3	*	241	1	0	0	*
Singapore	850	634	D	*	564	2	D	D	D
Latin America/OWH	865	811	242	50	27	6	419	*	20
Brazil	571	539	136	48	18	4	307	0	11
Middle East	847	693	29	D	506	0	0	D	D
Israel	846	693	29	D	506	0	0	D	D
Africa	65	53	21	1	0	*	26	2	*
South Africa	52	42	19	1	0	*	D	2	*

D = suppressed to avoid disclosure of confidential information; * = ≤ $500,000

NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2006 estimates for majority-owned (>50%) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Expenditures included for R&D conducted by foreign affiliates, whether for themselves or others under contract. Expenditures exclue for R&D conducted by others for affiliates under contract.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/international/index.htm#omc, accessed 6 May 2009.

Science and Engineering Indicators 2010

Brazil. Affiliates classified in chemicals performed half of R&D by U.S.-owned companies in Japan.

Reflecting the increasing global linkages in information technology production and development, affiliates classified in computer and electronic product manufacturing performed the majority of U.S.-owned R&D in some emerging markets: Malaysia (97%), China (67%), Singapore (66%), and Israel (60%) (table 4-20). In terms of service industries, affiliates classified in the information industry (which includes software and Internet publishers and telecommunications) performed about one-fourth of U.S.-owned R&D in Ireland. Finally, 35% of R&D by U.S.-owned affiliates in India was performed by those classified in professional, scientific, and technical services (which includes computer and scientific R&D services).[42] Nevertheless, European-located affiliates performed two-thirds of the $2.7 billion in overseas, U.S.-owned R&D in this industry.

Technology and Innovation Linkages

Increasingly, R&D and innovation are pursued in a collaborative and interactive environment, often embedded in global supply, production, and distribution networks (Dahlander and Gann 2007; Howells 2008; OECD 2008a). This section presents indicators on two types of innovation linkages: (1) business-to-business interactions in the form of contracted-out R&D, international transactions in R&D services, and global technology alliances, and (2) public-private collaborations. Overall, these indicators illustrate a variety of intra- and cross-organizational arrangements intended to absorb, manage, and exploit external and/or jointly developed knowledge (Chesbrough, Birkinshaw, and Teubal 2006; Ozman 2009). For ongoing development activities related to innovation indicators, see the sidebar "Recent Developments in Innovation-Related Metrics."

Recent Developments in Innovation-Related Metrics

Interest in R&D and innovation-related metrics by governments, academic researchers, and businesses has a long history (Earl and Gault 2006) but has intensified in recent years in the United States (DOC 2008; Mandel 2008; McKinsey & Company 2008; Moris, Jankowski, and Perolle 2008; NRC 2005a; NSF/TCB 2008) and elsewhere (Gault and von Hippel 2009; OECD 2008c). Recent developments in innovation-related metrics are driven by a number of factors, including:

- The rapidly evolving nature of innovation in terms of joint production and exploitation of knowledge, user-based innovation, new business models, entrepreneurship, and global linkages
- Advances in social, behavioral, economic, and management theories of creativity, productivity, and innovation
- Developments in national standards on statistical quality and protection of confidentiality
- Emerging international accounting standards and official statistics guidance on intangibles and other non-financial assets
- Advances in data development, integration, and empirical research methodology involving microdata sets, administrative data, data enclaves, and new computing and visualization tools

Innovation is defined as the introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or the marketplace (OECD/Eurostat 2005, p 146). R&D is only one of many possible knowledge inputs driving innovation. For example, innovation may result from the integration of existing technology or from a new business model. Enhanced international guidance and ongoing methodological studies to better capture statistics on nontechnological innovation, innovation linkages, and service-sector activities are driving development of metrics across OECD countries.

Part of the challenge in developing new metrics resides in the broad scope of innovation activities covering inputs, processes, cross-sector linkages, immediate outputs (for example, products or patents), long-term socioeconomic impacts, and infrastructure or system-wide variables (such as policy incentives or technology standards). Accordingly, data development spans multiple strategies, including surveys and data linking and integration, as well as non-survey-based methods, such as case studies, administrative databases, and Web-based information—pursued in parallel or in combination (NSF/SRS 2007a; NSF/TCB 2008). The following describes selected activities in the development of these indicators.

Intangible Investment and GDP

Treating spending on intangibles, such as software and R&D, as investment in the national income and product accounts (NIPA) (which include GDP and other U.S. economic accounts) recognizes intangible capital, along with other forms of investment inputs, in the production of economic output (Corrado, Hulten, and Sichel 2006; UNSC 2007). International statistical manuals are being updated or developed to provide guidance for comparable measures in this area, including an updated manual for the United Nations System of National Accounts (SNA) and a new OECD handbook covering intangibles and national accounts (Aspden 2008). Software has been considered an

(continued on next page)

Business-to-Business Linkages

Technology and innovation linkages vary by type of partner or knowledge source and level of interaction (OECD/Eurostat 2005). Knowledge sources range from academic papers, conference proceedings, and reports from government laboratories to information from commercial sources, such as marketing and management consultants, patent licensors, R&D contractors, and technology vendors. This section examines indicators related to business transactions and organizational arrangements to acquire or jointly develop new knowledge.

Contract R&D Expenses Within the United States

Increasingly, companies that perform R&D in the United States contract out these activities. These companies reported an estimated $19 billion in R&D performed by external organizations located in the United States[43] in 2007, compared with $12.4 billion in 2006 (appendix tables 4-39 and 4-40).[44] The all-industries ratio of contracted-out R&D to company-funded, company-performed R&D increased from 5.5% in 2006 to 7.8% in 2007.[45] For manufacturers, the ratio reached 8.5% in 2007, up from 5.7% in 2006 (figure 4-22).

Across R&D-intensive industries, pharmaceuticals had the highest ratio of contracted-out R&D (21%) in 2007. The ratio for automotive manufacturers was 7.3%, and for navigational, measuring, electromedical, and control instruments (a subsector of the computer and electronic products industry) was 3.8%. Within services, the contracted-out R&D ratio was 13.8% for scientific R&D services and 8.3% for telecommunications in 2007.

Exports and Imports of R&D Services

Across OECD countries, international trade in services, especially those involving intangibles and knowledge-based assets, presents unique measurement challenges for both business accounting and official statistics (OECD 2008b; Reinsdorf and Slaughter 2009; Yorgason 2007). An indicator in

investment in U.S. NIPA since 1999, and BEA and NSF continue to work on an R&D satellite account, as described earlier in this chapter. BEA plans to incorporate both R&D and spending on artistic and literary originals as intangible investment in the core economic accounts in 2013 and is considering an expanded satellite account that would contain experimental statistics for other intangibles (Aizcorbe, Moylan, and Robbins 2009).

Science of Science and Innovation Policy Program, Research Data Infrastructure, and Advanced Computing Tools

The NSF Science of Science and Innovation Policy (SciSIP) program supports research designed to advance the scientific basis of science and innovation policy. Research funded by the program is aimed at developing, improving, and expanding models, analytical tools, data, and metrics. An area of interest is the development of data infrastructure to support empirical research on innovations within organizations (NSF/TCB 2008). Other efforts focus on cyber-infrastructure research; advanced computing and Web-based tools to protect, archive, link, mine, and analyze data (Lane, Heus, and Mulcahy 2008); and advanced visualization and analytical tools for document-based information, such as patents and bibliographic entries (Börner, Chen, and Boyack 2003).

Entrepreneurship and Business Dynamics

Two National Research Council (NRC) reports cite the need to leverage business data collected by statistical agencies for research and policymaking purposes by more effectively integrating data sets (NRC 2006, 2007b). Data sets for the study of business dynamics include the Census Bureau's Business Dynamics Statistics (BDS) (Census Bureau 2009) and Longitudinal Employer-Household Dynamics (LEHD) program (Abowd, Haltiwanger, and Lane 2004), along with the Business Employment Dynamics published by the Bureau of Labor Statistics (BLS 2009). Research topics of interest include technology adoption, innovation, outsourcing, globalization, market entry and exit by companies, and new or small technology-based firms. Indeed, entrepreneurship has been extensively researched as a vehicle for transferring and exploiting new knowledge from public or private sources (Audretsch 2009). In the United States, the Kauffman Foundation funds research in entrepreneurship and innovation (Kauffman 2008) and sponsors a social longitudinal survey on young firms (Kauffman 2009).

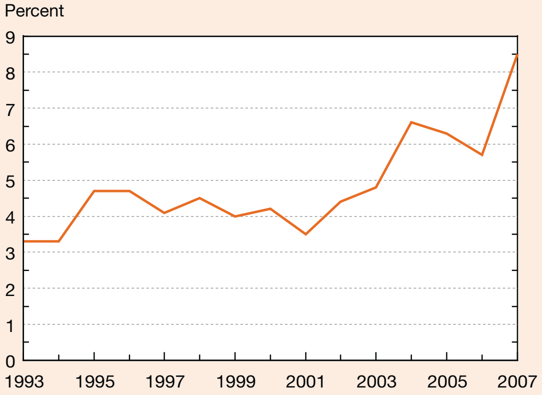
OECD Innovation Microdata Project and EU Community Innovation Surveys

The OECD innovation microdata project aims at exploiting microdata from the EU Community Innovation Surveys (CIS) for economic analysis. In recent years, research teams from different OECD countries have collaborated in applying similar methodologies to their national CIS. Expected products include analytical studies and new innovation indicators covering, for example, international technology transfer, nontechnological innovation, and intellectual property rights (OECD 2009a).

The project is part of a larger OECD Innovation Strategy initiative established in 2007; the objective is to explore strategies to harness the potential of innovation based on a better understanding of innovation. Research is focusing on markets and governance, human capital, global dimensions, and the changing nature of innovation, along with measurement, reporting, and assessment of innovation (OECD 2009b)

Figure 4-22

R&D contracted out in United States by manufacturing companies as ratio of company-funded and -performed R&D: 1993–2007



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series). See appendix table 4-39.

Science and Engineering Indicators 2010

this area is international trade in research, development, and testing (RDT) services, including transactions among unaffiliated or independent companies (unaffiliated trade) and trade within MNCs (affiliated trade). These data are part of balance-of-payment statistics and complement other fee-based transactions (such as royalties and licensing), as well as performance and funding information from R&D surveys (Moris 2009). U.S. data for total RDT trade have been available since 2001 from BEA's international transaction surveys.[46]

In 2007, total U.S. exports (affiliated and unaffiliated) of RDT services reached a record $14.7 billion, compared with record imports of $11.4 billion, resulting in a trade surplus of $3.3 billion. Affiliated trade dominates these U.S. RDT statistics (table 4-21)—which is not surprising, given the large role of MNCs (including U.S. parents and foreign-owned companies) in R&D performance. (See "R&D by Multinational Companies.") Affiliated trade in RDT has recorded between $4 billion and $4.5 billion in annual trade surpluses since 2001, compared with diminishing balances for unaffiliated trade (table 4-21). With affiliated transactions, U.S. trade surplus in RDT services is driven not by U.S. MNC parents but by the relatively high level of exports from U.S. affiliates of foreign MNCs to their foreign parents and other foreign affiliates of the parent companies (Moris 2009).

Newly available country detail shows that 62.8% of U.S. RDT exports in 2007 were purchased by European businesses and another 12.2% by Japanese businesses (appendix table 4-41). European countries accounted for virtually the same share of RDT import transactions (62.1%) in 2007, whereas Japan accounted for 5.6%. Several emerging markets appear as sources of U.S. RDT imports, namely Israel (6.2%) and India (5.3%).

International Technology Alliances

Interfirm R&D alliances, partnerships, and networks add an element of R&D co-production compared with R&D contracts or technology licensing.[47] R&D alliances may be defined as domestic or international cooperative arrangements that combine resources aimed at shared R&D objectives (Hagedoorn, Link, and Vonortas 2003).[48] U.S. restrictions on multifirm cooperative research were loosened by the 1984 National Cooperative Research Act (Public Law 98-462), followed by the 1993 National Cooperative Research and Production Act (NCPRA) (Public Law 103-42), as a way of addressing concerns about the technological leadership and international competitiveness of American firms in the early 1980s (Scott 2008).

This section features data from the Cooperative Agreements and Technology Indicators (CATI) database, which collects data on worldwide business technology partnerships.[49] It is based on public announcements and includes business alliances with an R&D or technology component, such as joint research or development agreements, R&D contracts, and equity joint ventures. The database contains counts dating back to 1980.[50]

Table 4-21

U.S. trade in research, development, and testing services: 2001–07

(Millions of dollars)

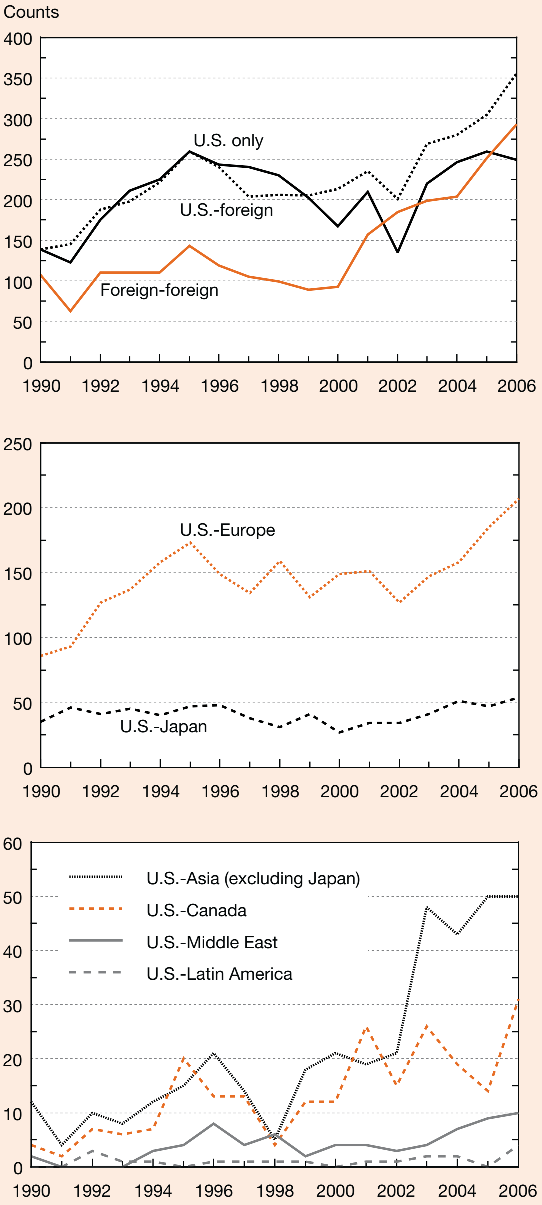
	Exports			Imports			Trade balance		
Year	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated
2001	7,610	6,564	1,046	3,389	2,664	725	4,221	3,900	321
2002	8,678	7,536	1,142	4,063	3,035	1,028	4,615	4,501	114
2003	9,467	8,291	1,176	5,071	3,761	1,310	4,396	4,530	–134
2004	9,563	8,275	1,288	5,778	3,816	1,962	3,785	4,459	–674
2005	10,431	9,135	1,296	7,239	4,950	2,289	3,192	4,185	–993
2006	12,821	11,165	1,655	9,429	6,726	2,702	3,392	4,439	–1,047
2007	14,698	12,686	2,012	11,437	8,364	3,073	3,261	4,322	–1,061

SOURCE: Bureau of Economic Analysis, U.S. International Services, http://www.bea.gov/international/intlserv.htm, accessed 6 May 2009.

Science and Engineering Indicators 2010

According to CATI, in 2006 (the latest available year), about 900 new worldwide business technology alliances were formed, approximately two-thirds of which involved at least one U.S.-owned company regardless of location. Close to 60% of the worldwide total focused on biotechnology, and 23% focused on information technology (appendix table 4-42). Other areas include materials research and engineering, aerospace, automotive, and chemicals. In terms of ownership, the 2006 counts can be grouped into alliances involving only U.S.-owned companies (249), U.S. and foreign-owned companies (356), and only foreign-owned companies (293).

Figure 4-23
U.S. industrial technology alliances with U.S. and foreign-owned companies, worldwide, by country/region of partner: 1990–2006



NOTE: Annual counts of new alliances.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database. See appendix table 4-42.

Science and Engineering Indicators 2010

Since 1999, the proportion of U.S.-foreign alliances annually has surpassed U.S.-only alliances, driven by rapid growth in U.S. alliances with European-owned companies (figure 4-23). The U.S.-Europe alliances increased 141% from 1990 to 2006, compared with about an 80% increase in U.S.-only alliances. The predominance of U.S. and European companies in CATI technology agreements is consistent with rankings of global R&D by major pharmaceutical, biotechnology, software, and automotive MNCs (UK DIUS 2008). At the same time, the number of U.S.-Japan alliances in 2006 (54) effectively reached parity with U.S. alliances with other Asia-Pacific countries (50), (reflecting the rapid growth of the latter since 1990, albeit from relatively low levels (figure 4-23). The 50 U.S. alliances with Asia-Pacific companies, excluding Japan, were driven by collaborative agreements with companies headquartered in India (15), China (12), and South Korea (11). This pattern reflects the increasing if still modest role of these countries as hosts for U.S.-owned R&D discussed earlier in this chapter. Of course, noting simple frequencies of international collaborative agreements is only a first step in tracking the economic and policy relevance for participating companies and their home and host countries (Bozeman and Dietz 2001; Siegel 2003).[51]

Federal Technology Transfer and Other Innovation-Related Programs

This section reviews two sets of indicators on public-private collaboration supporting technology transfer and innovation (for academic patents and related knowledge diffusion indicators, see chapter 5).[52] The first set includes federal programs for technology transfer from R&D funded and performed by government agencies and laboratories. The second set includes federal programs that support new or small U.S. companies in R&D or technology deployment activities with R&D funds or technical assistance.

In the late 1970s, concerns about the strength of U.S. industries and their ability to be competitive in the global economy intensified. Issues included the question of whether inventions from federally funded academic research were adequately exploited for the benefit of the national economy and the need to create or strengthen public-private R&D partnerships. Since the 1980s, several U.S. policies have facilitated cross-sector R&D collaboration and technology transfer. One major policy thrust was to enhance formal mechanisms for transferring knowledge arising from federally funded and performed R&D (Crow and Bozeman 1998; NRC 2003). Other policies addressed federally funded academic R&D, the transition of early-stage technologies into the marketplace, and R&D and innovation by small or minority-owned businesses. For a brief overview of these

Major Federal Legislation Related to Technology Transfer and Cooperative R&D

Technology Innovation Act of 1980 (Stevenson-Wydler Act) (Public Law 96-480)—established technology transfer as a federal government mission by directing federal labs to facilitate the transfer of federally-owned and originated technology to nonfederal parties.

University and Small Business Patent Procedures Act of 1980 (Bayh-Dole Act) (Public Law 96-517)—permitted small businesses, universities, and nonprofits to obtain titles to inventions developed with federal funds. Also permitted government-owned and government-operated laboratories to grant exclusive patent rights to commercial organizations.

Small Business Innovation Development Act of 1982 (Public Law 97-219)—established the Small Business Innovation Research (SBIR) program, which required federal agencies to set aside funds for small businesses to engage in R&D connected to agency missions.

National Cooperative Research Act of 1984 (Public Law 98-462)—encouraged U.S. firms to collaborate in generic precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures.

Patent and Trademark Clarification Act of 1984 (Public Law 98-620)—provided further amendments to the Stevenson-Wydler Act and the Bayh-Dole Act regarding the use of patents and licenses to implement technology transfer.

Federal Technology Transfer Act of 1986 (Public Law 99-502)—enabled federal laboratories to enter cooperative research and development agreements (CRADAs) with outside parties and to negotiate licenses for patented inventions made at the laboratory.

Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418)—in addition to measures on trade and intellectual property protection, the act directed attention to public-private cooperation on R&D, technology transfer, and commercialization. It also established NIST's Manufacturing Extension Partnership (MEP) program.

National Competitiveness Technology Transfer Act of 1989 (Public Law 101-189)—amended the Federal Technology Transfer Act to expand the use of CRADAs to include government-owned, contractor-operated federal laboratories and to increase nondisclosure provisions.

National Cooperative Research and Production Act of 1993 (Public Law 103-42)—relaxed restrictions on cooperative production activities, which enable research joint venture participants to work together in the application of technologies they jointly acquire.

National Technology Transfer and Advancement Act of 1995 (Public Law 104-113)—amended the Stevenson-Wydler Act to make CRADAs more attractive to federal laboratories, scientists, and private industry.

Technology Transfer Commercialization Act of 2000 (Public Law 106-404)—broadened CRADA licensing authority to make such agreements more attractive to private industry and increase the transfer of federal technology. Established procedures for performance reporting and monitoring by federal agencies on technology transfer activities.

America COMPETES Act of 2007 (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Sciences [COMPETES] Act) (Public Law 110-69)—increased investment in R&D; strengthened educational opportunities in science, technology, engineering, and mathematics from elementary through graduate school; and further developed the nation's innovation infrastructure. Among other measures, the act established NIST's Technology Innovation Program (TIP) and called for a President's Council on Innovation and Competitiveness.

initiatives, see the sidebar "Major Federal Legislation Related to Technology Transfer and Cooperative R&D."

Federal Technology Transfer

Federal technology transfer refers to processes through which the knowledge and capabilities of federal intramural laboratories and other research facilities can be directed to the R&D needs of outside public or private organizations—and through which the inventions and other intellectual assets arising from federal laboratory R&D can be conveyed to outside parties for development and commercialization (FLC 2006). Since the Stevenson-Wydler Act of 1980, all federal labs have been required to have technology transfer offices (Office of Research and Technology Applications [ORTA]) to assist in identifying transfer opportunities and establishing appropriate arrangements for relationships with external parties.[53] Indicators on these activities illustrate a diverse range of mechanisms used in federal technology transfer.[54] For background information, see the sidebar "Federal Technology Transfer: Activities and Metrics."

Table 4-22 shows total technology transfer activity statistics for FY 2007, as well as statistics for six agencies that account for the majority of this activity. In 2007, federal laboratories participated in 7,327 cooperative research and development agreements (CRADAs) with businesses and organizations, compared with 7,271 in 2006 and 5,949 in 2005 (appendix table 4-43). Federal labs also participated in 9,445 non-CRADA collaborative R&D relationships in 2007. Agencies issued more than 1,400 patents in 2007 and held 10,347 active licenses, including just below 4,000

Federal Technology Transfer: Activities and Metrics

Federal technology transfer can take a variety of forms (FLC 2006), including the following:

- *Commercial transfer.* Movement of knowledge or technology is developed by a federal lab and transferred to private organizations in the commercial marketplace.
- *Scientific dissemination.* Publications, conference papers, and working papers are distributed, and other forms of data dissemination are employed.
- *Export of resources.* Federal lab personnel are made available to outside organizations with R&D needs through collaborative agreements or other service mechanisms.
- *Import of resources.* The federal lab brings in outside technology or expertise to enhance the lab's existing capabilities.
- *Dual use.* Technologies, products, or families of products with both commercial and federal applications are developed.

Most federal labs engage in all of these forms of technology transfer to some extent. The emphases and relative levels of each vary widely across the federal agencies, depending on the parent agency's mission, the lab's main areas of scientific and technological interest, typical clients, prevailing scientific/technical culture, and any special transfer authorities the agency may have been granted. For some agencies and their labs, the principal technology transfer thrust is patents, patent licenses, and material transfer agreements. Others emphasize traditional public dissemination of new scientific or technical knowledge and cooperative R&D relationships with outside organizations—with patenting and licensing activity taking place only when it is determined that private-sector investment in a new technology is needed to achieve development and commercialization goals.

Several metrics illustrate activities and agency priorities among three main classes of mechanisms. The *invention disclosure and patenting* category involves counts of invention disclosures filed (typically, an inventing scientist or engineer filing a written notice of the invention with the lab's technology transfer office), patent applications filed with the U.S. Patent and Trademark Office (or abroad), and patent awards received. The *licensing* category covers federal lab licensing of federal intellectual property, such as patents or copyrights, to outside parties to enable further development and commercialization, usually through the technology transfer office. For example, in recent years, DOE's government-owned, contractor-operated laboratories have increasingly used their special authority to transfer software technology through relatively quickly executed copyright license mechanisms. The third main category is *collaborative relationships for R&D*, including CRADAs.

Table 4-22

Federal laboratory technology transfer activity indicators, by selected U.S. agency: FY 2007

Technology transfer activity indicator	Total	DOD	HHS	DOE	NASA	USDA	DOC
Invention disclosures and patenting							
Inventions disclosed	4,486	838	447	1,575	1,268	126	32
Patent applications filed	1,824	597	261	693	105	114	7
Patents issued	1,406	425	379	441	93	37	4
Licensing							
All licenses, total active	10,347	460	1,418	5,842	1,883	339	217
Invention licenses	3,935	460	915	1,354	461	339	217
Other intellectual property licenses	6,405	0	460	4,488	1,422	0	0
Collaborative relationships for R&D							
CRADAs, total active	7,327	2,971	285	697	1	230	2,778
Traditional CRADAs	3,117	2,383	206	697	1	184	154
Other collaborative R&D relationships	9,445	0	0	0	2,666	4,084	2,695

CRADA = Cooperative Research and Development Agreement; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = U.S. Department of Agriculture

NOTES: Other federal agencies not listed but included in total: Department of the Interior, Department of Transportation, Department of Veterans Affairs, and Environmental Protection Agency. Department of Homeland Security expected to provide technology transfer statistics starting in FY 2008. Invention licenses refers to inventions that are/could be patented. Other intellectual property refers to intellectual property protected through mechanisms other than a patent, e.g., copyright. Total active CRADAs refers to agreements executed under CRADA authority (15 U.S.C. 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. Federal agencies have varying authorities for other kinds of collaborative R&D relationships.

SOURCE: National Institute of Standards and Technology, Federal Laboratory Technology Transfer, Fiscal Year 2007, Summary Report to the President and the Congress, January 2009, http://patapsco.nist.gov/ts/220/external/index.htm, accessed 6 May 2009. See appendix table 4-43.

Science and Engineering Indicators 2010

invention licenses, based on their total stock of intellectual property. Appendix table 4-43 provides data for all agencies for FY 2000–07.

Small Business Innovation–Related Programs

This section reviews federal programs that support new or small U.S. companies in R&D or technology deployment activities. These programs include the Small Business Innovation Research (SBIR) program, the Small Business Technology Transfer (STTR) program, the Technology Innovation Program (TIP), and the Hollings Manufacturing Extension Partnership (MEP). The first three programs provide early-stage technology financing, whereas the last one provides technical assistance to small and medium-sized manufacturers.

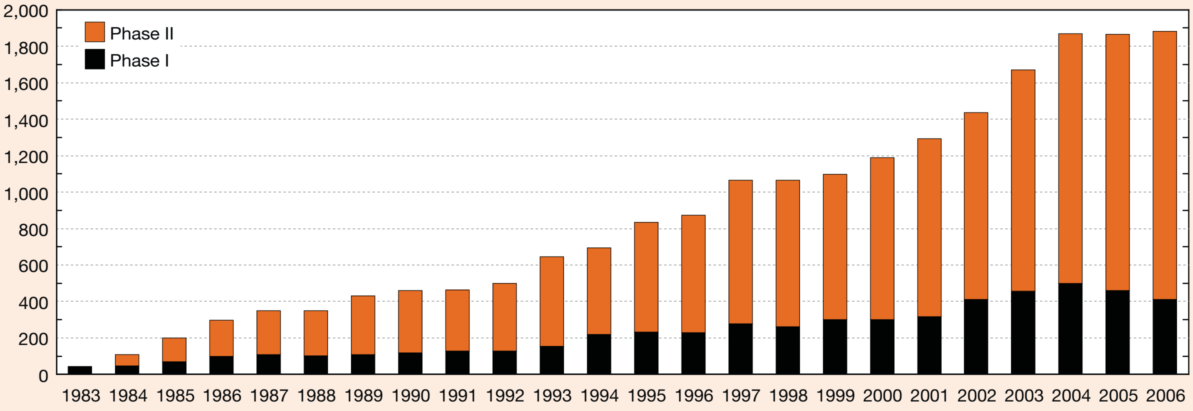
The SBIR program was created by the Small Business Innovation Development Act of 1982. According to the SBIR statute, federal agencies with extramural R&D obligations exceeding $100 million must set aside a fixed percentage of such obligations for projects involving small business (those with 500 or fewer employees). This set-aside has been 2.5% since FY 1997. The program has multiple objectives, namely stimulating technological innovation, fostering the use of small business to meet federal R&D needs, encouraging participation by minority and disadvantaged persons in technological innovation, and increasing private-sector commercialization of innovation derived from federal R&D. SBIR's sister program, the STTR program, was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs. Both of these programs are coordinated by the Small Business Administration (SBA). In FY 2007, SBIR and STTR combined awarded $2.3 billion (SBA 2009).[55]

In FY 2006, 11 federal agencies awarded a total of $1.9 billion to about 5,900 SBIR projects (appendix tables 4-44 and 4-45). Funded technology areas include computers and electronics, information services, materials, energy, and life science applications. DOD represented just below 50% of total SBIR funds, whereas HHS represented 30%, consistent with its large extramural R&D budgets.

The SBIR program is structured in three phases. Phase I evaluates the scientific and technical merit and feasibility of ideas. Phase II builds on phase I findings, is subject to further scientific and technical review, and requires a commercialization plan (NRC 2008). During phase III, the results from phase II R&D are further developed and introduced into private markets or federal procurement using private or non-SBIR federal funding.[56] Over the life of the program, the share of phase II funding has increased from about two-thirds in the mid-1980s to more than three-fourths (figure 4-24). Bridge funding and other support for startups beyond phase II were found to be critical for successful commercialization by a recent NRC study (NRC 2008, p 209). Some agencies have implemented "phase IIB" or "phase II+" matching funds and/or technical and business support for qualified awardees (NRC 2008, pp 209–16).

The STTR program is also structured in three phases and involves R&D performed jointly by small businesses and nonprofit research organizations. Federal agencies with extramural R&D budgets exceeding $1 billion participate in the STTR program. Starting in FY 2004, the required set-aside doubled to 0.3%, compared with the 2.5% set-aside for SBIR. In FY 2006, DHS participated for the first time, along with DOD, NSF, DOE, NASA, and HHS. From FY 1994 to 2006, STTR awarded $1.3 billion to about 6,000 projects, including $226 million to 878 projects in FY 2006 (appendix tables 4-44 and 4-46).

Figure 4-24
SBIR funding, by type: 1983–2006
Dollars (millions)



SBIR = Small Business Innovation Research Program

SOURCE: Small Business Administration, Small Business Innovation Research Program Annual Report (various years). See appendix table 4-45.

Science and Engineering Indicators 2010

According to SBA, small businesses interested in participating in the STTR program must find a research institution that meets the program's definition and develop a working agreement before competing for an STTR award. Universities are active as STTR partners. For example, in FY 2004, at least 200 universities, many with multiple awardees, partnered with small companies under STTR; 15 FFRDCs also collaborated with awardees (SBA 2005).

Established by the America COMPETES Act of 2007 and administered by NIST,[57] TIP was set up for "the purpose of assisting U.S. businesses and institutions of higher education or other organizations, such as national laboratories and nonprofit research institutions, to support, promote, and accelerate innovation in the United States through high-risk, high-reward research in areas of critical national need."[58] The new program replaces the Advanced Technology Program (ATP). From FY 1990 to 2007, ATP awarded funds for 824 projects with a combined funding of $4.6 billion, about equally split between the program and its participants (appendix table 4-47). The first TIP competition focused on advanced sensors to support monitoring and assessment of civil infrastructure, such as water pipelines, roads, bridges, and tunnels (appendix table 4-48).

A national system of affiliated manufacturing extension centers, MEP is also housed at NIST. It was established by the Omnibus Trade and Competitiveness Act of 1988 to enhance the productivity and technological performance of small and medium-sized U.S. manufacturers (15 U.S.C. 278(k)).

MEP centers receive federal funding on a competitive basis for their development and operations. Nonfederal funding is required for 50% or more of the centers' capital and annual operating funds. Companies receive technical and managerial assistance, generally on a reimbursable basis, but receive no direct federal funding (Schacht 2008). Federal funding for MEP reached $106.8 million in FY 2007 and $91 million in FY 2008 (appendix table 4-49). Activities included technology deployment and technical services involving advanced manufacturing systems and engineering services, as well as business services such as management and strategy development, marketing, and training. For nontechnical services, MEP centers generally partner with commercial and academic consultants and government agencies (Shapira 2001, pp 983–84).[59]

Conclusion

U.S. spending on R&D reached an estimated $397.6 billion in 2008, a 6.7% increase (or 4.5% in inflation-adjusted dollars) from the 2007 total. This 2008 figure is preliminary, however, and may not fully reflect the effects of the downturn in U.S. and worldwide economic conditions that took place in the latter half of the year.

In 2008, businesses performed an estimated $289.1 billion (current dollars), or 73%, of the total U.S. R&D. The academic sector is the second-largest performer of U.S. R&D, with estimated expenditures of $51.2 billion, or just below 13% of the U.S. total. Federal agencies, their laboratories, and FFRDCs accounted for an estimated $41.7 billion, or about 11% of the total. Nonprofit organizations performed the remainder, $15.6 billion, or about 4%.

Business and the federal government are the two largest sources of R&D funding. The business sector provided an estimated $267.8 billion (current dollars) of funding for R&D in 2008, 67% of the U.S. total. The federal government funded an estimated $103.7 billion of R&D, or 26% of the total. Over the past 5 years, expanded business spending on R&D has accounted for much of the growth (in both current and real-dollar terms) in total U.S. R&D spending. Federal funding overall has been flat or declining on a real-dollar basis. At the time of this writing, the impact of the current economic slowdown in U.S. R&D expenditures remains uncertain.

Historically, the federal government has been the prime source of funding for basic research, accounting for an estimated 57% of the nation's total in 2008. Moreover, in the same year, the federal government funded 61% of the basic research performed by universities and colleges, the nation's largest performers of basic research.

The budget appropriations for federal spending on R&D in FY 2009 totaled $147.1 billion, an increase of $3.3 billion, or 2.4%, over the FY 2008 spending level. The president's proposed budget for FY 2010 requests federal R&D spending of $147.6 billion, an increase of $0.6 billion, or 0.4%, over the appropriated FY 2009 level. Furthermore, the American Recovery and Reinvestment Act, enacted in early 2009, provided a one-time increase in funding for federal R&D and R&D infrastructure, estimated to total $18.3 billion in FY 2009.

Globally, R&D expenditures totaled an estimated $1,107 billion in 2007, the most recent year for which internationally comparable data are available. R&D is concentrated regionally in North America (35%), Asia (31%), and Europe (28%) and is further concentrated within a relatively few countries. According to OECD statistics, the United States (with 33% of the world total) and Japan (13%) account for almost half of global R&D. That figure increases to two-thirds by adding the next three countries on the list, China (9%), Germany (6%), and France (4%). Adding South Korea, the United Kingdom, the Russian Federation, Canada, and Italy completes the top 10 countries, accounting for about 80% of global R&D.

China, which ranks third globally in R&D spending, continues to exhibit the most dramatic growth pattern. Its real R&D growth over the past decade has averaged just over 19% annually. Both India and Brazil also are among the world's larger and faster-growing R&D performers, according to UNESCO statistics. India performed about $15 billion of R&D in 2004, and Brazil about $13 billion in 2005 (both figures are the most recent available data). The totals reported for both countries are about double the levels of R&D performance each reported in the mid-1990s. Comparability of these figures to the OECD statistics is unclear, but such levels of R&D expenditures would rank both India and Brazil among the world's top 15 R&D-performing nations.

Another dimension of the international character of R&D performance is the activities by U.S. MNCs overseas. More than 85% of annual global R&D expenditures by U.S. MNCs are made in the United States ($187.8 billion of $216.3 billion in 2006); however, the geographic distribution of R&D expenditures outside the United States by the overseas affiliates of U.S. MNCs ($28.5 billion in 2006) is gradually shifting to reflect the role of emerging markets. In particular, major developed economies or regions (Canada, Japan, and Europe) account for a decreasing share of the overseas R&D investments of U.S. MNCs, declining from 90% in 1994 to 80% in 2006. Over the same period, the share of the Asia region (excluding Japan) more than doubled, from 5.4% to 13.5%, driven by the R&D spending of U.S.-owned affiliates in China, Singapore, and South Korea. Among individual countries, R&D performed by U.S.-owned affiliates in China and India increased from less than $10 million in each country in 1994 to $804 million and $310 million, respectively, in 2006. The 2006 levels for China and India represented about 3% and 1%, respectively, of total overseas R&D by U.S. MNCs.

The increasing role of services and international collaboration in R&D and innovation is reflected in statistics on trade in R&D services. In 2007, total U.S. exports of research, development, and testing services reached a record $14.7 billion, compared with record imports of $11.4 billion, resulting in a trade surplus of $3.3 billion. Trade within MNCs dominates these statistics—which is not surprising, given the significant role of MNCs in R&D performance.

Rapid changes in the collaborative and global nature of R&D and the increasing role of services and nontechnological innovation call for continuous enhancements in the indicators of these activities and their impact. U.S. federal statistical agencies continue to collaborate domestically and internationally to facilitate improved and comparable data. Ongoing U.S. data development projects featured in this chapter include the new Business R&D and Innovation Survey, the R&D NIPA satellite account, exploratory work on intangibles and innovation accounts, and efforts in the area of research data infrastructure by NSF's Science of Science and Innovation Policy Program.

Notes

1. As financial input indicators, statistics on expenditures in and of themselves do not indicate the extent to which R&D efforts are effective or successful.

2. Adjustments for inflation reported in this chapter are based on the GDP implicit price deflator. GDP deflators are calculated on an economy-wide rather than an R&D-specific basis. As such, they should be interpreted as measures of real resources engaged in R&D rather than in other activities, such as consumption or physical investment. They are not a measure of cost changes in performing research. See appendix table 4-1 for GDP deflators used in this chapter.

3. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the federal government. They operate to provide R&D capability to serve agency mission objectives or, in some cases, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered by an industrial firm, a university, a nonprofit institution, or a consortium.

4. The topic of R&D categories is also part of ongoing survey redesign and methodological studies in the United States and internationally.

5. The OECD notes that in measuring R&D, the greatest source of error often is the difficulty of locating the cutoff point between experimental development and the related activities required to realize an innovation (OECD 2002, paragraph 111). Most definitions of R&D set the cutoff at the point when a particular product or process reaches "market readiness." At this point, the defining characteristics of the product or process are substantially set (at least for manufacturers if not also for services), and further work is primarily aimed at developing markets, engaging in preproduction planning, and streamlining the production or control system.

6. The latest data available on the distribution of U.S. R&D performance by state are for 2007. All U.S. R&D expenditures that year were estimated at $372.5 billion. Of this total, $359.7 billion could be attributed to expenditures in the 50 states and the District of Columbia. The state-attributed totals differ from the U.S. total for a number of reasons: some industry R&D expenditures cannot be allocated to any of the 50 states or the District of Columbia because respondents did not answer the question related to location; nonfederal sources of nonprofit R&D expenditures (an estimated $8.4 billion in 2007) could not be allocated by state; state-level university R&D data have not been adjusted for double-counting of R&D passed from one academic institution to another; state agency intramural R&D (collected by NSF starting in 2006 [see NSF/SRS 2008a]) are not included in the U.S. total; and state-level university and federal R&D performance data are not converted from fiscal to calendar years.

7. Federal intramural R&D includes costs associated with the administration of intramural and extramural programs by federal personnel, as well as actual intramural R&D performance. This explains the large amount of federal intramural R&D reported for the District of Columbia.

8. For most manufacturing industries, the Small Business Administration has established a size threshold of 500 employees to define small companies. The NSF Survey of Industrial Research and Development does not sample companies with fewer than five employees because of concerns about respondent burden.

9. These estimates were derived from the NSF-Census Bureau's annual Survey of Industrial Research and Development, which collects financial data related to R&D activities from companies performing R&D in the United States. These data provide a basis for analyzing R&D investment of the business sector and are the official source for U.S. busi-

ness R&D estimates. (See sidebar "New U.S. Business R&D and Innovation Survey.")

10. A similar measure of R&D intensity is the ratio of R&D to *value-added* (gross output minus cost of intermediate inputs). Value-added is often used in studies of productivity because it allows analysts to focus on the economic output attributable to the specific industrial sector in question by subtracting inputs produced in other sectors.

11. Industry-level analyses are complicated by the fact that each company's R&D is reported in only one industry.

12. In the North American Industry Classification System (NAICS), the utility industry comprises establishments engaged in the provision of electric power, natural gas, steam, and water, as well as the removal of sewage. Establishments that provide telephone and other communication services are included in other NAICS industries.

13. Because federal R&D funding is concentrated among a few companies in a small number of industries, the potential for disclosing information about a particular company is high; therefore, these data are often suppressed. This situation prevents the precise tabulation of total R&D performance and the calculation of R&D-to-net-sales ratios for many industries.

14. For a recent study on the role of service industries in R&D and innovation, see Gallaher, Link, and Petrusa (2006).

15. Methodological differences between the PhRMA Annual Membership Survey and the NSF Survey of Industrial Research and Development make it difficult to directly compare estimates from the two surveys. For example, the PhRMA survey definition of R&D includes phase IV clinical trials (trials conducted after a drug is licensed and available for doctors to prescribe), whereas the NSF survey definition does not. In addition, NSF survey sales data may contain income from sources not related to the production of drugs and medicines.

16. In NSF's Survey of Industrial Research and Development, companies that predominantly license their technology rather than manufacture finished products are often classified in the scientific R&D service industry. Therefore, a sizable amount of biotechnology R&D that serves the pharmaceutical industry is reported in the R&D service sector. (See "R&D and Related Services.")

17. Data for computer and electronic product manufacturing in this section refer to NAICS 334 except the federally funded R&D component of navigational, measuring, electromedical, and control instruments industry (NAICS 3345), which is included in aerospace and defense manufacturing.

18. Suppression of federal R&D funding information prohibits the precise tabulation of total R&D performance for some industries. Lower-bound analyst estimates are given in cases where the potential disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

19. The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited statistics, the R&D expenditures of companies in the software, other information, and computer system design and related service industries were combined. These three industries provided the closest approximation to the broader category cited for earlier years without exceeding the coverage of the broader category.

20. NAICS-based R&D estimates are available only to 1997. Estimates for 1997 and 1998 were bridged from a different industry classification scheme. Total R&D for this sector has grown from $9.2 billion in 1997 to $16.0 billion in 2007.

21. Although companies in the R&D and related-services sector and their R&D activities are classified as nonmanufacturing, they serve many manufacturing industries. For example, many biotechnology companies in this sector license their technology to companies in the pharmaceutical manufacturing industry. The R&D of a research firm that is a subsidiary of a manufacturing company rather than an independent contractor would be classified as R&D in a manufacturing industry. Consequently, growth in R&D services may, in part, reflect a more general pattern of industry's increasing reliance on outsourcing and contract R&D. For a related discussion, see "Technology and Innovation Linkages."

22. Because R&D expenses reported on financial documents differ from the data reported on the NSF Survey of Industrial Research and Development, direct comparisons of these sources are not possible. For an explanation of the differences between the two, see Shepherd and Payson (1999).

23. Support for private R&D can be studied along several dimensions, including the immediate effect in stimulating R&D relative to costs (e.g., tax expenditures [forgone public revenues]) and administrative expenses), longer-term impacts (e.g., growth and employment), and relationship to other policy tools. See Atkinson (2007) and Tassey (2007) for recent discussions on the U.S. tax credit, Wilson (forthcoming) and Wu (2004) for empirical studies on state R&D credits, and Bloom, Griffith, and Van Reenen (2002) and OECD (2003) for country-level empirical studies on the effectiveness of R&D tax credits.

24. Tax incentives include tax allowances, exemptions, or deductions (reductions in taxable income) and tax credits (reductions in tax liability). Each of these tax incentives may be designed with different features, such as eligibility criteria, allowable expenses, and level versus incremental bases (OECD 2003).

25. H.R.1424, Public Law No. 110-343 (Division C, Title III, Section 301).

26. Qualified R&D costs include company-funded expenses for wages paid, supplies used in the conduct of qualified research, and certain contract expenses. For tax purposes, R&D expenses are restricted to the somewhat narrower concept of R&E expenditures. Qualified expenses must satisfy tests involving the experimental and technological nature of activities (26 CFR 1.41-2). Research in the social sciences or humanities is excluded. See NSF/SRS (2006) for details.

27. One of two forms of alternative credit formulas may be used in lieu of regular credit provisions: an alternative

incremental R&E tax credit (AIRC), enacted in 1996, and a simplified alternative credit (ASIC), established in 2006. Companies may select only one of these three credit types on a permanent basis unless the IRS authorizes a change. The 2008 bill extending the overall R&E credit increased the statutory rate for the ASIC from 12% to 14% and repealed the AIRC for the 2009 tax year only (Guenther 2008).

28. The target population for SOI's corporate statistics consists of returns of active corporations required to file one of nine 1120 IRS tax forms, where *corporations* refers to for-profit corporations, joint-stock companies, and certain unincorporated associations. Estimates on corporate tax statistics are based on a stratified probability sample of unaudited active returns. Active returns include returns having current income or deductions. IRS data are for tax years, which cover accounting periods ending any month between July of the calendar year of reference through June of the following calendar year. Estimates are subject to sampling and nonsampling errors. For SOI statistical methodology, see section 3 in IRS (2009).

29. Actual credit amounts are lower than claims because of limits on overall or general business credits. Corporations requesting the R&E credit must complete IRS Form 6765 (the latest form is available at http://www.irs.gov/pub/irs-pdf/f6765.pdf). SOI tax credit estimates reported in this section cover only C corporations. In particular, data excludes pass-through entities (those that pay little or no federal income tax at the corporate level but are instead required by law to pass any profits or losses to their shareholders, where they are taxed at the individual rate) such as S corporations (IRS form 1120S), real estate investment trusts (1120-REIT), and regulated investment companies (1120-RIC).

30. See figure C in http://www.irs.gov/taxstats/article/0,,id=164402,00.html (accessed 19 June 2009). This source also has data by type of R&E credit and related IRS/SOI publications.

31. See appendix table 4-12. Although both IRS and NSF/Census statistics use NAICS as the underlying industry classification system, comparisons of R&D-related estimates at the industry level are problematic because of differences in classification and company consolidation procedures. For example, industry codes for tax purposes are based on gross receipts, whereas the classification in the NSF/Census survey is based on dollar payrolls.

32. Accordingly, the business share of R&D funding for the United States in table 4-14 is overstated—specifically in comparison with the business-sector shares for countries where foreign sources of R&D funding are reported separately from domestic sources. R&D investments by foreign MNCs (discussed later in this chapter) provide an indication of international participation in U.S. business R&D. However, foreign ownership does not necessarily imply foreign funding, given that an affiliate may fund activities through domestic sources.

33. For discussions of R&D diversity measurement, see Archibugi and Pianta (1992, 1996).

34. Some analysts argue that the low nondefense GBAORD share for economic development in the United States reflects the expectation that businesses will finance industrial R&D activities with their own funds. Moreover, government R&D that may be useful to industry is often funded with other purposes in mind, such as defense and space, and is therefore classified under other socioeconomic objectives.

35. For international intra-MNC transactions in R&D services, see "Technology and Innovation Linkages." See chapter 3 for MNC R&D employment and chapter 6 for FDI financial flows.

36. Western Europe and Asia have also attracted the majority of FDI financial flows by U.S. MNCs (Sethi et al. 2003).

37. For these data, the United States includes the 50 states; Washington, DC; Puerto Rico; and all U.S. territories and possessions.

38. BEA defines a parent company of a U.S. MNC as an entity (individual, branch, partnership, or corporation), resident in the United States, that owns or controls at least 10% of the voting securities, or equivalent, of a foreign business enterprise. Data are for nonbank U.S. MNC parent companies. Affiliate data cover majority-owned, nonbank foreign affiliates of nonbank U.S. parents. For selected NSF data on overseas R&D funded by companies with R&D activities in the 50 states and Washington, DC, see appendix tables 4-37 and 4-38.

39. Data on parents' R&D for 2004 and later are not fully comparable with earlier data because of improvements in statistical coverage. The improvements resulted from comprehensive information on parent R&D activities obtained from the Bureau of Economic Analysis 2004 Benchmark Survey of U.S. Direct Investment Abroad and from new information obtained through an ongoing interagency statistical project (see NSF/SRS [2007b]).

40. In comparison, the share of value-added (gross product) by affiliates located in Europe was 54.3% in 2006. Affiliates in the United Kingdom and Germany also reported the largest value-added figures over this period (BEA 2009).

41. See "International R&D Comparisons."

42. See Branstetter and Foley (2007, pp 15–21), NSF/SRS (2004), OECD (2008d), and von Zedtwitz, (2004) for FDI R&D and technology alliances in China. For information on India and other emerging markets, see Arora and Gambardella (2004) and NRC (2007a).

43. Outside organizations include independent companies, universities, nonprofit organizations, and government, but the majority of this R&D is performed by companies. See appendix table 4-40 for industry-specific data.

44. Data are for R&D contract expenditures paid by U.S. industrial R&D performers (using company and other nonfederal R&D funds) to other domestic performers. In this section, *contract R&D* refers to a transaction with external parties involving R&D payments or income, regardless of its legal form. Transactions by companies that do not perform

internal R&D in the United States are excluded, as are R&D activities contracted out to companies located overseas.

45. *Company-funded* is shorthand for "company and other nonfederal."

46. RDT is part of the larger category of business, professional, and technical services. RDT services include commercial and noncommercial research as well as product development and testing services. The latter component includes non-R&D testing services. RDT covers services by all companies regardless of industry classification, not just activities of companies or establishments classified in NAICS 5417. Starting with 2006 data, new BEA survey forms BE-120 (benchmark) and BE-125 (quarterly) collect both affiliated and unaffiliated transactions. For further methodological information, see http://www.bea.gov/surveys/iussurv.htm.

47. In practice, these activities may be part of a given business arrangement or innovation project. Furthermore, technology alliances may or may not be part of larger agreements involving manufacturing, marketing, and other business functions.

48. Drivers for R&D collaboration include reduction in costs and/or time to market, sharing of instrumentation and other infrastructure, technology diversification (exploration and experimentation across multiple technology platforms), and long-term learning (Cantwell, Gambardella, and Granstrand 2004; Ozman 2009). The policy environment, especially antitrust regulation and intellectual property protection, is also critical to the incidence of these drivers and their economy-wide impact (Scott 2008).

49. For data from the Cooperative Research (CORE) database, based on Department of Justice registrations required by NCRPA, see NSF/SRS (2006, p 4-34).

50. CATI is a literature-based database that draws on sources such as newspapers, journal articles, books, and specialized journals that report on business events. Agreements involving small or startup firms are likely to be underrepresented. Another limitation is that the database draws primarily from English-language materials. Data on alliance structure, size, duration, or outputs are not available. For studies combining CATI and other data sources, see papers and references in Hagedoorn, Link, and Vonortas (2003).

51. For an overview of indicator development in this area, see Jankowski, Link, and Vonortas (2001) and Hagedoorn, Link, and Vonortas (2003).

52. Science or research parks, another example of public-private collaboration, may facilitate knowledge diffusion, technology development and deployment, and entrepreneurship by involving universities, government laboratories, and business startups. Two recent U.S. workshops focused on science parks. A December 2007 NSF workshop was aimed at fostering a better understanding and measurement of science parks' activities, including the role of science parks in the national innovation system. Participants identified a need for systematic studies on topics such as the social benefits of public investment in science parks, ways in which the university–science park interaction engenders entrepreneurial activity, and lessons that U.S. science parks can learn from comparative studies with European and Asian parks. For material from this workshop, see http://www.nsf.gov/statistics/workshop/sciencepark07. A subsequent workshop sponsored by the National Academies explored international models and best practices in science parks (NRC 2009). See also PCAST (2008) and chapters 8 and 9 in Link and Siegel (2007).

53. Federal agencies frequently cited in government reports on federal technology transfer include the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security, the Interior, Transportation, and Veterans Affairs; the Environmental Protection Agency; and the National Aeronautics and Space Administration. Data include both federal intramural laboratories and FFRDCs.

54. Notably missing among these indicators are technical articles published in professional journals, conference papers, and other kinds of scientific communications; however, few labs regularly tabulate and report this information.

55. FY 2007 figures are preliminary. As this volume was going to press, the House and Senate agreed to the latest in a series of short-term extensions of these programs.

56. To obtain federal funding under this program, a small company applies for a phase I SBIR grant of up to $100,000 for up to 6 months to assess the scientific and technical feasibility of ideas with commercial potential. If the concept shows further potential, the company may receive a phase II grant of up to $750,000 over a period of up to 2 years for further development.

57. See Section 3012 of the America COMPETES Act (Public Law 110-69), enacted 9 August 2007. Final rules prescribing TIP procedures were released 25 June 2008 (15 C.F.R. Part 296). The first competition was announced in July 2008, and the first awards were made in January 2009.

58. Public Law 110-69, Section 3012.

59. For example, beginning in 2006, MEP began collaborating to connect small manufacturers with trade promotion specialists of DOC's International Trade Administration and its export assistance centers in specific industry sectors, such as machinery and microelectronics (GAO 2007, p 20). For MEP impact studies, see http://blue.nist.gov/sshome.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (in terms of 10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

Development: Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

EU-27: Prior to 2004, the European Union (EU) consisted of 15 member nations: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. In 2004, the membership expanded to include an additional 10 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. And, in January 2007, Bulgaria and Romania were added, bringing the total of member countries to 27.

Federally funded research and development center (FFRDC): R&D-performing organizations that are exclusively or substantially financed by the federal government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes; each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution.

Foreign affiliate: Company located overseas but owned by a U.S. parent.

Foreign direct investment (FDI): Ownership or control of 10% or more of the voting securities (or equivalent) of a business located outside the home country.

G-7 countries: The Group of Seven industrialized nations includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

General university fund (GUF): Block grants provided by all levels of government in Europe, Canada, and Japan to the academic sector that can be used to support departmental R&D programs that are not separately budgeted; the U.S. federal government does not provide research support through a GUF equivalent.

Gross domestic product (GDP): The market value of goods and services produced within a country.

Intellectual property: Any product of the human intellect—such as an invention, discovery, technology, creation, development, or other form of expression of an idea—regardless of whether the subject matter is protectable under the laws governing the different forms of intellectual property. The most common forms of intellectual property protection include patents, copyrights, trademarks, and trade secrets.

Majority-owned affiliate: Company owned or controlled by more than 50% of the voting securities (or equivalent) by its parent company.

Multinational company (MNC): A parent company and its foreign affiliates.

National income and product accounts: The economic accounts of a country that display the value and composition of national output and the distribution of incomes generated in this production.

Organisation for Economic Co-operation and Development (OECD): An international organization of 30 countries, headquartered in Paris, France. The member countries are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Among its many activities, the OECD compiles social, economic, and science and technology statistics for all member and selected non-member countries.

Public-private partnership: Collaboration between private or commercial organizations and at least one public or nonprofit organization such as a university, research institute, or government laboratory. Examples include cooperative research and development agreements (CRADAs), industry-university alliances, and science parks.

R&D: Research and development, also called research and experimental development, comprises creative work undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and its use to devise new applications.

R&D intensity: A measure of R&D expenditures relative to size, production, financial, or other characteristic for a given R&D-performing unit (e.g., country, sector, company). Examples include R&D to GDP ratio, company-funded R&D to net sales ratio, and R&D per employee.

R&D plant: Expenditures in the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Technology alliance: Cooperative arrangement aimed at co-development of new products or capabilities through R&D and other technical collaboration.

Technology transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place for some other purpose. In the federal setting, technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal research and development funding are utilized to fulfill public and private needs.

U.S. affiliate: Company located in the United States but owned by a foreign parent.

References

Abowd J, Haltiwanger MJ, Lane J. 2004. Integrated longitudinal employer-employee data for the United States. *American Economic Review* 94(2):224–9. (Papers and proceedings of the 116th annual meeting of the American Economic Association; 3–5 January; San Diego.)

Aizcorbe AM, Moylan CE, Robbins CA. 2009. Toward better measurement of innovation and intangibles. *Survey of Current Business* 89(January):10–23. http://www.bea.gov/national/newinnovation.htm. Accessed 28 September 2009.

American Chemistry Council (ACC). 2009. http://www.americanchemistry.com/s_acc/index.asp#. Accessed 20 October 2009.

Archibugi D, Pianta M. 1992. Specialization and size of technological activities in industrial countries: The analysis of patent data. *Research Policy* 21(1):79–93. http://www.danielearchibugi.org/papers/index.htm. Accessed 18 June 2009.

Archibugi D, Pianta M. 1996. Measuring technological change through patents and innovation surveys. *Technovation* 16(9):451–68. http://www.danielearchibugi.org/papers/index.htm. Accessed 18 June 2009.

Arora A, Gambardella A. 2004. The globalization of the software industry: Perspectives and opportunities for developed and developing countries. National Bureau of Economic Research (NBER) Working Paper No. 10538.

Aspden C. 2008. OECD task force on R&D and other intellectual property products. Report prepared for OECD Working Party of National Experts on Science and Technology Indicators. DSTI/EAS/STP/NESTI(2008)31. Paris.

Atkinson RD. 2007. Expanding the R&E tax credit to drive innovation, competitiveness and prosperity. *Journal of Technology Transfer* 32:617–28.

Audretsch DB. 2009. The entrepreneurial society. *Journal of Technology Transfer* 34:245–54.

Bloom N, Griffith R, Van Reenen J. 2002. Do R&D tax credits work? Evidence from a panel of countries 1979–1997. *Journal of Public Economics* 85:1–31.

Börner K, Chen C, Boyack K.2003. Visualizing knowledge domains. *Annual Review of Information Science & Technology* 37:179–255.

Bozeman B, Dietz JS. 2001. Strategic research partnerships: Constructing policy-relevant indicators. *Journal of Technology Transfer* 26:385–93.

Branstetter L, Foley CF. 2007. Facts and fallacies about U.S. FDI in China. National Bureau of Economic Research (NBER) Working Paper 13470. http://www.nber.org/papers/w13470. Accessed 28 September 2009.

Bureau of Economic Analysis (BEA). 2009. International Economic Accounts, Operations of Multinational Companies—Interactive Tables. http://www.bea.gov/international/index.htm#omc. Selected data downloaded 15 January 2009.

Bureau of Labor Statistics (BLS). 2009. BLS Business Employment Dynamics (BED). http://www.bls.gov/bdm/. Accessed 20 October 2009.

Cantwell J, Gambardella A, Granstrand O. 2004. *The Economics and Management of Technological Diversification*. New York: Routledge.

Census Bureau. 2009. Census Business Dynamics Statistics (BDS). http://www.ces.census.gov/index.php/bds/bds_home. Accessed 20 October 2009.

Census Bureau, Bureau of Economic Analysis, and National Science Foundation, Division of Science Resources Statistics. 2005. Research and Development Data Link Project: Final Report. http://www.census.gov/mcd/RDD/rddatalink.pdf. Accessed 28 September 2009.

Chesbrough H, Birkinshaw J, Teubal M. 2006. Introduction to the research policy 20th anniversary special issue of the publication of "Profiting from Innovation" by David J. Teece. *Research Policy* 35(8):1091–9.

Corrado CA, Hulten CR, Sichel DE. 2006. Intangible capital and economic growth. Finance and Economics Discussion Series. Washington, DC: Federal Reserve Board.

Crow M, Bozeman B. 1998. *Limited by Design—R&D Laboratories in the U.S. National Innovation System*. New York: Columbia University Press.

Dahlander L, Gann D. 2007. How open is innovation? Paper presented at the DRUID Summer Conference; 18 June; Copenhagen Business School, Copenhagen.

Department of Commerce (DOC), Advisory Committee on Measuring Innovation in the 21st Century Economy. 2008. Innovation measurement: Tracking the state of innovation in the American economy. http://www.innovationmetrics.gov/. Accessed 28 September 2009.

Dougherty S, Inklarr R, McGuckin R, van Ark B. 2007. International comparisons of R&D expenditures: Does an R&D PPP make a difference? National Bureau of Economic Research Working Paper 12829. Cambridge, MA.

Earl L, Gault F, editors. 2006. *National Innovation, Indicators, and Policy*. Cheltenham, UK: Edward Elgar Policy Publishing.

Federal Laboratory Consortium (FLC) for Technology Transfer. 2006. *FLC Technology Transfer Desk Reference.* Cherry Hill, NJ. http://www.federallabs.org/pdf/T2_Desk_Reference.pdf. Accessed 28 September 2009.

Gallaher MP, Link AN, Petrusa JE. 2006. *Innovation in the U.S. Service Sector*. London: Routledge.

Gault F, von Hippel E. 2009. The prevalence of user innovation and free innovation transfers: Implications for statistical indicators and innovation policy. Working Paper No. 4722–09. Cambridge, MA: MIT Sloan School of Management.

General Accounting Office (GAO). 2001. *Research and Development: Reported Gap Between Data From Federal Agencies and Their R&D Performers: Results From Noncomparable Data*. GAO-01-512R. Washington, DC.

Government Accountability Office (GAO). 2007. *Information on Federal Programs and Interagency Efforts That Support Small Businesses Engaged in Manufacturing.* GAO-07-714. Washington, DC.

Guenther G. 2008. Research and Experimentation Tax Credit: Current Status Legislative Proposals in the 109th Congress, and Policy Issues. RL31181. Washington, DC: Congressional Research Service.

Hagedoorn J, Link A, Vonortas N. 2003. Strategic research partnerships: Economic, managerial, and policy implications [introduction to special issue]. *Technology Analysis & Strategic Management* 15(2):155–7.

Howells J. 2008. New directions in R&D: Current and prospective challenges. *R&D Management* 38(3):241–52.

Industrial Research Institute (IRI). 2009. IRI's R&D trends forecast for 2009. *Research Technology Management* 52(1):19–26.

Institute of Electronics and Electronics Engineers (IEEE). 2009. IEEE Spectrum Top 100 R&D Spenders. Standard and Poor's data. http://www.spectrum.ieee.org/images/dec07/images/12.RDchart.pdf. Accessed 30 October 2009.

Internal Revenue Service (IRS). 2009. Statistics of Income—2006 Corporation Income Tax Returns. Washington, DC. http://www.irs.gov/pub/irs-soi/06coccr.pdf. Accessed 19 June 2009.

Jankowski JE, Link AN, Vonortas NS. 2001. *Strategic Research Partnerships: Proceedings From an NSF Workshop*. NSF 01–336. Arlington, VA: National Science Foundation. http://www.nsf.gov/statistics/nsf01336/. Accessed 28 September 2009.

Jorgenson DW, Landefeld JS, Nordhaus WD, editors. 2006. *A New Architecture for the U.S. National Accounts*. Chicago: University of Chicago Press.

Kauffman Foundation. 2008. Data Symposium Proceedings. http://www.kauffman.org/research-and-policy/data/2008data.aspx. Accessed 28 September 2009.

Kauffman Foundation. 2009. Kauffman Firm Survey. http://www.kauffman.org/research-and-policy/kauffman-firm-survey.aspx. Accessed 28 September 2009.

Keller W. 2004. International technology diffusion. *Journal of Economic Literature* 42(September):752–82.

Lane J, Heus P, Mulcahy T. 2008. Data access in a cyber world: Making use of cyberinfrastructure. *Transactions on Data Privacy* 1:2–16.

Link AN, Siegel DS. 2007. *Innovation, Entrepreneurship, and Technological Change*. Oxford: Oxford University Press.

Mandel M. 2008. Can America invent its way back? *Business Week*. 11 September. http://www.businessweek.com/magazine/content/08_38/b4100052741280.htm. Accessed 28 September 2009.

McKinsey & Company. 2008. Survey on innovation metrics. *The McKinsey Quarterly*. October.

Moris F. 2009. R&D exports and imports: New data and methodological issues. In: Reinsdorf M, Slaughter M, editors. *International Flows of Invisibles: Trade in Services and Intangibles in the Era of Globalization*. Studies in Income and Wealth, vol. 69, National Bureau of Economic Research. Chicago: University of Chicago Press.

Moris F, Jankowski J, Perolle P. 2008. Advancing measures of innovation in the United States. *Journal of Technology Transfer* 33(2):123–30.

National Research Council (NRC). 2003. *Government-Industry Partnerships for the Development of New Technologies*. Washington, DC: National Academies Press.

National Research Council (NRC). 2005a. *Measuring Research and Development Expenditures in the U.S. Economy*. Brown LD, Plewes TJ, Gerstein MA, editors. Washington, DC: National Academies Press.

National Research Council (NRC). 2005b. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: National Academies Press.

National Research Council (NRC). 2006. *Improving Business Statistics Through Interagency Data Sharing: Report of a Workshop*. Kuebler C, Mackie C, rapporteurs. Washington, DC: National Academies Press.

National Research Council (NRC). 2007a. *Innovation Policies for the 21st Century: Report of a Symposium*. Wessner, CW, editor. Washington, DC: National Academies Press.

National Research Council (NRC). 2007b. *Understanding Business Dynamics: An Integrated Data System for America's Future*. Haltiwanger J, Lynch LM, Mackie C, editors. Washington, DC: National Academies Press.

National Research Council (NRC). 2008. *An Assessment of the SBIR Program*. Wessner CW, editor. Washington, DC: National Academies Press.

National Research Council (NRC). 2009. *Understanding Research, Science and Technology Parks: Global Best Practices*. Wessner CW, editor. Washington, DC: National Academies Press. http://sites.nationalacademies.org/pga/step/index.htm. Accessed 28 September 2009.

National Science Board (NSB). 2008. Research and development: National trends and international linkages. *Science and Engineering Indicators 2008*. NSB 08–01. Arlington, VA: National Science Foundation. http://www.nsf.gov/statistics/seind08/. Accessed 28 September 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2004. U.S.-China R&D linkages: Direct investment and industrial alliances in the 1990s. NSF 04–306. Arlington, VA. http://www.nsf.gov/statistics/infbrief/nsf04306/. Accessed 28 September 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2006. Definitions of research and development: An annotated compilation of official sources. Arlington, VA. http://www.nsf.gov/statistics/randdef/. Accessed 28 September 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2007a. Advancing measures of innovation knowledge flows, business metrics, and measurement strategies: NSF Workshop Report. NSF 07–306. Arlington, VA. http://www.nsf.gov/statistics/workshop/innovation06/. Accessed 28 September 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2007b. Linking multinational corporations data from international investment surveys and industrial R&D surveys. NSF InfoBrief 07–310. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2008a. New NSF survey finds six states account for nearly half of state agencies' R&D expenditures. NSF InfoBrief 08–309. Arlington, VA. http://www.nsf.gov/statistics/infbrief/nsf08309/. Accessed 28 September 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2008b. NSF announces new U.S. business R&D and innovation survey. NSF InfoBrief 09–304. Arlington, VA. http://www.nsf.gov/statistics/infbrief/nsf09304. Accessed 16 June 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009. U.S. industrial R&D expenditures increase in 2007; small companies performed 19% of nation's business R&D. NSF InfoBrief 09–316. Arlington, VA. http://www.nsf.gov/statistics/infbrief/nsf09316. Accessed 7 October 2009.

National Science Foundation/The Conference Board (NSF/TCB). 2008. Workshop on developing a new research data infrastructure for the study of organizations and innovation: Workshop report. Corrado C. The Conference Board; November; New York. http://www.conference-board.org/events/nsf/. Accessed 28 September 2009

Niosi J. 1999. The internationalization of industrial R&D: From technology transfer to the learning organization. *Research Policy* 28:107–17.

Office of Science and Technology Policy (OSTP), Executive Office of the President. 2009. A renewed commitment to science and technology: Federal R&D, technology, and STEM education in the FY 2010 budget. http://www.ostp.gov/galleries/budget/FY2010RD.pdf. Accessed 20 May 2009.

Organisation for Economic Co-operation and Development (OECD). 2002. *Proposed Standard Practice for Surveys on Research and Experimental Development* (Frascati Manual). Paris.

Organisation for Economic Co-operation and Development (OECD). 2003. Tax incentives for research and development: Trends and issues. Paris.

Organisation for Economic Co-operation and Development (OECD). 2007. *The Internationalisation of Business R&D: Evidence, Impacts, and Implications.* DSTI/STP(2007)28. Paris.

Organisation for Economic Co-operation and Development (OECD). 2008a. *Globalisation and Open Innovation.* DSTI/STP(2008)11. Paris.

Organisation for Economic Co-operation and Development (OECD). 2008b. *Globalisation in Services: From Measurement to Analysis.* STD/DOC(2008)3/REV1. Paris.

Organisation for Economic Co-operation and Development (OECD). 2008c. *Innovation Indicators. Working Party of National Experts on Science and Technology Indicators.* DSTI/EAS/STP/NESTI(2008)14. Paris.

Organisation for Economic Co-operation and Development (OECD). 2008d. *OECD Reviews of Innovation Policy—China.* Paris.

Organisation for Economic Co-operation and Development (OECD)/Eurostat. 2005. *Oslo Manual.* Paris.

Organisation for Economic Co-operation and Development (OECD). 2009a. *OECD Innovation Microdata Project.* http://www.oecd.org/document/2/0,3343,en_2649_34451_40132674_1_1_1_37417,00.html. Accessed 28 September 2009.

Organisation for Economic Co-operation and Development (OECD). 2009b. OECD Innovation Strategy. http://www.oecd.org/innovation/strategy. Accessed 28 September 2009.

Organisation for Economic Co-operation and Development (OECD). 2009c. *Research and Development Expenditure in Industry Analytical Business Enterprise Research and Development (ANBERD).* 2009 edition. Paris.

Ozman M. 2009. Inter-firm networks and innovation: A survey of literature. *Economics of Innovation and New Technology* 18(1):39–67.

Pharmaceutical Research and Manufacturers of America (PhRMA). 2008a. New drug approvals in 2007: Pharmaceutical companies receive approval for 26 new treatments in 2007. http://www.phrma.org/media/NDA2007.pdf. Accessed 28 September 2009.

Pharmaceutical Research and Manufacturers of America (PhRMA). 2008b. *Pharmaceutical Industry Profile 2008.* Washington, DC. http://www.phrma.org/files/2008%20Profile.pdf. Accessed 28 September 2009.

President's Council of Advisors on Science and Technology (PCAST), Executive Office of the President. 2008. University-private sector research partnerships in the innovation ecosystem. Washington, DC. http://www.ostp.gov/galleries/PCAST/past_research_partnership_report_BOOK.pdf. Accessed 20 May 2009.

Reinsdorf M, Slaughter M. 2009. Introduction. In: Reinsdorf M, Slaughter M, editors. *International Flows of Invisibles: Trade in Services and Intangibles in the Era of Globalization*. Studies in Income and Wealth, vol. 69, National Bureau of Economic Research. Chicago: University of Chicago Press.

Robbins CA, Moylan CE. 2007. Research and development satellite account update: Estimates for 1959–2004 and new estimates for industry, regional, and international accounts. *Survey of Current Business* 87(October):49–92. http://www.bea.gov/national/rd.htm. Accessed 28 September 2009.

Schacht W. 2008. Manufacturing Extension Partnership Program: An Overview. Washington, DC: Congressional Research Service.

Scott JT. 2008. The National Cooperative Research and Production Act. In: *Issues in Competition Law and Policy* 2:1297–1317 (ABA section of Antitrust Law).

Sethi D, Guisinger SE, Phelan SE, Berg DM. 2003. Trends in foreign direct investment flows: A theoretical and empirical analysis. *Journal of International Business Studies* 34:315–26.

Shapira, P. 2001. U.S. manufacturing extension partnerships: Technology policy reinvented? *Research Policy* 30:977–992.

Shepherd C, Payson S. 1999. *U.S. Corporate R&D*. Washington, DC: National Science Foundation.

Siegel DS. 2003. Data requirements for assessing the private and social returns to strategic research partnerships: Analysis and recommendations. *Technology Analysis & Strategic Management* 15(2):207–25.

Small Business Administration (SBA). 2005. *STTR FY 2004 Annual Report.* Washington, DC.

Small Business Administration (SBA), Office of Advocacy. 2009. *The Small Business Economy: A Report to the President.* 2008 ed. Washington, DC: U.S. Government Printing Office. http://www.sba.gov/advo/research/sb_econ2008.pdf. Accessed 28 September 2009.

Stuart TE, Sorenson O. 2003. Liquidity events and the geographic distribution of entrepreneurial activity. *Administrative Science Quarterly* 48(2, June):175–201.

Tassey G. 2007. Tax incentives for innovation: Time to restructure the R&E tax credit. *Journal of Technology Transfer* 32:605–15.

Thursby J, Thursby M. 2006. *Here or There? A Survey on the Factors in Multinational R&D Location*. Washington, DC: National Academies Press.

United Kingdom Department for Innovation, Universities, and Skills (UK DIUS). 2008. 2008 R&D Scoreboard. http://www.innovation.gov.uk/rd_scoreboard/. Accessed 28 September 2009.

United Nations Statistical Commission (UNSC). 2007. Full set of consolidated recommendations—The recommendations made by the Advisory Expert Group for the Update of the System of National Accounts, 1993. Prepared by the Intersecretariat Working Group on National Accounts, 27 February–2 March 2007. http://unstats.un.org/unsd/sna1993/sui.asp. Accessed 28 September 2009.

von Zedtwitz M. 2004. Editorial: Managing R&D in China. *R&D Management* 34(4):341–3.

von Zedtwitz M, Gassmann O. 2002. Market versus technology drive in R&D internationalization: Four different patterns of managing research and development. *Research Policy* 31:569–88.

Ward M. 1985. *Purchasing Power Parities and Real Expenditures in the OECD*. Paris: OECD.

Wilson DJ. Forthcoming. Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits. Federal Reserve Bank of San Francisco Working Paper. Forthcoming in *Review of Economics and Statistics*.

Wu Y. 2004. The effects of state R&D tax credits in stimulating private R&D expenditure: A cross-state empirical analysis. *Journal of Policy Analysis and Management* 24(4):785–802.

Yorgason DR. 2007. Treatment of international research and development as investment: Issues and estimates. BEA/NSF R&D Satellite Account Background Paper. Washington, DC: Bureau of Economic Analysis.

Chapter 5

Academic Research and Development

List of Sidebars

List of Tables

List of Figures

Highlights

Financial Resources for Academic R&D

In 2008, U.S. academic institutions spent $52 billion on R&D, and the higher education sector continues to account for the majority of basic research performed in the United States.

- Academic performers are estimated to account for 55% of U.S. basic research ($69 billion), 31% of total (basic plus applied) research ($157 billion), and 13% of all R&D ($395 billion) estimated to have been conducted in the United States in 2008.
- Higher education's share of total U.S. research expenditures increased by 11 percentage points between 1982 and 2002 (from 24% to 35%), but has since declined to an estimated 31% in 2008.

Support from the federal government decreased in recent years with no funding growth for 3 straight years.

- The federal government provided 60% ($31.2 billion) of funding for academic R&D expenditures in 2008. In inflation-adjusted dollars, this represents a 0.2% increase from FY 2007 and follows decreases of 1.6% in FY 2007 and 0.2% in FY 2006.
- According to the federal agencies providing the funding, total federal obligations for academic R&D peaked in 2004 at $22.1 billion (in constant 2000 dollars) and have since declined by almost 7% to an estimated $20.7 billion in FY 2009.

Higher education R&D funding from all nonfederal sources combined has grown steadily since FY 2004.

- The share of support provided by institutional funds increased steadily between 1972 (12%) and 1991 (19%) but since then has remained fairly stable at roughly one-fifth of total funding.
- After a 3-year decline between 2001 and 2004 (low of $2.1 billion), industry funding of academic R&D increased for the fourth year in a row, to $2.9 billion in 2008.

The distribution of academic R&D expenditures across the various broad S&E fields has remained relatively constant since 1990, with the life sciences receiving the most funding.

- In 2008, the life sciences continued to receive the largest share of investment in academic R&D, accounting for roughly 60% of all expenditures.
- Over the past two decades, the broad field of life sciences was the only field to experience any meaningful increase in its share of total academic R&D, rising more than 4 percentage points since 1998.

In 2008, about $1.9 billion was spent for academic research equipment. This represents a real increase of 1.0% from FY 2007, but a decline of more than 10% from the 2004 level.

- About 80% of FY 2008 equipment expenditures were concentrated in three fields: the life sciences (43%), engineering (23%), and the physical sciences (16%).
- After a period of steady growth between 2001 and 2004, equipment expenditures in the physical sciences, medical and biological sciences, and engineering have all declined since 2005.

Academic R&D Infrastructure

Research-performing colleges and universities continued to expand their physical resources for conducting research. However, while cyberinfrastructure capabilities continued to expand significantly, the expansion of traditional "bricks and mortar" infrastructure slowed.

- A large majority of institutions now have connections to high-speed networks; 25% of institutions have more than one connection.
- By FY 2007, 74% of all institutions had internal network distribution speeds of at least 1 gigabit.
- For the first time in 20 years, almost half of all S&E fields experienced a decline in their research space.

Doctoral Scientists and Engineers in Academia

The size of the doctoral academic S&E workforce reached an estimated 272,800 in 2006 but grew more slowly than the number of S&E doctorate holders in other employment sectors from 1973 to 2006. Full-time faculty positions, although still the predominant type of employment, increased more slowly than postdoc and other full- and part-time positions, especially at research universities.

- The share of all S&E doctorate holders employed in academia dropped from 55% in 1973 to 45% in 1991 and has remained at about that level through 2006.
- Among S&E doctorate holders in academia, full-time faculty declined continually from 88% in the early 1970s to 72% in 2006.
- Postdocs and others in full-time nonfaculty positions constitute an increasing percentage of academic S&E employment, having grown from 10% in 1973 to 22% in 2006. This change was especially pronounced in the 1990s.
- The share of part-time positions was roughly 2% to 4% from 1973 through 1999, but has risen since then to 6% in 2006.

The number of academic S&E doctorate holders reporting research as their primary or secondary work activity showed greater growth from 1973 to 2006 than the number reporting teaching as their primary or secondary activity.

- The number of researchers grew 2.5% per year (from 82,300 to 183,700) between 1973 and 2006, and the number of teachers grew 1.7% per year (from 94,900 to 163,300).
- About two-thirds of doctoral scientists and engineers employed in academic institutions are engaged in research as either a primary or secondary work activity.

Life scientists accounted for more than one-third of academic doctorate holders reporting research as a primary or secondary work activity in 2006. Life scientists also accounted for most of the growth in academic researchers.

- The number of academic researchers in the physical sciences and mathematics grew more slowly, at average annual growth rates of 1.1% and 1.6%, respectively, from 1973 to 2006. Growth rates for academic researchers in all fields were greatest in the 1980s.
- The number of full-time faculty in the life sciences has risen, but the percentage of full-time faculty in the life sciences who are tenured or on the tenure track has declined because the number of tenured and tenure-track life scientists has remained fairly stable since the late 1980s.

The demographic composition of academic researchers changed substantially between 1973 and 2006.

- Women increased from 6% to 29% of full-time doctoral S&E research faculty from 1973 to 2006.
- Underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives) increased from about 2% to about 8% of full-time doctoral S&E research faculty.
- The Asian/Pacific Islander share of full-time doctoral S&E research faculty increased substantially, from 4% to 13%.
- The share of whites among full-time doctoral S&E research faculty fell from 92% to 79% during the period.

In most fields, the percentage of full-time doctoral S&E faculty with federal support for their work was about the same in 2006 as it was in the late 1980s.

- A little less than half (46%) of full-time doctoral S&E faculty received federal support in both 1987 and in 2006.
- Among full-time faculty, recent doctorate recipients were less likely to receive federal support than their more established colleagues.

Outputs of Academic S&E Research: Articles and Patents

S&E article output worldwide grew at an average annual rate of 2.5% between 1995 and 2007. The U.S. growth rate was much lower, at 0.7%.

- The United States accounted for 28% of the world total S&E articles in 2007, down from 34% in 1995. The share of the European Union also declined, from 35% in 1995 to 32% in 2007.
- In Asia, average annual growth rates were high—for example, 17% in China and 14% in South Korea. As a result, in 2007 China moved past the United Kingdom, Germany, and Japan to rank as the world's 2nd-largest producer, up from 5th place in 2005 and 14th place in 1995.

The research portfolios of the top article-producing countries, as indicated by publication of S&E articles, varied widely. China, Japan, and eight other Asian countries (the "Asia-8") emphasized the physical sciences more than the United States and the European Union.

- In 2007, S&E research articles in chemistry and physics accounted for just under one-half of China's total article production, 36% of Japan's, and 37% of the Asia-8's. These two fields accounted for 17% of the total for the United States and 25% of the total for the European Union.
- Articles in the life sciences (biological, medical, agricultural, and related sciences) accounted for 57% of all U.S. S&E articles, compared with 49% for the European Union, 25% for China, 45% for Japan, and 34% for the Asia-8.
- Country research portfolios also differed in their emphasis on engineering, with the Asian countries more heavily concentrated in this broad field (China at 16%, Japan at 11%, and the Asia-8 at 19%) than the U.S. or the European Union (7%–8%).

S&E research articles continue to indicate increasing collaboration across institutions in the United States and internationally.

- Coauthored articles grew from 40% of the world's total S&E articles in 1988 to 64% in 2008. Coauthored articles listing only authors from different institutions in the same country increased from 32% of all articles in 1988 to 42% in 2008. Articles listing authors from institutions in more than one country grew from 8% to 22% over the same period.
- Within-sector coauthorship increased in all U.S. sectors, growing, for example, from 38% of academic S&E article output in 1998 to 45% in 2008. Cross-sector coauthorship increased generally, mainly due to an increase of 7–10 percentage points in each nonacademic sector's coauthor-

ship with academia. U.S. sector coauthorship with foreign authors grew in all sectors by 7–10 percentage points.

The U.S. share of world article output and article citations has declined but not the influence of U.S. research articles, as indicated by the percentage of U.S. articles that are among the most highly cited worldwide.

- Between 1998 and 2008, the U.S. share of world articles declined from 34% in 1998 to 29% in 2008, while its share of total citations in S&E articles declined from 47% to 38%. Over the same period, China's share of publications increased from 2% to 6%, and its share of citations from 1% to 4%.
- The percentage of U.S.-authored S&E articles receiving the highest number of citations—an indicator of research quality and high impact on subsequent research—has changed little. Between 1998 and 2008, the U.S. index of highly cited articles declined from 1.83 to 1.78 and remained well above the expected index value of 1. Indexes of the European Union, China, Japan, and the Asia-8 all increased but remained below 1.

Indicators of academic patenting are mixed. U.S. Patent and Trademark Office (USPTO) data show that patent grants to U.S. universities declined to about 3,000 in 2008. Other indicators relating to academic patenting suggest increasing activity.

- According to USPTO data, patent grants to universities and colleges increased sharply from 1988 to about 1999, when they peaked at just under 3,700 patents, and then fell to about 3,000 in 2008. Three technology areas have dominated these patent awards (chemistry, biotechnology, and pharmaceuticals), accounting for 45% of the total patents awarded to U.S. universities in 2008.
- Data from another source show that invention disclosures filed with university technology management offices grew from 13,700 in 2003 to 17,700 in 2007 and that patent applications filed by reporting universities and colleges increased from 7,200 in 2003 to almost 11,000 in 2007.

Introduction

America's academic institutions play a pivotal role in the U.S. system for conducting R&D and fostering innovation. They conduct the bulk (55%) of U.S. basic research and in the process train the nation's new researchers. U.S. universities have also become active participants in turning new research-based knowledge into innovative products and processes and in broader regional economic development activities. This chapter analyzes available data bearing on these points. (For the key output of trained personnel, see chapter 2.)

Chapter Overview

U.S. universities and colleges carry out the majority of basic research activity (55%) and a substantial portion of all R&D in the United States. The federal government has been and continues to be the major financial supporter of academic R&D, providing more than 60% of the funding in 2007. Other major funding sources are the institutions themselves, industry, and state and local government.

Over the past two decades, the shares of funding allocated to the various S&E fields[1] have changed, with the share going to medical sciences growing substantially and the share going to physical sciences and engineering declining.

Academic R&D is conducted largely by doctoral scientists and engineers. Over time, universities and colleges have relied less on full-time tenure-track faculty and more on postdocs and other nonfaculty to conduct research; in addition, a steady percentage of full-time graduate students has been supported by research assistantships. The demographic composition of academic researchers is changing, with increasing numbers of women and minorities, especially among the younger age groups, and increasing numbers of foreign-born scientists and engineers.

A measure of research output, the number of U.S. S&E articles published in the world's leading S&E journals, recently began to increase after remaining flat for almost a decade, concurrent with strong growth in the European Union and several Asian countries. However, the U.S. share of the world's S&E article output has declined since the early 1970s. The U.S. share of the world's influential—i.e., most highly cited—articles has declined, though U.S. scientific publications remain highly influential relative to those of other countries. Article output by the academic sector, which publishes most U.S. research articles, mirrored the overall U.S. trend, even as research inputs (specifically, academic R&D expenditures and research personnel) continued to increase.

Both domestic and international R&D collaboration have increased significantly over the past two decades. U.S. scientists and engineers in all sectors collaborated extensively with colleagues in other U.S. sectors and abroad. The results of academic research increasingly extend beyond articles to patents, which are an indicator of academic institutions' efforts to protect the intellectual property derived from their inventions, and to technology transfer, university-industry collaboration, and other related activities such as revenue-generating licenses and formation of startup companies that emanate from their institution.

This chapter addresses key aspects of the academic R&D enterprise, including the level, field allocation, and institutional distribution of academic R&D funds; the state of research equipment and facilities at academic institutions; trends in the number and composition of the academic S&E doctoral labor force; and indicators of research outputs.

Chapter Organization

The first section of this chapter discusses the role of academia within the national R&D enterprise. This discussion is followed by an examination of trends in the financial resources provided for academic R&D, including identification of key funders and allocations of funds across both academic institutions and S&E fields. Because the federal government has been the primary source of support for academic R&D for more than half a century, the importance of selected agencies to both overall support and support for individual fields is explored in some detail. This section also presents data on changes in the distribution of funds among academic institutions, on the number of academic institutions that receive federal R&D support, and on equipment.

The next section examines the status of the physical infrastructure necessary to conduct university research activities. Data are presented on both the traditional research infrastructure such as research space, and on infrastructure resulting from technological changes such as networking.

The third section discusses trends in employment of academic doctoral scientists and engineers, especially those engaged in research. Major trends examined include numbers and characteristics of academic doctoral scientists and engineers, the types of positions they hold, their research activities, and the federal support for their research. The section also examines reported collaboration among researchers.

The chapter concludes with an analysis of trends in two types of research outputs: S&E articles, as measured by data from a set of journals covered by the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI), and patents issued to U.S. universities. (A third major output of academic R&D, educated and trained personnel, is discussed in chapter 2 and in the preceding section of this chapter.) This section looks specifically at the volume of research (article counts), collaboration in the conduct of research (joint authorship), use in subsequent scientific activity (citation patterns), and use beyond science (citations to the literature that are found in patents). It concludes with a discussion of academic patenting and some returns to academic institutions from their patents and licenses.

Financial Resources for Academic R&D

Academic R&D is a significant part of the national R&D enterprise.[2] Academic scientists and engineers conduct the bulk of the nation's basic research, about one-third of its

Data Sources for Financial Resources for Academic R&D

The data used to describe financial and infrastructure resources for academic R&D are derived from three National Science Foundation (NSF) surveys. These surveys use similar but not always identical definitions, and the nature of the respondents also differs across the surveys. The three main surveys are as follows:

- Survey of Federal Funds for Research and Development
- Survey of Research and Development Expenditures at Universities and Colleges
- Survey of Science and Engineering Research Facilities

The first survey collects data from federal agencies, whereas the last two collect data from universities and colleges.

Data presented in the first part of this section, "Academic R&D Within the National R&D Enterprise," are derived from the NSF series National Patterns of R&D Resources, which sums results from several NSF surveys of the various sectors of the U.S. economy (for example, universities, businesses, and the federal government) so that the components of the overall R&D effort are placed in a national context. These data are reported on a calendar-year basis, and the data for 2008 are preliminary. Since 1998, the series has also attempted to eliminate double counting in the academic sector by subtracting current fund expenditures for separately budgeted S&E R&D that are passed through to other institutions via subcontracts and similar collaborative research arrangements.

Data in subsequent portions of the section derive from the Survey of Research and Development Expenditures at Universities and Colleges (Academic R&D Expenditures Survey). They are reported on an academic fiscal-year basis (e.g., FY 2008 covers July 2007 to June 2008 for most institutions) and do not net out the funds passed through to other institutions; therefore, they differ from those reported earlier. Data on major funding sources, funding by institution type, distribution of R&D funds across academic institutions, and expenditures by field and funding source are also derived from this survey.

The data on "Top Agency Supporters" and "Agency Support by Character of Work" in the "Federal Support of Higher Education R&D" section come from NSF's Survey of Federal Funds for Research and Development. This survey collects data on R&D obligations for each federal fiscal year (e.g., FY 2008 covers October 2007 through September 2008) from 30 federal agencies. Data for FY 2008–09 are preliminary estimates. The amounts reported for FY 2008–09 are based on administration budget proposals and do not necessarily represent actual appropriations. It should be noted that federal obligation data (e.g., $25.7 billion in federal FY 2008) do not match the federally funded expenditures data reported by academic institutions ($31.2 billion in academic FY 2008) for several reasons. First, the period covered by the two surveys is slightly different; second, there is necessarily a lag between the obligation date and the beginning of project expenditures and some awards span multiple years; and third, some of the expenditures data double count federal R&D awards that are reported both by the primary institution receiving the funds and again by an academic subrecipient to whom funds are passed through (about $1.5 billion in FY 2008).

Data on research equipment are taken from the Survey of Research and Development Expenditures at Universities and Colleges. Data on research facilities and cyberinfrastructure are taken from the Survey of Science and Engineering Research Facilities and are also reported by academic fiscal year. The population for this survey is a subset of the population for the Academic R&D Expenditures Survey and includes all institutions reporting $1 million or more in current fund expenditures for R&D. The Facilities survey was broadened starting in FY 2003 to include data on computing and networking capacity. Although terms are defined specifically in each survey, in general, *facilities expenditures* are classified as capital projects, are fixed items such as buildings, often cost millions of dollars, and are not included in R&D expenditures as reported here. *Research equipment,* however, is purchased with *current funds* (those in the yearly operating budget for ongoing activities) and is included within R&D expenditures. Because the categories are not mutually exclusive, some large instrument systems could be classified as either facilities or equipment. Generally, academic institutions account separately for capital projects and current fund expenditures.

Redesign of the Survey of R&D Expenditures at Universities and Colleges

The Survey of Research and Development Expenditures at Universities and Colleges has been conducted annually since 1972. In 2007, NSF began an intensive 3-year effort to evaluate and redesign the survey. The goals of the redesign were to (1) update the survey instrument to reflect current accounting principles in order to obtain more valid and reliable measurements of the amount of academic R&D spending in the United States, (2) expand the current survey items to collect the additional detail most often requested by data users, and (3) evaluate the feasibility of expanding the scope of data collected beyond that of R&D expenditures.

As part of the redesign effort, NSF held data user workshops and expert panel meetings, worked with accounting and survey methodology experts, and visited more than 40 institutions to receive input on possible changes to the survey. A pilot test of the redesigned survey was administered to 40 institutions during the fall of 2009, and full implementation of the redesigned survey is planned for the fall of 2010.

The new survey, now titled the "Higher Education R&D Survey," will continue to capture core information on R&D expenditures by sources of funding and field. In addition, it will include the following data:

- Total R&D expenditures funded by nonprofit institutions (previously included under "Other sources")
- Total R&D expenditures funded from all types of foreign sources
- Total R&D expanded to include R&D expenditures in both S&E and non-S&E fields as well as clinical trial expenditures
- Detail by field (both S&E and non-S&E) for R&D expenditures from each source of funding (federal, state/local, institution, industry, nonprofit, and other)
- Total R&D expenditures from projects within university interdisciplinary research centers (test metric on interdisciplinary R&D)
- Total R&D expenditures by direct cost categories (salaries, software, equipment, etc.)
- Counts of proposals submitted during the fiscal year
- Counts and dollar amounts of R&D awards during the fiscal year, with a breakout of stimulus awards

In addition to these changes, NSF has also been working with data users and experts to explore the feasibility of collecting systematic data on both R&D personnel and intellectual property and commercialization within universities and colleges. It is expected that additional questions on these topics will be added to the Higher Education R&D Survey in future years.

total (basic plus applied) research, and 13% of its total R&D. To carry out world-class research and advance the scientific knowledge base, U.S. academic researchers require adequate and stable financial resources and the research facilities and instrumentation that facilitate high-quality work. For a discussion of the sources of the data used in this section, see sidebar, "Data Sources for Financial Resources for Academic R&D."

Academic R&D Within the National R&D Enterprise

Universities and colleges play an important role in the nation's overall R&D effort, especially by contributing to the generation of new knowledge through basic research.[3] Since 1998, basic research performed within institutions of higher education has accounted for more than half of the basic research performed in the United States.

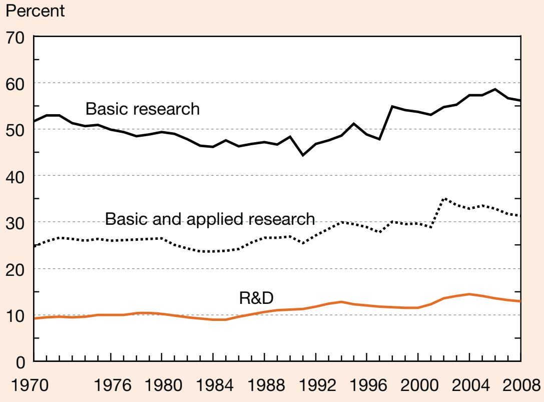
In 2008, U.S. universities and colleges spent $52 billion ($42 billion in constant 2000 dollars) on R&D. Higher education's prominence as an R&D performer increased slightly during the past three decades, rising from about 10% of all R&D performed in the United States in the early 1970s to an estimated 13% in 2008 (figure 5-1). For a comparison with other countries, see "International R&D Comparisons" in chapter 4.

Academic R&D involves mostly basic and applied research and little development activity.[4] In 2008, an estimated 96% of academic R&D expenditures went for research (76% for basic and 21% for applied) and 4% for development (appendix table 5-1). Universities and colleges accounted for an estimated 31% of the U.S. basic and applied research total in 2008, down from a high of 35% in 2002 but still above the levels prevalent until then (figure 5-1). Higher education's share of total U.S. research expenditures had previously increased by 11 percentage points between 1982 and 2002. In terms of basic research alone, the higher education sector is the country's largest performer, currently accounting for an estimated 55% of the national total.

Federal Support of Higher Education R&D

Higher education R&D relies heavily on federal support, along with a variety of other funding sources. The federal government has consistently contributed the majority of the funds (figure 5-2).[5] It accounted for about 60% of the $51.9 billion of R&D funds expended by universities and colleges in FY 2008 (appendix table 5-2).[6] In current dollars, federally funded

Figure 5-1
Academic R&D, basic and applied research, and basic research as share of U.S. total from all performing sectors in each category: 1970–2008

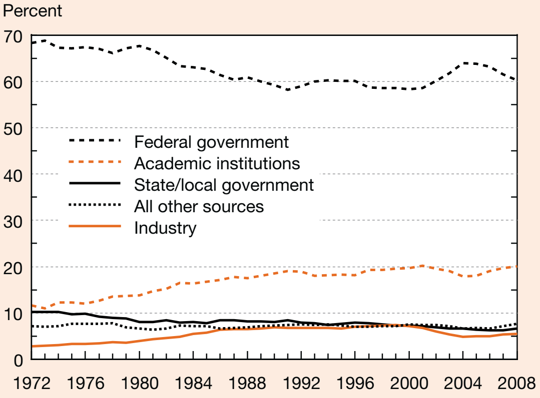


NOTES: Preliminary data for 2008. Because of changes in estimation procedures, character of work data before FY 1998 not comparable with later years. Data based on annual reports by performers.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 5-1. Also see appendix tables 4-3, 4-7, 4-11, and 4-15 for data underlying percentages.

Science and Engineering Indicators 2010

Figure 5-2
Sources of academic R&D funding: 1972–2008



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2008. See appendix table 5-2.

Science and Engineering Indicators 2010

academic R&D expenditures rose 2.5% between FY 2007 and FY 2008 to $31.2 billion. After adjustment for inflation, this represents a 0.2% increase from FY 2007 and follows 2 years of slight declines in constant dollars since FY 2005.

Another look at recent trends is provided by federal agency-reported inflation-adjusted obligations for academic R&D—funds going to academic institutions in a given fiscal year, to be spent over the current and succeeding years. In constant 2000 dollars, federal academic R&D obligations peaked in FY 2004 at $22.1 billion and have since declined by almost 7% to an estimated $20.7 billion in FY 2009 (appendix table 5-3). Constant dollar federal R&D obligations had grown more than 10% each year between FY 1998 and FY 2001, largely reflecting a commitment to double the R&D budget of the National Institutes of Health (NIH) over 5 years. Consequently, between 1998 and 2004, NIH's share of federal academic R&D funding increased from 57% to 63%.

The American Recovery and Reinvestment Act, signed into law by President Obama on February 17, 2009, provides an additional $18.3 billion in appropriations for federal R&D and R&D facilities and equipment in FY 2009. (See "Federal R&D" in chapter 4.)[7]

The federal government's overall contribution is the combined result of numerous discrete funding decisions made by several R&D-supporting agencies with differing missions and purposes, which in turn affect research priorities in the academic sector. Most of the federal R&D funding to the higher education sector is allocated through competitive peer review (see sidebar, "Congressional Earmarks").

Examining and documenting the funding patterns of the key funding agencies is important to understanding both their roles and that of the federal government overall. For a discussion of a major federal program with the objective of improving the geographical distribution of federal obligations for academic R&D, see sidebar, "EPSCoR: The Experimental Program to Stimulate Competitive Research."

Congressional Earmarks

Academic earmarking is the congressional practice of providing federal funds to educational institutions for facilities or projects without merit-based peer review. Obtaining exact figures for either the amount of funds or the number of projects earmarked for universities and colleges, overall or for research, is difficult. There is no accepted definition of an earmark, and funding legislation is often obscure in its description of the earmarked projects. Broad estimates using a consistent approach in compiling these data are as follows.

Academic earmarks stood at an estimated $2.3 billion in FY 2008 (Brainard and Hermes 2008), a 15% increase over an estimated $2.0 billion reported last in FY 2003 in the *Chronicle of Higher Education* (Brainard and Borrego 2003). Approximately two-thirds ($1.6 billion) of the FY 2008 funds and $1.4 billion of FY 2003 funds were for R&D projects, R&D equipment, or construction or renovation of R&D laboratories.

Top Agency Supporters

Six agencies are responsible for most of the federal obligations for higher education R&D, providing an estimated 97% of the $25.7 billion obligated in FY 2009 (appendix table 5-3).[8] NIH was by far the largest funder, providing an estimated 65% of total federal academic R&D obligations in FY 2009. The National Science Foundation (NSF) provided an additional 15%, the Department of Defense (DOD) 8%, the Department of Energy (DOE) 4%, the National Aeronautics and Space Administration (NASA) 2%, and the U.S. Department of Agriculture (USDA) 2%.

Agency Support by Character of Work

More than 56% of federal obligations from FY 2007 through FY 2009 funded basic research projects (appendix table 5-4). The two agencies funding the majority of academic basic research were NIH and NSF. More than one-third of federal obligations for academic R&D from 2007 through 2009 funded applied research, with NIH providing the vast majority of funds in that category as well. About 5% of R&D obligations went toward development during 2007–09. DOD and NASA were responsible for more than 80% of the small amount of federal academic R&D funds spent on development.

Other Sources of Funding

In contrast to the recent trend in federal R&D funding, higher education R&D funding from nonfederal sources has grown steadily since FY 2004, and grew by 8% (6% in inflation-adjusted terms) between 2007 and 2008 (figure 5-3).

- **Institutional funds.** In FY 2008, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, accounting for

EPSCoR: The Experimental Program to Stimulate Competitive Research

EPSCoR, the Experimental Program to Stimulate Competitive Research, originated as a response to a number of stated federal objectives. Section 3(e) of the National Science Foundation Act of 1950, as amended, states that "it shall be an objective of the Foundation to strengthen research and education in the sciences and engineering, including independent research by individuals, throughout the United States, and to avoid undue concentration of such research and education."

In 1978, Congress authorized NSF to implement EPSCoR in response to broad public concerns about the extent of geographical concentration of federal funding for R&D. Eligibility for EPSCoR participation was limited to those jurisdictions that historically had received lesser amounts of federal R&D funding and had demonstrated a commitment to develop their research bases and to improve the quality of S&E research conducted at their universities and colleges.

The success of the NSF EPSCoR programs during the 1980s subsequently prompted the creation of EPSCoR and EPSCoR-like programs in six other federal agencies: the Departments of Energy, Defense, and Agriculture; the National Aeronautics and Space Administration; the National Institutes of Health; and the Environmental Protection Agency. In FY 1992, the EPSCoR Interagency Coordinating Committee (EICC) was established by the federal agencies with EPSCoR or EPSCoR-like programs. The major objectives of the EICC focused on improving coordination among and between the federal agencies in implementing EPSCoR and EPSCoR- like programs consistent with the policies of the participating agencies.

EPSCoR seeks to increase the R&D competitiveness of an eligible state through the development and utilization of the science and technology (S&T) resources residing in its colleges and universities. It strives to achieve this objective by (1) stimulating sustainable S&T infrastructure improvements at the state and institutional levels that significantly increase the ability of EPSCoR researchers to compete for federal and private sector R&D funding and (2) accelerating the movement of EPSCoR researchers and institutions into the mainstream of federal and private sector R&D support.

In FY 2008, the seven ElCC agencies invested a total of $419 million on EPSCoR and EPSCoR-like programs, up from approximately $97 million in 1999 (see table 5-A). The Environmental Protection Agency discontinued issuing separate EPSCoR program solicitations in FY 2006.

Table 5-A
EPSCoR and EPSCoR-like program budgets, by agency: FY 1998–2008
(Millions of dollars)

Agency	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
All agencies	74.1	96.7	139.8	225.3	288.9	358.0	353.3	367.4	367.1	363.1	418.9
DOD	18.0	19.0	24.0	18.7	15.7	15.7	8.4	11.4	11.5	9.5	17.0
DOE	6.8	6.8	6.8	7.7	7.7	11.7	7.7	7.6	7.3	7.3	14.7
EPA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	0.0	0.0	0.0
NASA	5.0	10.0	10.0	10.0	10.0	10.0	10.0	12.0	12.5	12.8	15.5
NIH	5.0	10.0	40.0	100.0	160.0	210.0	214.0	222.0	220.0	218.0	223.6
NSF	36.8	48.4	51.3	74.8	79.3	88.8	93.7	93.4	97.8	101.5	120.0
USDA	NA	NA	5.2	11.6	13.7	19.3	17.0	18.6	18.0	14.0	28.1

NA = not available

DOD = Department of Defense; DOE = Department of Energy; EPA = Environmental Protection Agency; EPSCoR = Experimental Program to Stimulate Competitive Research; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NSF = National Science Foundation; USDA = U.S. Department of Agriculture

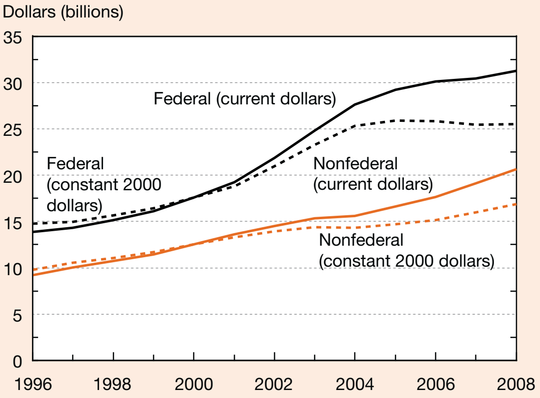
NOTE: EPA discontinued issuing separate EPSCoR program solicitations in FY 2006.

SOURCE: Data provided by agency EPSCoR representatives; collected by NSF Office of Integrative Activities, Office of EPSCoR, May 2009.

Science and Engineering Indicators 2010

20% ($10.4 billion) of the total (appendix table 5-2). Institutional funds encompass (1) institutionally financed research expenditures and (2) unrecovered indirect costs and cost sharing. They exclude departmental research, a more informal type of research that is usually coupled with instructional activities in departmental budget accounts and thus does not meet the Office of Management and Budget definition of organized research. The share of support represented by institutional funds increased steadily from 12% in 1972 to 19% in 1991 and has since remained at roughly that level. Funds for institutionally financed R&D may derive from general-purpose state or local government appropriations; general-purpose awards from industry, foundations, or other outside sources; endowment income; and gifts. Universities may also use income from patents, licenses, or patient care revenues to support R&D. (See section "Patent-Related Activities and Income" later in this chapter for a discussion of patent and licensing income.)

Figure 5-3
Federal and nonfederal academic R&D expenditures: 1996–2008



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2000 dollars.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2008. See appendix table 5-2.

Science and Engineering Indicators 2010

- **State and local government funds.** State and local governments provided 7% ($3.4 billion) of higher education R&D funding in FY 2008. Even though their absolute funding total continues to rise annually, the nonfederal government share has declined since its peak of 10.2% in the early 1970s. However, these figures are likely to understate the actual contribution of state and local governments to academic R&D, particularly for public institutions, because they only reflect funds that these governments directly target to academic R&D activities.[9] They exclude any general-purpose state or local government appropriations that academic institutions designate and use to fund separately budgeted research or pay for unrecovered indirect costs; such funds are categorized as *institutional funds*.[10] (See chapter 8, "State Indicators," for some indicators of academic R&D by state.)
- **Industry funds.** Industrial support accounts for the smallest share of academic R&D funding (6%), and support of academia has never been a major component of industry-funded R&D. After a 3-year decline between 2001 and 2004, industry funding of academic R&D increased for the fourth year in a row, to $2.9 billion in FY 2008. (See appendix table 4-5 for time-series data on industry-reported R&D funding.)
- **Other sources of funds.** In FY 2008, other sources of support accounted for 8% ($4.0 billion) of academic R&D funding, a level that has stayed about the same since 1972. This category of funds includes but is not limited to grants and contracts for R&D from nonprofit organizations and voluntary health agencies and all other sources not included in the other categories.

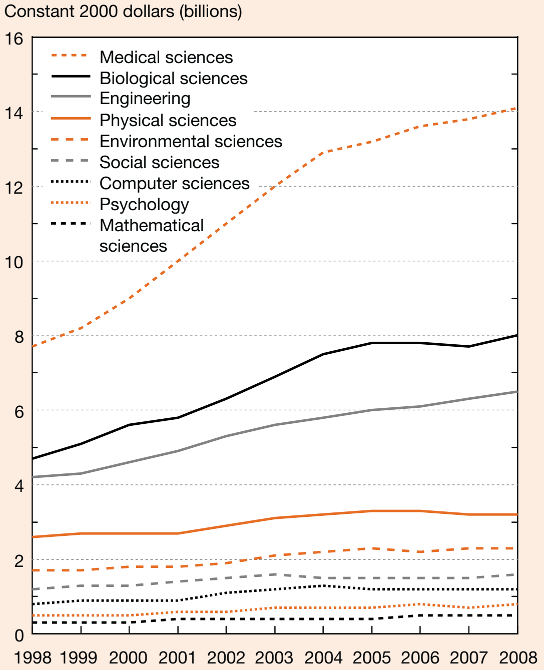
Expenditures by Field and Funding Source

Investment in academic R&D historically has been concentrated in a few individual S&E fields. The life sciences have for decades accounted for more than half of all academic R&D expenditures. In FY 2008, they accounted for approximately 60% of both the federal and nonfederal totals (appendix table 5-5). Within the life sciences, the medical sciences accounted for 33% of all academic R&D expenditures and the biological sciences accounted for another 19% (appendix table 5-5).[11]

Between 1998 and 2008, R&D expenditures in the medical sciences almost doubled, from $7.7 billion to $14.1 billion in constant 2000 dollars (figure 5-4), changing the distribution of academic R&D expenditures across the various broad S&E fields. The life sciences gained 4 percentage points over the period, driven by a 4-percentage-point rise in the share of medical sciences, from 29% to 33% of the total (appendix table 5-6). The physical sciences lost 2 percentage points, from 10% to 8% of the total. Figure 5-5 shows share gains and losses in both the 1990–2000 and 2000–08 periods.

Of the $31.2 billion in academic R&D expenditures funded by the federal government, R&D projects in the life sciences accounted for $18.7 billion (60%) in FY 2008 (appendix table 5-7).

Figure 5-4
Academic R&D expenditures, by field: 1998–2008

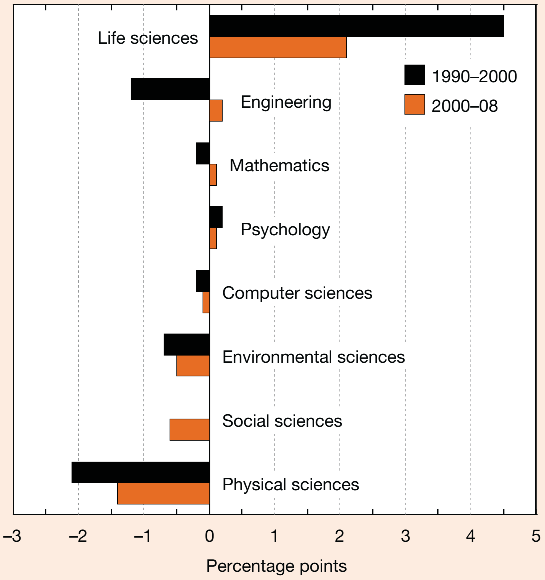


NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2000 dollars.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2008. See appendix table 5-6.

Science and Engineering Indicators 2010

Figure 5-5
Changes in share of academic R&D in selected S&E fields: 1990–2000 and 2000–08



NOTE: Fields ranked by change in share during 2000–08, in descending order.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2008. See appendix table 5-6.

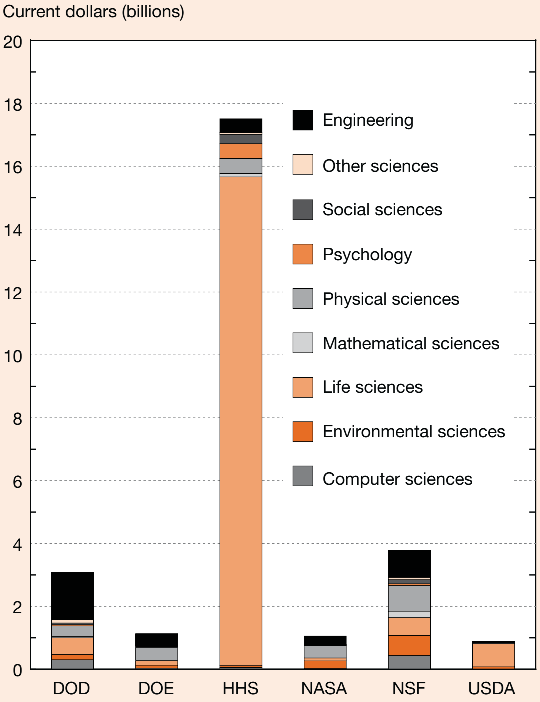
Science and Engineering Indicators 2010

The Department of Health and Human Services (HHS), notably NIH, contributes the majority of this life science funding (83%). Although their share of total academic R&D funding is much smaller, DOD, DOE, NASA, and NSF have more diversified funding patterns (figure 5-6). In FY 2008, NSF was the lead federal funding agency for academic research in the physical sciences (29% of federally funded R&D expenditures); mathematical sciences (47%); computer sciences (42%); and environmental sciences (34%). DOD was the lead funding agency in engineering (32%).

The proportion of academic R&D expenditures funded by the federal government also varies significantly by field (appendix table 5-8). The field with the largest proportion of federal funding in FY 2008 was atmospheric sciences, at 80%, followed by physics (76%), mathematical sciences (72%), and aeronautical/astronautical engineering (72%). The fields with the smallest percentages of federal funding in FY 2008 were economics (32%), political science (37%), and agricultural sciences, which received less than 30% of their funds from federal sources.

Between 1975 and 1990, the federally financed proportion of R&D spending declined in *all* of the broad S&E fields (appendix table 5-8).[12] Since 1990, those declines have either stabilized or reversed, and the federal share reported in FY 2008 was higher than the 1990 share for all fields except mathematical sciences and physical sciences.

Figure 5-6
Federally financed academic R&D expenditures, by agency and field: FY 2008



DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTE: Some institutions unable to provide complete agency data by field. Data not adjusted for nonresponse.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2008. See appendix table 5-7.

Science and Engineering Indicators 2010

Non-S&E R&D Expenditures

Academic institutions spent a total of $2.2 billion on R&D in non-S&E fields in FY 2008 (table 5-1).[13] This represents an increase of 9% over the $2.1 billion spent in FY 2007.[14] This $2.2 billion is in addition to the $51.9 billion expended on S&E R&D. The largest amounts reported for R&D in non-S&E fields were for education ($880 million), business and management ($325 million), and humanities ($254 million). The federal government funds smaller proportions of R&D in non-S&E than in S&E fields: 37% of the $2.2 billion in non-S&E R&D in FY 2008.

Academic R&D by Institution

The previous sections examined R&D for the entire academic sector. This section looks at some of the differences across institution types.

Table 5-1

R&D expenditures in non-S&E fields at universities and colleges: FY 2007–08

(Millions of current dollars)

Field	2007 Total expenditures	2007 Federal expenditures	2008 Total expenditures	2008 Federal expenditures
All non-S&E fields	2,051	802	2,241	838
Business and management	273	52	325	65
Communication, journalism, and library science	90	31	89	29
Education	899	471	880	451
Humanities	241	60	254	63
Law	73	29	88	28
Social work	93	40	124	59
Visual and performing arts	46	4	59	4
Other non-S&E fields	335	116	422	139

NOTE: Detail may not add to total because some respondents reporting non-S&E R&D expenditures did not break out total and federal funds by non-S&E fields.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2008.

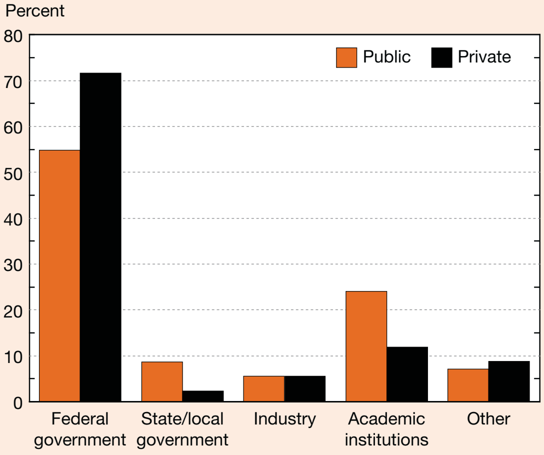
Science and Engineering Indicators 2010

Funding for Public and Private Universities and Colleges

Public and private universities rely on the same major sources to fund their R&D projects, but the relative contribution of those sources differs substantially (figure 5-7; appendix table 5-9). In FY 2008, the federal government provided 72% of the R&D funds spent by private institutions, compared with 55% for public institutions. Conversely, public institutions received approximately 9% of their $35.3 billion in R&D expenditures from state and local governments, compared with 2% of private institutions' $16.6 billion.

Figure 5-7

Sources of academic R&D funding for public and private institutions: 2008



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2008. See appendix table 5-9.

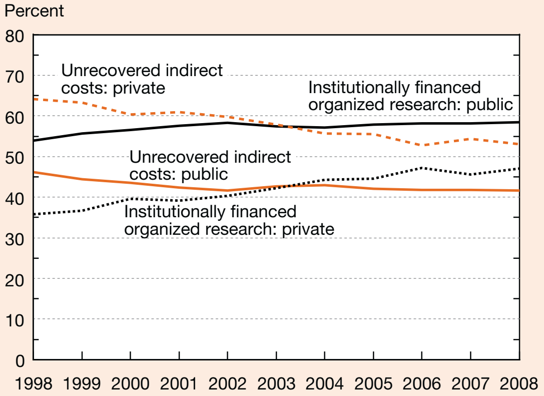
Science and Engineering Indicators 2010

Public academic institutions also supported a larger portion of their R&D from their own sources (24% versus 12% at private institutions). Their larger proportion of institutional R&D funds may reflect general-purpose state and local government funds that public institutions have directed toward R&D.[15] Private institutions in turn report a larger proportion of unrecovered indirect costs (53% of their institutional total in 2008, versus 42% for public institutions). For both types of institutions, these shares have declined over the past decade, from 64% to 53% for private institutions and from 46% to 42% for public institutions (figure 5-8).

Both public and private institutions received approximately 6% of their R&D support from industry in FY 2008.

Figure 5-8

Components of institutional R&D expenditures for public and private academic institutions: 1998–2008



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations (2009).

Science and Engineering Indicators 2010

The share of total R&D expenditures funded by all other sources was also comparable, at 7% and 9%, respectively.

Distribution of R&D Funds Across Academic Institutions

Academic R&D expenditures are concentrated in a relatively small number of institutions. In FY 2008, 679 institutions reported spending at least $150,000 on S&E R&D. Of these, the top-spending 20 accounted for 30% of total academic R&D spending and the top 100 for 80% of all academic R&D expenditures. Appendix table 5-10 presents the detailed distribution among the top 100 institutions. The concentration of academic R&D funds among the top 100 institutions has stayed constant over the past two decades (figure 5-9), as have the shares held by both the top 10 and the top 20 institutions.

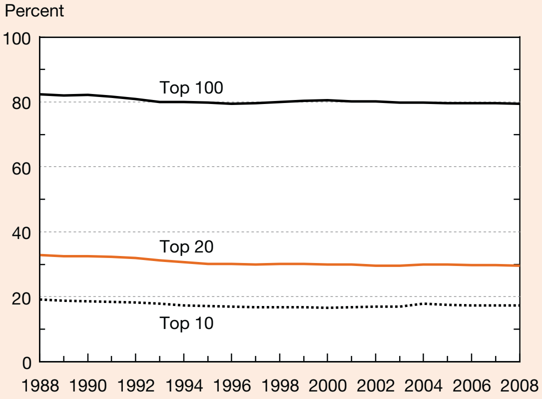
It should be noted that the composition of the universities in each of these groups varies over time as universities increase or decrease their R&D activities. For example, 5 of the top 20 institutions in FY 1988 were no longer in the top 20 in FY 2008.

A similar concentration of funds is found among university performers of non-S&E R&D. The top 20 performers accounted for 36% of the total non-S&E R&D expenditures in FY 2008 (appendix table 5-11).

R&D Collaboration Between Higher Education Institutions

One way to measure the extent of collaboration among academic institutions is to examine how much of their total R&D expenditures was passed through to other academic institutions or received by institutions as subrecipient funding. R&D funds for joint projects that were passed through universities to other university subrecipients more than doubled from FY 2000 to FY 2008, from $699 million to $1.7 billion (figure 5-10; appendix table 5-12). This amount represents 3.3% of total academic R&D expenditures in FY 2008, compared with 2.3% of the total in FY 2000. In FY 2008, 90% ($1.5 billion) of these pass-through funds came from federal sources.

Figure 5-9
Academic R&D, by rank of university and college academic R&D expenditures: 1988–2008



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, special tabulations (2009).

Science and Engineering Indicators 2010

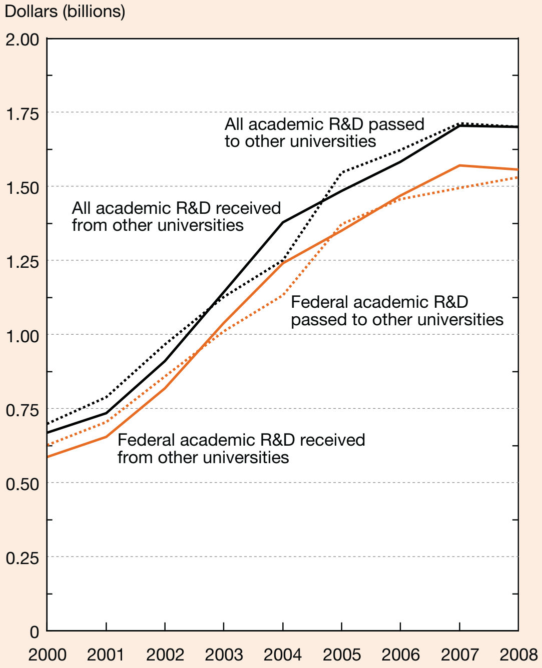
Not coincidentally, universities receiving pass-through funds from other universities likewise reported a rapid increase in subrecipient R&D expenditures between FY 2000 and FY 2008, from $669 million to $1.7 billion. More than 90% ($1.6 billion) of these subrecipient funds originated from federal sources.[16]

Overall, $3.5 billion was passed through institutions to all types of subrecipients in FY 2008 (including both academic and nonacademic institutions), and $3.9 billion was received as subrecipient funding from all types of pass-through entities (appendix table 5-12). Again, the majority of these funds were from federal sources (87% of pass-through funds and 90% of subrecipient expenditures).

Academic R&D Equipment

Research equipment is an integral component of the academic R&D enterprise. This section examines expenditures for moveable research equipment necessary for the conduct of organized research projects (e.g., computers, telescopes) and the federal role in funding these expenditures.

Figure 5-10
Total and federally funded academic R&D pass-throughs: FY 2000–08



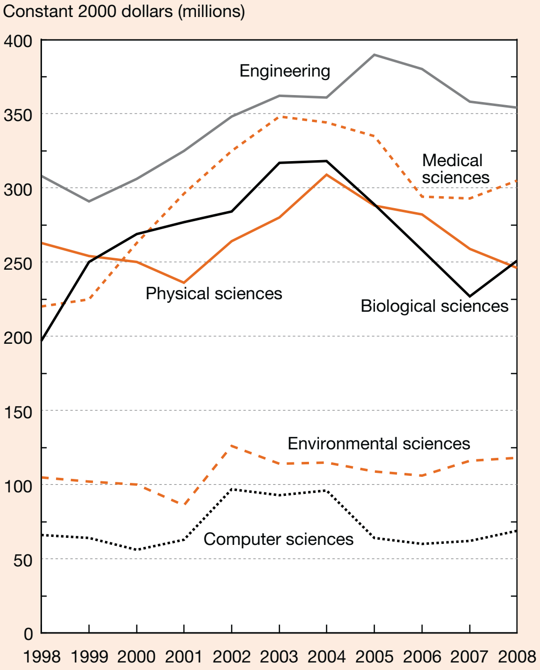
SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges: FY 2008. See appendix table 5-12.

Science and Engineering Indicators 2010

In FY 2008, about $1.9 billion in current funds was spent for academic research equipment (appendix table 5-13).[17] In constant dollars, this represents an increase of 1.0% from FY 2007 but a decline of more than 10% from the 2004 level. Overall, expenditures for R&D equipment have risen 61% in real dollars since 1985. About 80% of FY 2008 expenditures were concentrated in three fields: the life sciences (43%), engineering (23%), and the physical sciences (16%) (appendix table 5-13). After a period of steady growth between 2001 and 2004, equipment expenditures in the physical sciences, medical and biological sciences, and engineering have declined since FY 2005 (figure 5-11).

Federal funds for research equipment are generally received as part of research grants or as separate equipment grants. The share of federal funding for research equipment varies significantly by field (appendix table 5-14). The field of atmospheric sciences had the largest proportion of federally funded R&D equipment (85%) in FY 2008. The overall share of research equipment funded by the federal government fluctuated between 56% and 64% over the past two decades.

Figure 5-11
Current fund expenditures for research equipment at academic institutions, by field: 1998–2008



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2000 dollars.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2008. See appendix table 5-13.

Science and Engineering Indicators 2010

Academic R&D Infrastructure

Physical infrastructure is an essential resource for the conduct of R&D. Not long ago, R&D capital infrastructure primarily consisted of instruments and research space such as laboratories and computer rooms. Consequently, the principal indicators of the state of research infrastructure have been square footage of designated research space and counts of instruments.

Over the past two decades, technological advances have brought fundamental changes not only in the methods of scientific research but also in the infrastructure necessary to conduct R&D. The infrastructure resulting from these technological innovations is often called *cyberinfrastructure.* Cyberinfrastructure may involve single resources such as a network used to transfer data, or it may involve a complex interaction of numerous resources resulting in sophisticated capabilities such as high-performance computation or remote use of scientific instrumentation. Regardless of how simple or complex this infrastructure may be, cyberinfrastructure has become an essential resource for science.

Cyberinfrastructure: Networking

Networking is a critical component of academic cyberinfrastructure that facilitates many research-related activities such as communication, data transfer, high-performance computation, and remote use of instrumentation.[18] In FY 2007, networking infrastructure was pervasive on many academic campuses and rapidly expanding in capability and coverage. Research-performing institutions[19] had greater numbers of connections, bandwidth, and campus coverage compared with earlier in the decade. Colleges and universities reported external network connections with greater bandwidth, faster internal network distribution speeds, more connections to high-speed networks, and greater wireless coverage on campus.

External Bandwidth

Early in the decade, some institutions reported no Internet1 connections of any kind, but by mid-decade, all institutions had connections and their bandwidths significantly increased. Between FY 2005 and FY 2007, the number of institutions with total Internet1 and Internet2 bandwidth of more than 100 megabits increased almost 30% (table 5-2). At the same time, the number of institutions with the fastest bandwidth speeds also continued to expand. The percentage of institutions with total Internet1 and Internet2 bandwidth of 1 gigabit or faster rose by more than 50% in FY 2007, reaching 34% of all institutions. If institutional estimates are realized, the percent of institutions with total bandwidth of 1 gigabit or faster will double between FY 2005 and FY 2008 to 42%.

Bandwidth capability increased across different types of academic institutions. However, the colleges and universities with the fastest bandwidths were dominated by doctorate-granting institutions. In FY 2007, all but one institution with total Internet1 and Internet2 bandwidth greater than 2.4 gigabits granted doctorates. Of all institutions with bandwidth of at least 1 gigabit, 83% were doctorate granting. This trend is likely to continue into FY 2008 and beyond. If institutions

Table 5-2
Bandwidth to commodity Internet (Internet1) and Internet2 at academic institutions: FY 2005–08
(Percent distribution)

Bandwidth	FY 2005	FY 2007	FY 2008
All bandwidth	100	100	100
No bandwidth	0	0	0
≤10 mb	6	3	2
11–100 mb	42	33	24
101–999 mb	30	31	30
1–2.5 gb	15	23	26
>2.5 gb	6	10	16
Other	*	1	1

* = >0 but <0.5%

gb = gigabits/second; mb = megabits/second

NOTES: Internet2 is a high-performance backbone network that enables the development of advanced Internet applications and the deployment of leading-edge network services to member colleges, universities, and research laboratories across the country. FY 2008 data estimated. Percents may not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 2005 and 2007.

Science and Engineering Indicators 2010

Table 5-3
Highest internal network speeds, by highest degree granted: FY 2003–08
(Percent distribution)

Fiscal year and connection speed	All academic institutions	Highest degree granted	
		Doctorate	Nondoctorate
FY 2003	100	100	100
≤10 mb	2	3	2
11–999 mb	64	55	88
1–2.5 gb	33	43	10
2.6–9 gb	0	0	0
10 gb	0	0	0
>10 gb	0	0	0
Other	0	0	0
FY 2005	100	100	100
≤10 mb	0	0	1
11–999 mb	46	38	64
1–2.5 gb	50	56	35
2.6–9 gb	1	1	0
10 gb	3	4	0
>10 gb	*	*	0
Other	0	0	0
FY 2007	100	100	100
≤10 mb	1	1	1
11–999 mb	24	18	39
1–2.4 gb	61	63	55
2.5–9 gb	2	2	1
10 gb	10	14	3
>10 gb	1	2	0
Other	1	1	1
FY 2008	100	100	100
≤10 mb	1	1	1
11–999 mb	20	14	34
1–2.4 gb	51	51	51
2.5–9 gb	4	4	2
10 gb	21	26	10
>10 gb	2	3	1
Other	1	1	1

* = >0 but <0.5%

gb = gigabits per second; mb = megabits per second

NOTE: FY 2008 data estimated. Percents may not add to 100% because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Science and Engineering Research Facilities, Fiscal Years 2003–07.

Science and Engineering Indicators 2010

achieve their estimates for FY 2008, there will be a 70% increase in the number of institutions with bandwidths of greater than 2.4 gigabits. All but two will be doctorate granting.

Part of the increase in total bandwidth speed can be at least partially attributed to an increase in the number of connections to high-performance networks. The number of connections to Internet2 grew gradually over the decade, and by the end of FY 2007, a large majority (70%) of institutions had Internet2 connections. Between FY 2005 and FY 2007, the percentage of institutions with connections to the National Lambda Rail (NLR) increased 150% to approximately 25% of all institutions. After holding steady since the beginning of the decade, the number of institutions anticipating connections to federal government high-performance networks such as the Department of Energy's ESnet increased in FY 2007. Institutions have also begun connecting to more than one high-performance network. For example, in FY 2007, 25% had connections to both Internet2 and NLR.

Internal Institutional Networks

Similar to the trend of increased external bandwidth speed, internal network distribution speeds at academic institutions increased considerably. Since early in the decade, the percentage of institutions with slower bandwidth has rapidly decreased while the percentage with faster bandwidths has rapidly increased. In FY 2003, 66% of institutions had bandwidth of less than 1 gigabit; by the end of FY 2007, only 25% did (table 5-3). In FY 2003, no institutions had distribution speeds faster than 2.5 gigabits, but by FY 2007, 13% of academic institutions did. By FY 2007, the large majority (74%) of institutions had distribution speeds of 1 gigabit or faster.

In FY 2007, all but one academic institution had at least some wireless coverage in their campus buildings. In FY 2003, only 14% of these institutions had more than half of their building infrastructure covered by wireless; by FY 2007, the comparable figure was 59%.

Bricks and Mortar

Research Space

Research-performing colleges and universities continued a two-decade trend of increasing the amount of research space at their institutions.[20] By FY 2007, academic institutions had 192 million net assignable square feet (NASF) of research space (table 5-4). In recent years though, the rate of increase in research space has begun to slow. During

Table 5-4
S&E research space in academic institutions, by field: FY 1988–2007
(Millions of net assignable square feet)

Field	1988	1990	1992	1994	1996	1998	1999	2001	2003	2005	2007
All fields	112	116	122	127	136	143	148	155	172.7	185.1	191.9
Agricultural and natural resources	18	21	20	20	22	25	24	27	26.4	26.8	28.4
Biological and biomedical sciences	24	27	28	28	30	31	32	33	36.0	38.5	45.6
Computer and information sciences	1	1	2	2	2	2	2	2	3.1	4.1	4.9
Engineering	16	17	18	21	22	23	24	26	27.4	28.9	30.2
Health and clinical sciences	19	20	22	23	25	25	26	28	34.9	39.7	37
Mathematics and statistics	1	1	1	1	1	1	1	1	1.5	1.6	1.7
Physical sciences	22	22	23	24	25	26	27	27	29.3	29.6	29.3
Earth, atmospheric, and ocean sciences	6	6	7	7	7	8	8	8	8.9	8.6	8.5
Astronomy, chemistry, and physics	16	16	16	17	18	18	19	19	20.4	21.0	20.8
Psychology	3	3	3	3	3	3	3	4	4.4	4.8	5.0
Social sciences	3	3	3	3	4	5	5	5	5.7	6.3	6.2
Other sciences	4	2	2	2	2	3	3	3	3.8	4.9	3.7
Research animal space	na	na	9	11	12	12	13	na	16.7	16.5	18.3

na = not applicable, question not asked

NOTES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS) bases S&E fields used in its Survey of Science and Engineering Research Facilities on those in National Center for Education Statistics (NCES) Classification of Instructional Programs (CIP). NCES updates CIP every 10 years. S&E fields used in FY 2007 Survey of Science and Engineering Research Facilities reflect NCES 2000 CIP update. For comparison of subfields in FY 2005 and FY 2007 surveys, see S&E Research Facilities: FY 2007, detailed statistical tables. Detail may not add to total because of rounding. Research animal space listed separately and also included in individual field totals.

SOURCE: NSF/SRS, Survey of Science and Engineering Research Facilities, Fiscal Years 1987–2007.

Science and Engineering Indicators 2010

FY 2005–07, institutions increased their research space at the slowest rate (3.7%) since FY 1998–99 (table 5-4). The rate of increase peaked in FY 2001–03 at 11%. Since then, the rate of increase has gradually declined.

Although the stock of research space increased overall in FY 2005–07, for the first time in 20 years, almost half of the S&E fields[21] experienced a decline in their research NASF. Particularly notable is that for the first time since FY 1988, the health and clinical sciences experienced an actual loss in research space of 7%. This decrease followed some of the largest increases in research space in any S&E field since the beginning of decade.

Even with the decline in FY 2007 though, the health and clinical sciences still had the second largest amount of research NASF (37 million) of all S&E fields. Only the biological and biomedical sciences had a greater amount of square footage (46 million), having increased 18% from the amount reported in FY 2005. In addition to the health and clinical sciences, the social sciences; the physical science subfields of earth, atmospheric and ocean sciences and astronomy, chemistry, and physics; and the fields classified as "other" experienced losses in research space. Only the earth, atmospheric, and ocean sciences had experienced a loss in the previous biennial period.

Continuing a trend that began in FY 2001, research space in the computer sciences once again experienced the largest rate of increase when compared with all other fields. In FY 2007, research space in the computer sciences increased 20% to approximately 5 million NASF.

New Construction

In conjunction with the slowdown in the increase in research space, the total amount of newly constructed research space also began to slow at the beginning of the decade (table 5-5). Since FY 2002–03, the total amount of new research space constructed declined by approximately 45%. However, within this overall broad decline, the amount and direction of change in new construction varied significantly by S&E field.

During FY 2006–07, initiation of construction of new research space was greatest in the biological and biomedical sciences (3 million NASF), the health and clinical sciences (2 million NASF), and engineering (1 million NASF). Relative to previous years, however, these three fields experienced a decline in the amount of new construction. The amount of newly constructed research space in engineering and in the biological and biomedical sciences declined from FY 2002–03 to FY 2004–05 and again, to a lesser extent, in FY 2006–07. In the health and clinical sciences, the amount of newly constructed research space declined 34% from FY 2002–03 to FY 2004–05. From FY 2004–05 to FY 2006–07, it declined another 48%.

Three fields of science reversed the decline in the amount of newly constructed space from earlier in the decade: the physical, computer, and agricultural sciences. The amount of newly constructed research space in the physical sciences increased 25% between FY 2004–05 and FY 2006–07, with the majority of new space located in astronomy, chemistry, and physics.

Table 5-5

New construction of S&E research space in academic institutions, by field and time of construction: FY 2002–07

(Millions of net assignable square feet)

Field	Started in FY 2002 or FY 2003	Started in FY 2004 or FY 2005	Started in FY 2006 or FY 2007
All fields	16.2	10.2	8.9
Agricultural and natural resources	0.8	0.4	0.5
Biological and biomedical sciences	4.0	3.2	3.0
Computer and information sciences	1.0	0.3	0.6
Engineering	2.2	1.5	1.3
Health and clinical sciences	5.0	3.3	1.7
Mathematics and statistics	*	*	*
Physical sciences	2.1	0.8	1.0
Earth, atmospheric, and ocean sciences	0.6	0.3	0.3
Astronomy, chemistry, and physics	1.5	0.5	0.7
Psychology	0.2	0.2	0.1
Social sciences	0.2	0.1	0.1
Other sciences	0.7	0.3	0.7
Research animal space	1.4	1.2	1.0

* = >0 but <50,000 net assignable square feet

NOTES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS) bases S&E fields used in its Survey of Science and Engineering Research Facilities on those in National Center for Education Statistics (NCES) Classification of Instructional Programs (CIP). NCES updates CIP every 10 years. S&E fields used in FY 2007 Survey of Science and Engineering Research Facilities reflect NCES 2000 CIP update. For comparison of subfields in FY 2005 and FY 2007 surveys, see S&E Research Facilities: FY 2007, detailed statistical tables. Detail may not add to total because of rounding. Research animal space listed separately and also included in individual field totals.

SOURCE: NSF/SRS, Survey of Science and Engineering Research Facilities, Fiscal Years 2003–2007.

Science and Engineering Indicators 2010

In FY 2006–07, the funding of newly constructed research space returned to the pattern prevalent since the mid-1990s. Institutions use one or more sources to fund their capital projects, including the federal government, state or local governments, and the institutions' own funds. In the previous biennial period, the proportion of new construction costs funded by state and local governments dropped significantly relative to other funding sources, to 22%. Concurrently, funding by the institutions' own sources rose to 70% of all new construction funds ($5.8 billion).[22] In FY 2006–07, state and local governments returned to funding about one-third of new construction, while institutional internal sources funded about 60%. The remaining funding came from the federal government. The federal proportion of funding has remained relatively stable and small over time.

Doctoral Scientists and Engineers in Academia

The role of research in U.S. universities is both to create new knowledge and to educate students who will become the future generations of researchers and teachers (Association of American Universities 2006). Doctoral scientists and engineers in academia, and in particular faculty in U.S. colleges and universities, are an important aspect of academic R&D, as they generally engage in both research and teaching. The focus of this section is on the research aspects of doctoral scientists and engineers in academia.

This section examines trends in employment and labor market conditions of doctoral scientists and engineers in U.S. universities and colleges, with a particular focus on research activity. Trends in and characteristics of S&E doctoral researchers, including young investigators, are discussed as well as trends in government support for research. Chapter 3 provides more information on the workforce as a whole, and chapter 2 provides information on the output of students and degrees.

Trends in Academic Employment of Doctoral Scientists and Engineers

Academic employment of doctoral scientists and engineers grew over the past three decades, although growth was slower than in the business or government sectors. As a result, the share of all S&E doctorate holders employed in academia dropped from about 55% to 45% during the 1973–2006 period (NSB 2008).[23] The number of S&E doctorate holders employed in academia grew from 118,000 in 1973 to 272,800 in 2006 (table 5-6). Mirroring trends in R&D funding, life scientists accounted for much of the growth in academic employment. In engineering and many science fields, growth in academic employment slowed in the early 1990s but increased in recent years (figure 5-12).

Although full-time faculty positions continue to be the norm in academic employment, S&E doctorate holders increasingly are employed in part-time, postdoc, or full-time nonfaculty positions. From 1973 to 2006, the share of S&E doctorate holders employed in full-time faculty positions

Table 5-6
S&E doctorate holders employed in academia, by position: Selected years, 1973–2006
(Percent)

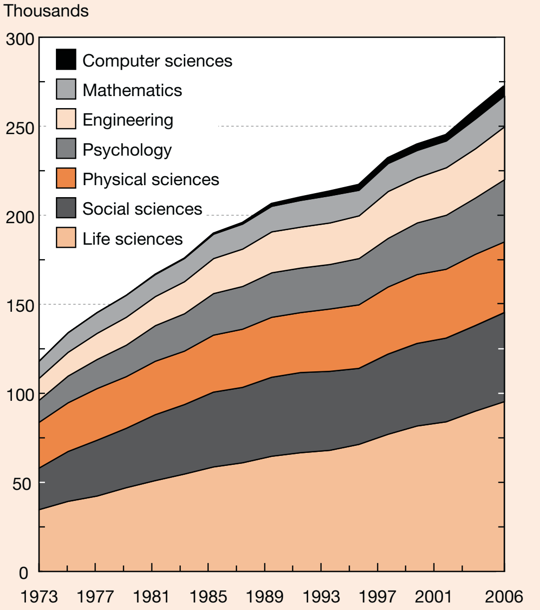
Position	1973	1983	1993	2006
All positions (number in thousands)	118.0	176.1	213.8	272.8
Full-time professors	36.1	39.7	37.4	31.3
Full-time associate professors	26.6	26.0	22.7	19.8
Full-time junior faculty	24.8	18.6	20.5	21.2
Full-time nonfaculty	6.4	7.6	10.4	13.4
Postdocs	3.6	4.7	6.2	8.5
Part-time positions	2.5	3.4	2.8	5.8

NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Full-time junior faculty includes assistant professors and instructors, and full-time nonfaculty includes positions such as research associates, adjunct appointments, lecturers, and administrative positions. Total excludes those employed part time because they are students or retired.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Figure 5-12
S&E doctorate holders employed in academia, by degree field: 1973–2006



NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired. Physical sciences include earth, atmospheric, and ocean sciences.

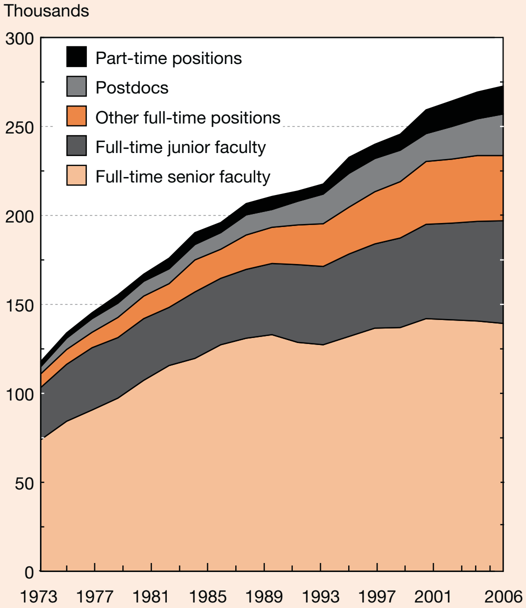
SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

decreased while the share employed in postdoc or other full- and part-time positions increased (table 5-6 and figure 5-13). The full-time faculty share was 72% of all academic employment in 2006, down from 88% in the early 1970s. The full-time nonfaculty share rose from 6% in 1973 to 13% in 2006. Part-time positions accounted for only a small share (between 2% and 4%) of all academic S&E doctoral employment throughout most of the period before rising to almost 6% in 2006. Postdocs rose from 4% in 1973 to 9% of all academically employed S&E doctorate holders in 2006.

The lack of growth in the number of tenured and tenure-track positions in the life sciences, concurrent with increasing numbers of new doctorate holders, has been a subject of much focus in recent years (Benderly 2004, NRC 2005, Check 2007, Garrison and McGuire, 2008). Although the number of tenured full-time faculty in all fields increased from 90,700 in 1979 to 122,500 in 2006, their percentage of the academic workforce decreased from 69% to 62% (appendix table 5-15). This decline is largely accounted for by decreases in the life sciences (from 65% to 56%) and physical sciences (from 74% to 65%). Despite large increases in

Figure 5-13
S&E doctorate holders, by type of academic appointment: 1973–2006



NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Senior faculty includes full and associate professors; junior faculty includes assistant professors and instructors. Other full-time positions include nonfaculty positions such as research associates, adjunct appointments, lecturers, and administrative positions. Part-time positions exclude those employed part time because they are students or retired.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

academic R&D expenditures (appendix table 5-6) and in the number of doctorates granted in the life sciences (appendix table 2-26), the number of tenured and tenure-track life scientists has remained fairly stable since the late 1980s (appendix table 5-15).

Research as Either Primary or Secondary Work Activity

About two-thirds of doctoral scientists and engineers employed in academic institutions are engaged in research as either a primary or secondary work activity. From 1973 to 2006, the number of academic S&E doctorate holders reporting research as a primary or secondary work activity showed greater growth than the number reporting teaching as a primary or secondary activity (table 5-7). On average, the number of researchers grew 2.5% per year and the number of teachers grew 1.7% per year.

The life sciences accounted for much of this trend, with the number of life science researchers growing from 26,000 to 66,700, an average annual growth rate of 2.9% (table 5-8 and appendix table 5-16). Life scientists accounted for more than one-third of academic doctorate holders reporting research as a primary or secondary work activity in 2006. The number of researchers in computer sciences grew the fastest, at 16.3% from 1979 to 2006, although from a small base. The number of academic researchers in the physical sciences and mathematics grew more slowly, at average annual growth rates of 1.1% and 1.6%, respectively, from 1973 to 2006. Growth rates for academic researchers in all fields were greatest in the 1980s. From 1979 to 1989, the average

Table 5-7
S&E doctorate holders employed in academia with research or teaching as primary or secondary work activity, by degree field: 1973 and 2006
(Thousands)

	1973		2006		Growth rate 1973–2006 (%)	
Degree field	Research	Teaching	Research	Teaching	Research	Teaching
All fields	82.3	94.9	183.7	163.3	2.5	1.7
Physical sciences	18.8	20.2	26.9	24.1	1.1	0.5
Mathematics	6.8	8.8	11.4	13.8	1.6	1.4
Computer sciences	NA	NA	4.1	4.0	NA	NA
Life sciences	26.0	25.3	66.7	45.4	2.9	1.8
Psychology	7.3	9.8	20.5	21.1	3.2	2.3
Social sciences	14.3	20.2	32.8	37.9	2.5	1.9
Engineering	9.0	10.5	21.4	17.1	2.7	1.5

NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Total excludes those employed part time because they are students or retired. Research includes basic or applied research, development, or design. Because individuals may select both a primary and a secondary work activity, they can be counted in both groups.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, 1973 and 2006, special tabulations.

Science and Engineering Indicators 2010

Table 5-8
Average annual growth rate for employment of S&E doctorate holders in academia reporting research as a primary or secondary work activity, by degree field: 1973–2006
(Percent)

Degree field	1973–2006	1973–79	1979–89	1989–99	1999–2006
All fields	2.5	1.5	5.4	1.0	1.3
Physical sciences	1.1	–0.5	3.5	0.6	–0.2
Mathematics	1.6	0.2	4.0	–0.4	2.0
Computer sciences	NA	NA	34.4	7.1	6.4
Life sciences	2.9	3.6	4.9	1.6	1.3
Psychology	3.2	2.1	5.7	1.8	2.5
Social sciences	2.5	0.4	7.6	0.1	0.8
Engineering	2.7	1.5	6.0	1.0	1.4

NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired. Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

annual growth rate for doctoral scientists and engineers with research as a primary or secondary work activity was more than 5% per year, compared with less than 2% per year in the 1970s, 1990s, and 2000s.

Demographic Characteristics of Academic Researchers

The demographic composition of doctoral S&E researchers has changed over the past three decades, reflecting changes in the student population (see chapter 2 and appendix table 5-17). As women, minorities, and foreign-born researchers became an increasing share of academic researchers over the past two decades, men, and particularly white men, became a decreasing share.

Women in the Doctoral S&E Workforce. In 2006, 33% of all S&E doctorate holders employed in academia were women, up from 9% in 1973 (table 5-9). This rise reflects the increase in the proportion of women among recent S&E doctorate holders. Women hold a larger share of junior faculty positions than positions at either the associate or full professor rank (figure 5-14). In 2006, women constituted 25% of full-time senior faculty (full and associate professors) and 42% of full-time junior faculty (assistant professors and lecturers), the latter slightly higher than their share of recently earned S&E doctorates (table 5-9; see also "Doctoral Degrees by Sex" in chapter 2). However, their share of both junior and senior faculty positions rose substantially between 1973 and 2006. Although women are growing numbers of full-time faculty, they constitute more than half of academic S&E doctorate holders employed part time.

The percentage of women among full-time doctoral S&E research faculty is similar to the percentage of women among all S&E doctorate holders employed in academia. Women increased from 6% to 29% of full-time doctoral S&E research faculty from 1973 to 2006 (appendix table 5-16). Women's representation in some fields is higher than in others. Women make up almost half of full-time faculty researchers in psychology, about one-third of those in life sciences and social sciences,[24] and 11% of those in engineering (figure 5-15 and table 5-9).

Women are also a growing percentage of faculty at research institutions—up from 8% in 1977 to 23% in 2003—yet they remain less well represented at these institutions than at freestanding medical schools or at master's granting institutions (NSF/SRS 2008). (See sidebar "Women Faculty at Research Universities.") For a more complete discussion of the role of women, see *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009* (NSF/SRS 2009b).

Racial/Ethnic Groups in the Academic Doctoral Workforce. Asians and underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives) constitute increasing shares of the academic doctoral workforce (table 5-10 and figure 5-16).[25] Between 1973 and 2006, the percentages of Asians and underrepresented minorities in the S&E academic doctoral workforce increased from 4% to 14% and 2% to 8%, respectively. These changes reflect increases in these groups' shares of recently earned doctorates. See "Doctoral Degrees by Race/Ethnicity" in chapter 2 for trends in doctoral degrees.

Table 5-9
Women as percentage of S&E doctorate holders, by position: Selected years, 1973–2006

Position and degree field	1973	1983	1993	2006
All positions	9.1	15.0	21.9	33.0
Full-time senior faculty	5.8	9.3	14.2	25.0
Full-time junior faculty	11.3	23.5	32.2	42.3
Full-time faculty researchers	6.3	11.4	17.7	28.6
Physical sciences	3.0	4.6	7.7	15.2
Mathematics	4.7	7.4	9.0	18.8
Computer sciences	NA	9.2	15.8	22.9
Life sciences	7.9	12.6	21.5	32.9
Psychology	13.1	23.8	35.4	48.9
Social sciences	8.2	16.3	21.5	33.7
Engineering	0.3	2.0	4.1	11.2
Full-time nonfaculty	14.5	23.1	30.2	36.2
Postdocs	14.3	30.1	30.8	40.8
Part-time positions	48.3	41.7	61.0	51.5

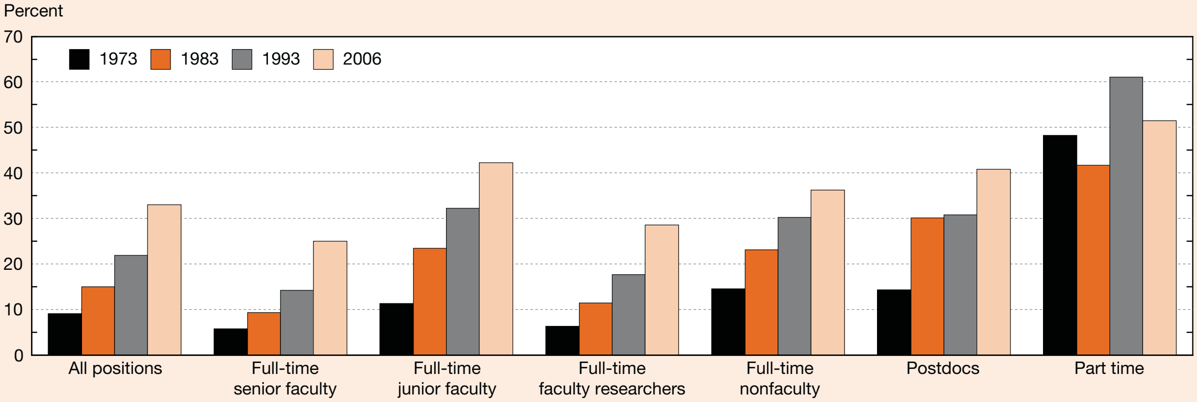
NA = not available

NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Senior faculty includes full and associate professors; junior faculty includes assistant professors and instructors; and full-time nonfaculty includes positions such as research associates, adjunct appointments, lecturers, and administrative positions. Total excludes those employed part time because they are students or retired. Physical sciences include earth, atmospheric, and ocean sciences. Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Figure 5-14
Women as percentage of S&E doctorate holders employed in academia with research as a primary or secondary work activity, by position: Selected years, 1973–2006



NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Senior faculty includes full and associate professors; junior faculty includes assistant professors and instructors. Full-time nonfaculty includes positions such as research associates, adjunct appointments, lecturers, and administrative positions. Part-time positions exclude those employed part time because they are students or retired. Research includes basic or applied research, development, and design.

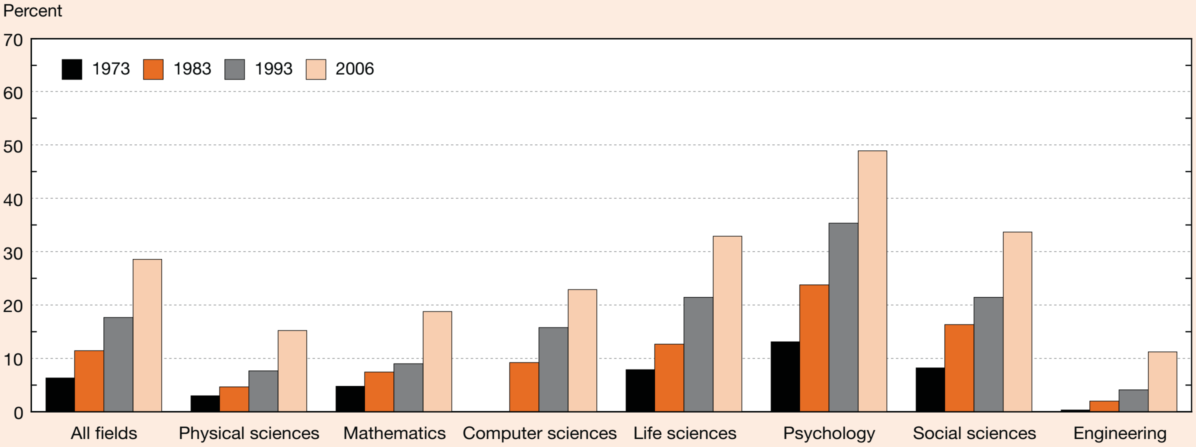
SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Among full-time doctoral research faculty, Asians increased from 4% to 13% from 1973 to 2006, and underrepresented minorities increased from 2% to 8%. Because of these increases, the proportion of full-time doctoral research faculty who are white decreased from 92% in 1973 to 79% in 2006 (appendix table 5-17).

Underrepresented minorities constituted a smaller share of employment at research universities than other racial/ethnic groups. In 2006, 35% of underrepresented minority S&E doctorate holders employed in academia were employed in research institutions, compared with 51% of Asian and 42% of white S&E doctorate holders employed in academia (NSB 2008). Notably, in 2003, the percentage of black S&E faculty employed at research universities (28%) was lower than the percentage employed at comprehensive universities (31%), largely because of this group's prevalence in historically black colleges and universities, most of which are comprehensive institutions (NSF/SRS 2006).[26]

Figure 5-15
Women as percentage of full-time S&E research faculty, by field: Selected years, 1973–2006



NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired. Faculty includes full, associate, and assistant professors and instructors. Physical sciences include earth, atmospheric, and ocean sciences. Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Women Faculty at Research Universities

In a congressionally mandated study of women faculty in research universities, the National Research Council (2009) found that women faculty do as well as or better than men in hiring, promotions, and access to university resources. The study focused on tenured or tenure-track faculty in 6 disciplines (biology, chemistry, civil engineering, electrical engineering, mathematics, and physics) at 89 research universities. Women constituted 12% of the faculty in the disciplines and universities studied. The study found that in these research universities, women were a lower percentage of applicants for tenured or tenure-track positions than they were of recent doctorates, especially in chemistry and biology. However, women were a higher percentage of interviewees than of applicants and a higher percentage of those hired than of interviewees. The study also found that women constituted a lower percentage of tenure candidates than of assistant professors, but that among those up for tenure review, women were more likely than men to receive tenure. The study found little difference in lab space, equipment, or percentage of time teaching or doing research and little difference in outcomes (e.g., honors, funding, salaries) of tenured or tenure-track faculty, with a few exceptions, including salaries of full professors and publications. Because of its specific mandate, the report did not address women who did not apply to research universities or those who left research universities, but noted the need for further research in these areas. By necessity, it did not address other types of academic employment, other types of academic institutions, or other issues affecting women's employment in academia, including dual careers, effects of children and family obligations, or institutional climate. Many other studies of women in academia address some of these issues (e.g., Long 2001; COSEPUP 2007; NSF 2004; Ginther 2001; Hosek et al. 2005; Rosser, Daniels, and Wu 2006; Fox 2005).

Table 5-10

Minorities as percentage of S&E doctorate holders, by position: Selected years, 1973–2006

	1973		1983		1993		2006	
Position and degree field	Underrepresented minority	Asian	Underrepresented minority	Asian	Underrepresented minority	Asian	Underrepresented minority	Asian
All positions	2.0	4.2	3.7	6.7	5.0	9.8	8.2	14.1
Full-time faculty	1.9	3.9	3.6	6.1	5.0	8.6	7.9	11.7
Full-time faculty researchers	1.7	4.3	3.2	7.4	4.8	10.1	7.6	13.5
Physical sciences	1.8	4.0	3.0	7.7	4.5	10.9	4.6	11.5
Mathematics	1.8	4.4	2.8	10.0	3.3	14.0	7.5	19.3
Computer sciences	NA	NA	NA	20.7	7.3	36.3	6.6	36.8
Life sciences	2.0	3.6	2.8	6.5	3.7	8.2	7.3	13.2
Psychology	1.7	S	3.1	1.9	5.7	2.2	8.5	4.3
Social sciences	1.7	4.3	4.8	5.4	7.0	6.2	9.9	8.1
Engineering	0.9	9.5	2.7	14.8	3.9	21.6	7.3	25.7
Postdocs	2.4	11.9	4.8	13.3	4.5	27.1	7.5	35.4
Other positions	2.9	5.7	4.1	8.2	5.3	8.9	9.3	13.7

NA = not available; S = data suppressed for reasons of confidentiality and/or reliability

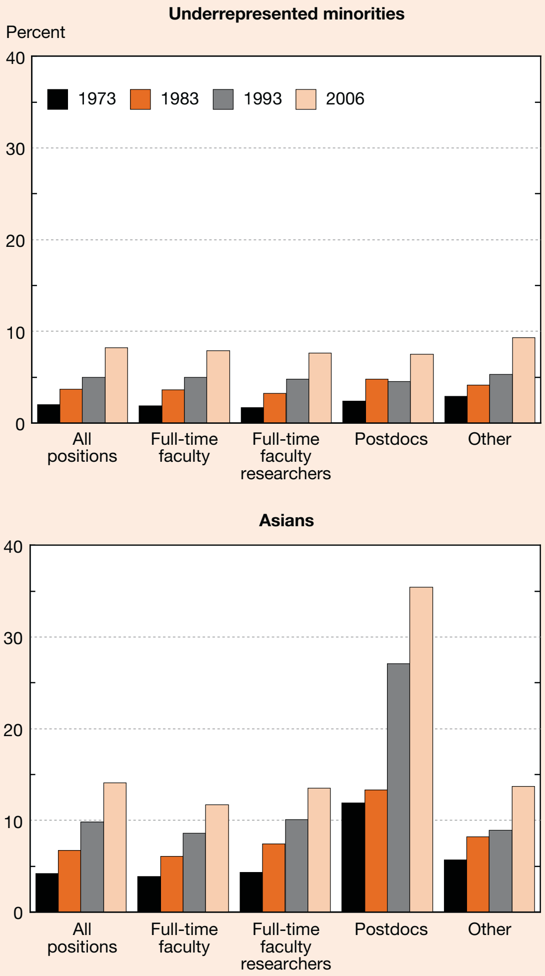
NOTES: Underrepresented minority includes blacks, Hispanics, and American Indians/Alaska Natives. Asian includes Pacific Islanders through 1999, but excludes in 2001 through 2006. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Faculty includes full, associate, and assistant professors plus instructors. Other positions include part-time positions and nonfaculty positions such as research associates, adjunct appointments, lecturers, and administrative positions. Total excludes those employed part time because they are students or retired. Physical sciences include earth, atmospheric, and ocean sciences. Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

The distribution of racial/ethnic groups within S&E fields differs (appendix table 5-18). The percentage of underrepresented minorities among full-time faculty researchers ranges from about 5% in the physical sciences to about 10% in the social sciences. Asians are more heavily represented in engineering and computer sciences (where they constitute 26% and 37% of full-time faculty researchers, respectively) and represented at very low levels in psychology (4%) and social sciences (8%). For a more complete discussion of the role of Asians and underrepresented minorities, see *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009* (NSF/SRS 2009b).

Figure 5-16
Minorities as percentage of S&E doctorate holders, by position: 2006



NOTES: Underrepresented minorities include blacks, Hispanics, and American Indians/Alaska Natives. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Faculty includes full, associate, and assistant professors plus instructors. Other includes part-time positions and nonfaculty positions such as research associates, adjunct appointments, lecturers, and administrative positions. Data exclude those employed part time because they are students or retired. Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Foreign-Born Doctorate Holders in the Academic Doctoral S&E Workforce. Foreign-born S&E doctorate holders contribute substantially to academic R&D in the United States. Reliance by U.S. colleges and universities on foreign talent increased during the 1990s. Chapter 3 discusses more fully trends in immigration and employment characteristics of foreign-born scientists and engineers.

Approximately 31,400 noncitizens (permanent residents and temporary visa holders) and 31,300 naturalized U.S. citizens with a U.S. S&E doctorate were employed in academia in 2006 (appendix table 5-19). In addition, U.S. universities and colleges employ an unknown but probably large number of foreign-born S&E doctorate holders with doctorates from foreign universities.[27] (Chapter 3 of *Science and Engineering Indicators 2008* [NSB 2008] estimated that about 36% of foreign-born S&E doctorate holders had foreign-earned doctorates.) The discussion in this section is limited to U.S. doctorate holders.

Foreign-born S&E doctorate holders (both noncitizens and naturalized citizens) with U.S. S&E doctorates were 23% of the total academic doctoral S&E workforce in 2006 and close to half (47%) of academic postdocs (appendix table 5-19). Foreign-born S&E doctorate holders constitute a higher percentage of researchers than of all academically employed S&E doctorate holders. In 2006, they represented 27% of all academic researchers, regardless of rank or type of position, 24% of full-time faculty researchers, and 20% of all full-time faculty. U.S. S&E doctorate holders with temporary or permanent visas increased from about 4% of full-time faculty researchers with U.S. doctorates in 1973 to 10% in 2006 (appendix table 5-17).

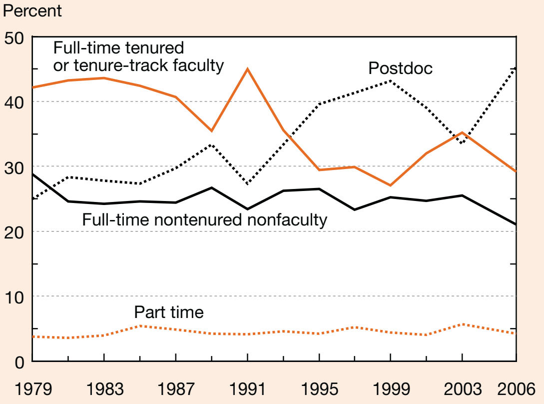
Foreign-born S&E doctorate holders with U.S. doctorates are more heavily concentrated in computer sciences, mathematics, and engineering than in other fields. These foreign-born doctorate holders account for more than half of all academic researchers and of full-time faculty researchers in computer sciences and for 39%–48% of all academic researchers and full-time faculty researchers in mathematics and engineering. In contrast, they represent 27% or less of all academic researchers and 21% or less of full-time faculty researchers in the life sciences, the physical sciences, psychology, and the social sciences (appendix table 5-19).

Recent S&E Doctorate Holders

Many doctoral candidates aspire to an academic, tenured faculty position, even though nonacademic employment has for many years exceeded that in universities and colleges, and the composition of academic hiring has changed as relatively fewer full-time faculty and relatively more part-time and nonfaculty are hired. Nevertheless, the relative availability of faculty positions is thought to have provided market signals to aspiring graduate students.

Over the past three decades, the share of recent doctorate holders (i.e., those with doctorates earned within 3 years of the survey) in full-time tenured or tenure-track faculty positions decreased and the prevalence of postdoc positions increased (figure 5-17). Between 1979 and 2006, the share of recent doctorate holders hired into full-time tenured or tenure-track faculty positions fell from 42% to 29%. Conversely, the overall share of recent S&E doctorate holders who reported being in postdoc positions rose from 25% to 45% during that period. (See the discussion of postdocs in chapter 3, "Science and Engineering Labor Force," for more

Figure 5-17
Recent S&E doctorate holders employed in academia, by position: 1979–2006



NOTES: Recent is defined as 1–3 years since doctorate. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired. Full-time faculty includes full, associate, and assistant professors plus instructors. Full-time nontenured nonfaculty includes positions such as research associates, adjunct appointments, lecturers, and administrative positions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

information, including reasons for accepting a postdoc position and short-term career trajectory.) The share employed in part-time positions also rose in the 1970s and early 1980s but remained at roughly 5% from 1985 through 2006. The share employed in other full-time positions (e.g., adjunct faculty, lecturers, research associates, administrators) remained fairly stable over the period except for decreases from 1979 to 1981 and from 2003 to 2006.

The percentage of recent S&E doctorate holders and recent full-time S&E doctoral faculty engaged in research is higher than is the case for those who have had their doctorate for 12 or more years (table 5-11).[28] In some fields (e.g., computer sciences and engineering), research is a more prevalent activity among those who have had their doctorate for less than 8 years. In the life sciences, although research is most prevalent within 1 to 3 years of award of the doctorate, a relatively high percentage of doctorate holders remain in research, even among those with more experience.

Young Doctorate Holders With a Track Record

For those employed in academia 4–7 years after earning their doctorate, the trends are quite similar to those for doctorate holders who have had their degree for 1–3 years, although the former group's percentage employed in postdoc positions is much smaller and their percentage employed in faculty positions much larger. About half of S&E doctorate holders who have had their degree for 4–7 years had full-time tenured or tenure-track faculty positions in 2006, down from 64% in 1979 (figure 5-18). The percentage in postdoc positions rose from 6% to 15%, and the percentage in part-time positions rose from 3% to 6%. The percentage employed in full-time, non-tenure-track, nonfaculty positions changed little over time.

Government Support of Academic Doctoral Researchers

Academic researchers rely on the federal government for a majority of their overall research support. This section presents data from reports by S&E doctorate holders in academia about the presence or absence of federal support for their work.[29] However, nothing is known about the amount of funds received by individual researchers.

In 2006, 46% of full-time S&E doctoral faculty reported federal government support, about the same percentage as was the case in the late 1980s and only slightly higher than in 1973 (figure 5-19). As appendix table 5-20 shows, the percentage of S&E doctorate holders in academia who received federal support and the percentage of full-time S&E faculty who received federal support differed greatly across the S&E fields. In 2006, more than half of full-time S&E doctoral faculty in the physical sciences, the life sciences, and engineering and less than half of those in mathematics, computer sciences, psychology, and the social sciences received federal support. The percentage receiving federal support was lowest in social sciences (24%).

The percentage with federal support was higher among S&E doctorate holders in research universities (64%) and medical schools (70%) and lower among those employed in doctoral/research universities (28%), master's-granting universities (21%), and baccalaureate colleges (22%) (appendix table 5-20).

Federal Support of Young S&E Doctorate Holders in Academia

Early receipt of federal support is viewed as critical to launching a promising academic research career, yet federal support is less available to young S&E faculty with doctorates than to more established faculty, and the percentage of young S&E faculty with federal support is declining. Among full-time faculty, the percentage reporting federal support in 2006 was lower for those with recently earned doctorates than for all full-time faculty. Moreover, for younger faculty as well as all faculty, the percentage reporting federal support was lower in 2006 than in 1991 (a peak year) (figure 5-19). It should be pointed out that these data provide no information about whether an individual reporting federal support is being supported as a principal investigator on a research project or is participating in a more dependent status rather than as an independent researcher.

Among S&E doctorate holders with recently earned doctorates, those in full-time faculty positions were less likely to receive federal support than those in postdoc or other

Table 5-11
S&E doctorate holders employed in academia and full-time S&E faculty reporting research as primary or secondary work activity, by field and years since doctorate: 2006
(Percent)

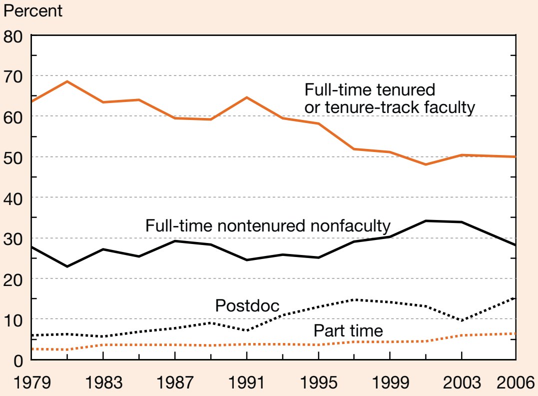
Group and years since doctorate	All fields	Physical sciences	Mathematics and statistics	Computer and information sciences	Life sciences	Psychology	Social sciences	Engineering
S&E doctorate holders employed in academia								
All	67.3	68.0	65.7	70.5	69.8	58.5	65.4	72.4
1–3	78.9	84.5	78.9	79.6	80.0	67.8	71.5	88.3
4–7	72.0	76.2	78.2	79.7	73.0	59.7	68.4	80.7
8–11	69.3	69.9	73.5	63.5	72.7	56.8	69.1	73.1
≥12	63.2	62.7	59.6	65.0	65.8	56.6	62.9	65.5
Full-time S&E faculty								
All	68.6	66.5	68.4	74.0	69.9	63.6	68.8	70.9
1–3	73.5	64.4	71.1	83.9	66.6	69.0	79.9	82.0
4–7	74.0	73.9	81.5	85.1	70.1	68.1	73.1	85.6
8–11	73.4	74.7	80.3	68.1	75.1	64.0	74.1	73.3
≥12	66.0	64.0	63.4	68.0	69.1	61.8	65.4	66.3

NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired. Faculty includes full, associate, and assistant professors plus instructors. Physical sciences include earth, atmospheric, and ocean sciences. Research includes basic or applied research, development, and design.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Figure 5-18
S&E doctorate holders employed in academia 4–7 years after receiving degree, by position: 1979–2006

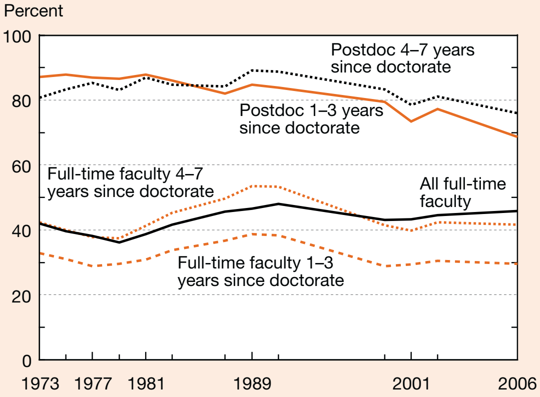


NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired. Full-time faculty includes full, associate, and assistant professors plus instructors. Full-time nontenured nonfaculty includes positions such as research associates, adjunct appointments, lecturers, and administrative positions.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Figure 5-19
S&E doctorate holders employed in academia with federal support, by years since doctorate: 1973–2006



NOTES: 1985 and 1993–97 not comparable with other years and understate degree of federal support by asking whether work performed during week of April 15 was supported by government. In other years, question pertains to work conducted over course of year. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Full-time faculty includes full, associate, and assistant professors plus instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

Table 5-12
S&E doctorate holders employed in academia with federal support, by degree field, years since doctorate, and position: 2006
(Percent)

Years since doctorate and position	All fields	Physical sciences	Mathematics and statistics	Computer and information sciences	Life sciences	Psychology	Social sciences	Engineering
1–3 years since doctorate								
All positions	49.1	66.1	36.6	37.4	55.9	45.2	18.8	58.9
Full-time faculty	29.5	39.2	18.4	23.7	31.6	38.1	16.5	42.5
Other full-time positions	48.7	64.7	S	64.3	56.2	32.2	32.9	50.7
Postdocs	68.6	77.8	60.5	100.0	67.7	66.0	27.0	74.4
4–7 years since doctorate								
All positions	47.3	58.2	32.0	45.3	57.5	35.7	21.5	63.9
Full-time faculty	41.7	52.8	29.7	43.0	49.9	36.6	21.9	61.3
Other full-time positions	43.4	59.2	29.5	49.9	49.4	31.0	22.5	62.6
Postdocs	76.0	72.2	79.5	S	77.4	88.8	S	87.9

S = suppressed, too few cases

NOTES: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Recent doctorate holders earned doctorate within either 3 years or 4–7 years preceding survey. Full-time faculty includes full, associate, and assistant professors plus instructors. Other full-time positions include nonfaculty appointments such as research associates, adjunct appointments, lecturers, and administrative positions. Physical sciences include earth, atmospheric, and ocean sciences. Total includes part-time positions not shown separately but excludes those employed part time because they are students or retired.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

full-time positions in 2006 (table 5-12). Almost half of those with recently earned doctorates reported receiving federal support, with 30% of those in full-time faculty positions, 49% in other full-time positions, and 69% in postdoc positions receiving federal support. Over the past three decades, the percentage of recent S&E doctorate holders in full-time faculty positions who have federal support remained fairly constant (except in the life sciences, where it declined), but the percentage in postdocs and in full-time nonfaculty positions with federal support declined (NSB 2008). The share of recent doctorate holders with federal support was relatively low in the social sciences and higher in the life and physical sciences and in engineering (table 5-12).

Among full-time faculty and postdocs in 2006, those who had received their doctorate 4–7 years earlier were more likely to receive federal support than those with recently earned doctorates (table 5-12). However, those who had received their doctorate 4–7 years earlier were also less likely to receive support in 2006 than in 1991 (figure 5-19 and table 5-13).

Collaborative Research

Research in many fields has increasingly involved collaboration of researchers, whether on large or small projects. Funding entities often encourage collaborative research, which can bring together people of different disciplines, different types of institutions, different economic sectors, and different countries. As noted in the section "R&D Collaborations Between Higher Education Institutions," R&D funds for joint projects that were passed through academic institutions to other institutions increased from FY 2000 to FY 2008, and most of the funds were from federal sources. This section explores S&E doctorate holders' reports of their collaboration with others. Information on trends in and the

Table 5-13
S&E doctorate holders employed in academia 4–7 years after receiving degree reporting receipt of federal support in previous year, by degree field: Selected years, 1973–2006
(Percent)

Degree field	1973	1983	1991	2006
All fields	47.1	50.1	57.4	47.3
Physical sciences	44.8	66.2	67.2	58.2
Mathematics	29.0	39.8	28.3	32.0
Computer sciences	NA	43.5	66.2	45.3
Life sciences	59.7	67.1	70.6	57.5
Psychology	37.8	32.3	38.8	35.7
Social sciences	29.0	28.1	36.6	21.5
Engineering	50.7	64.3	73.2	63.9

NA = not available

NOTES: 1991 used because 1993 not comparable with other years and understates degree of federal support by asking whether work performed during week of April 15 supported by government. In other years, question pertains to work conducted over course of year. Physical sciences include earth, atmospheric, and ocean sciences. Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities and excludes those employed part time because they are students or retired.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science and Engineering Indicators 2010

extent of coauthorship and collaboration using indicators developed from the research literature can be found later in this chapter under "Coauthorship and Collaboration."

In 2006, close to 70% of S&E full-time research faculty employed in academic institutions reported working in an immediate work group or team (appendix table 5-21).[30] Seventy-five percent worked with others elsewhere in the same organization, 58% worked with individuals in other organizations in the United States, and 29% worked with individuals located in other countries. Team work is most common among life scientists, physical scientists, and engineers (80%, 72%, and 77%, respectively) and least common among mathematicians (49%) and social scientists (50%). The percentage of full-time research faculty engaged in international collaboration was higher among those who were born outside the United States (34%) than among those born in the United States (28%). Differences between foreign and native-born researchers were even more pronounced in some fields, such as mathematics (36% compared with 21%), psychology (39% compared with 24%), and social sciences (41% compared with 28%). Although the differences in computer sciences appear large, they are not statistically significant.

Among full-time S&E research faculty, much of the international collaboration was by e-mail or telephone (98%), 52% involved travel abroad, 54% involved travel to the United States, and 38% involved Web-based or virtual technology (appendix table 5-22). Web-based or virtual technology was used far more by computer scientists (56%) than by other scientists and engineers engaged in international collaboration (38% overall). In many fields, a higher percentage of foreign-born than of U.S.-born research faculty travelled abroad for collaboration. More information on collaboration in scientific articles can be found in the next section.

Outputs of S&E Research: Articles and Patents

Chapter 2 of this volume discusses the human capital outputs of higher education in S&E. The present chapter focuses on the S&E functions of U.S. colleges and universities, including funding and performance, physical infrastructure, and human capital devoted to R&D. This section examines the intellectual output of academic S&E research using indicators derived from formal research articles and U.S. patent data.

Researchers have traditionally published the results of their work in the world's peer-reviewed S&E journals,[31] and article-level data from these journals are used here to explore total S&E research output by countries and—within the United States—by sectors of the economy.[32] These so-called *bibliometric* data are also useful for tracking trends in S&E research collaboration using coauthorship measures between and among departments, institutions, sectors, and countries. (See sidebar "Bibliometric Data and Terminology.") Finally, citations in more current research articles to previous research offer insight into the importance and impact of previous research.

The 2008 edition of *Indicators* (NSB 2008) focused attention throughout these bibliometric indicators on three large geographic units: the United States, the 27 members of the European Union, and a group of 10 fast-growing countries in Asia. This edition adjusts that particular organization of the data to focus instead on five S&E article-producing countries/regions that together account for more than four-fifths of the world total: the United States, the European Union, China, Japan, and eight countries/economies together referred to as the "Asia-8" (India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand).

S&E researchers publish the results of their work in the peer-reviewed literature, and symbolic payment for their work is a citation to their article when it is used by future researchers (see Merton 1973). This recognition is uniquely valuable inside the scientific community, where it can be critical to career advancement, and does not necessarily reflect the value society might place on particular scientific findings.

In contrast, when researchers file for patent protection for a practical advance over "prior art" and the claim is granted in a successful patent, the patent owner obtains certain rights to the potential value of the advance. This chapter uses the patenting activities of U.S. academic institutions as another type of indicator of the outputs of academic S&E research. (Chapter 6, "Industry, Technology, and the Global Marketplace," discusses patenting by other sectors in "Global Trends in Patenting.") Because citations to the S&E literature in successful patents indicate the use of past research in practical advances, literature/patent linkage data illuminate patterns of the impacts of academic S&E research on potential technological development.

S&E Article Output

Between 1995 and 2007, the total world S&E article output as contained in the journals tracked by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI), which are analyzed in this chapter, grew at an average annual rate of 2.5% (table 5-14). Scientists and engineers in institutions in the member countries of the European Union authored or coauthored 32% of the world total in 2007,[33] followed by the United States with 28%. China, Japan, and the Asia-8 accounted for another 22% of the world total (appendix table 5-25).[34]

Growth in S&E article output across these five countries/regions has been uneven. Twelve-year growth rates in the mature economies of the U.S. (0.7%), Japan (1.0%), and the European Union (1.9%) have been lower than in the rapidly growing economies of the Asia-8 (9.0%) and China (16.5%) (appendix table 5-25; figure 5-20).

Exactly 200 countries or other entities[35] receive credit for publishing S&E articles (appendix table 5-23). A small number account for most of the publications.[36] Thus, table 5-14 shows that five countries (the U.S., China, Germany,

Bibliometric Data and Terminology

The article counts, coauthorship data, and citations discussed in this section are derived from S&E articles, notes, and reviews published in a set of scientific and technical journals tracked by Thomson Reuters in the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) (http://thomsonreuters.com/products_services/science/). The data exclude letters to the editor, news stories, editorials, and other material whose purpose is not the presentation or discussion of scientific data, theory, methods, apparatus, or experiments. The data are refined in a database prepared for NSF by The Patent Board™, formerly CHI Research, Inc., under a license agreement between The Patent Board™ and Thomson Reuters.

Journal Selection. Since *Science and Engineering Indicators 2004*, this section has used a changing set of journals that reflects the current mix of journals and articles in the world, rather than a fixed journals set. Thomson Reuters selects journals each year as described at http://www.thomsonreuters.com/products_services/science/free/essays/journal_selection_process/, and the selected journals become part of the SCI and SSCI portions of the Web of Science, a digital data product. Using citation data, Thomson Reuters then creates subsets of the SCI and SSCI that are available on CD-ROM and in print. These published data files are notable for the relatively high citation rank of the journals within their corresponding S&E subfields and the exclusion of journals of only regional interest, especially in the social sciences. Likewise, a declining citation rank can result in the removal of a journal from these highly selective data products.

Using the CD-ROM data, the Patent Board™ updates the NSF master file of journals; the number of journals analyzed by NSF from SCI/SSCI was 4,093 in 1988 and 5,266 in 2008. These journals give good coverage of a core set of internationally recognized peer-reviewed scientific journals. The coverage extends to electronic-only journals and print journals with electronic versions. In the period 1995–2008, the database contained 9,358,420 S&E notes, reviews, and articles.

Article Data. Except where noted, *author* means *departmental or institutional author.* Articles are attributed to countries or sectors by the country or sector of the institutional address(es) given in the articles. If no institutional affiliation is listed, the article is excluded from the counts in this chapter. Likewise, *coauthorship* refers to institutional coauthorship. An article is considered coauthored only if it shows different institutional affiliations or different departments of the same institution; multiple listings of the same department of an institution are considered as one institutional author. The same logic applies to cross-sector and international collaboration.

Two methods of counting articles are used: fractional and whole counts. *Fractional counting* is used for article and citation counts. In fractional counting, credit for multiauthor articles is divided among the collaborating institutions or countries based on the proportion of their participating departments or institutions. *Whole counting* is used for coauthorship data. In whole counting, each institution or country receives one credit for its participation in the article.

Several changes introduced in this edition of *Indicators* inhibit comparison with data from the same source used in previous editions.

- Previous editions reported data based on the year an article entered the database (tape year), not on the year it was published (publication year). NSF analysis has shown that, for the U.S. data, each new tape year file fails to capture from 10% to 11% of articles that will eventually be reported for the most current publication year; for some countries, the discrepancy is much larger. Here, data in the first section only ("S&E Article Output") are reported by publication year through 2007, which contains virtually complete data for this and prior publication years.
- Publication data in the remaining bibliometrics sections ("Trends in Output and Collaboration Among U.S. Sectors," "Coauthorship and Collaboration," and "Trends in Citation of S&E Articles") are reported by tape year through 2008.

The regions and countries/economies included in the bibliometric data are listed in appendix table 5-23. Data reported in this section are grouped into 13 broad S&E fields and 125 subfields, which are listed in appendix table 5-24.

Japan, and the United Kingdom) accounted for more than 50% of the total world S&E article output in 2007. The 45 countries in table 5-14—less than one-quarter of the countries in the data—produced 98% of the world total of S&E articles. Nevertheless, the data are constantly evolving to reflect changes in the makeup of nations around the world or the sudden appearance of an author from a heretofore nonpublishing country.[37]

Trends in Country and Regional Authorship

Steadily increasing investments in S&E education and research infrastructure in many countries, especially in Asia, have led to increased R&D in those countries and laid the groundwork for increased research productivity. As a result, scientists and engineers in those countries are increasingly prominent contributors to international peer-reviewed journals.

Table 5-14

S&E articles in all fields, by country/economy: 1995 and 2007

Rank	Country	1995	2007	Average annual change (%)	Percent of total (2007)	2007 cumulative world total (%)
na	World	564,645	758,142	2.5	na	na
1	United States	193,337	209,695	0.7	27.7	27.7
2	China	9,061	56,806	16.5	7.5	35.2
3	Japan	47,068	52,896	1.0	7.0	42.1
4	United Kingdom	45,498	47,121	0.3	6.2	48.3
5	Germany	37,645	44,408	1.4	5.9	54.2
6	France	28,847	30,740	0.5	4.1	58.3
7	Canada	23,740	27,799	1.3	3.7	61.9
8	Italy	17,880	26,544	3.3	3.5	65.4
9	Spain	11,316	20,981	5.3	2.8	68.2
10	South Korea	3,803	18,467	14.1	2.4	70.6
11	India	9,370	18,194	5.7	2.4	73.0
12	Australia	13,125	17,831	2.6	2.4	75.4
13	Netherlands	12,089	14,210	1.4	1.9	77.3
14	Russia	18,603	13,953	-2.4	1.8	79.1
15	Taiwan	4,759	12,742	8.6	1.7	80.8
16	Brazil	3,436	11,885	10.9	1.6	82.3
17	Sweden	9,287	9,914	0.5	1.3	83.6
18	Switzerland	7,220	9,190	2.0	1.2	84.9
19	Turkey	1,715	8,638	14.4	1.1	86.0
20	Poland	4,549	7,136	3.8	0.9	86.9
21	Belgium	5,172	7,071	2.6	0.9	87.9
22	Israel	5,741	6,622	1.2	0.9	88.7
23	Denmark	4,330	5,236	1.6	0.7	89.4
24	Finland	4,077	4,989	1.7	0.7	90.1
25	Greece	2,058	4,980	7.6	0.7	90.8
26	Austria	3,425	4,825	2.9	0.6	91.4
27	Iran	279	4,366	25.7	0.6	92.0
28	Mexico	1,937	4,223	6.7	0.6	92.5
29	Norway	2,920	4,079	2.8	0.5	93.1
30	Singapore	1,141	3,792	10.5	0.5	93.6
31	Czech Republic	1,955	3,689	5.4	0.5	94.0
32	Portugal	990	3,424	10.9	0.5	94.5
33	Argentina	1,967	3,362	4.6	0.4	94.9
34	New Zealand	2,442	3,173	2.2	0.4	95.4
35	South Africa	2,351	2,805	1.5	0.4	95.7
36	Ireland	1,218	2,487	6.1	0.3	96.1
37	Hungary	1,764	2,452	2.8	0.3	96.4
38	Egypt	1,388	1,934	2.8	0.3	96.6
39	Ukraine	2,516	1,847	-2.5	0.2	96.9
40	Chile	889	1,740	5.8	0.2	97.1
41	Thailand	340	1,728	14.5	0.2	97.3
42	Slovenia	434	1,280	9.4	0.2	97.5
43	Romania	678	1,252	5.2	0.2	97.7
44	Croatia	600	1,102	5.2	0.1	97.8
45	Serbia	NA	1,057	NA	0.1	98.0

na = not applicable; NA = not available

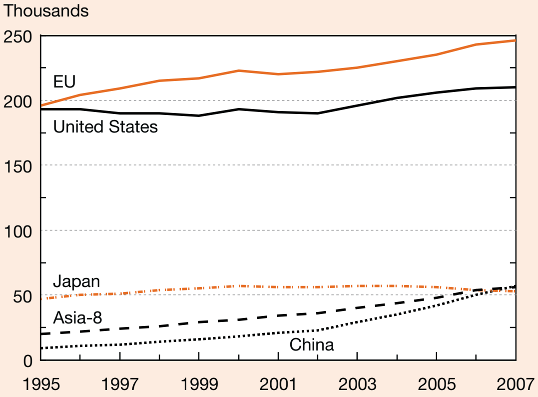
NOTES: Countries shown produced >1,000 articles in 2007. Countries ranked on 2007 total. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to country/economy on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. Detail does not add to total because countries omitted.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board^{TM}; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-25.

Science and Engineering Indicators 2010

Figure 5-20

S&E article output, by major S&E publishing region/country: 1995–2007



EU = European Union

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. See appendix table 5-23 for countries/economies included in EU and Asia-8.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-25.

Science and Engineering Indicators 2010

Differences in recent rates of growth in article production are striking. In the major Asian countries, average annual growth rates between 1995 and 2007 were highest in China, at 17%. Across the Asia-8 countries, growth rates have been 9% annually for the same period (appendix table 5-25), led by Thailand (15%), South Korea (14%), Singapore (11%), and Taiwan (9%) (table 5-14). These growth rates mirror those in R&D expenditures and number of researchers. Japan's growth in article output averaged a modest 1% annually between 1995 and 2007. China's rapid growth rate in S&E article output propelled it in 2007 past the United Kingdom, Germany, and Japan to rank as the world's second-largest producer, up from 5th place in 2005 and 14th place in 1995 (appendix table 5-25).[38] During the same period, South Korea went from 22nd to 10th place.

These high rates of growth in S&E article authorship in Asia contrast with much slower rates for the world as a whole (2.5%), for countries with mature S&E infrastructures such as the United States (0.7%), and for the European Union (1.9%) (appendix table 5-25). Russia's article output decreased over the period, from 18,600 in 1995 to 14,000 in 2007, as did Ukraine's, from 2,500 to 1,800. Many of the other former republics of the Union of Soviet Socialist Republics (USSR) experienced negative growth on this indicator as well.

Countries within the European Union showed different trends in S&E article output between 1995 and 2007. Growth rates below 3% were common, for example, in Austria, Belgium, Denmark, Germany, and the Netherlands. Among the lowest rates of growth on this indicator were the United Kingdom (0.3%), France (0.5%), and Sweden (0.5%). Relatively high growth was experienced by the Czech Republic (5.4%), Greece (7.6%), Ireland (6.1%), Portugal (10.9%), and Spain (5.3%). Although not a member of the European Union, Turkey experienced one of the fastest growth rates in S&E article output in the world: 14.4% annually (from 1,700 articles in 1995 to 8,600 in 2007 (appendix table 5-25).

The countries in Central and South America together increased their S&E article output between 1995 and 2007 at an annual rate of 7.8%. Among the Central and South American countries that had more than 1,000 articles in 2007, Brazil had the highest growth rate (10.9%), followed by Mexico (6.7%), Chile (5.8%), and Argentina (4.6%). Brazil is also steadily increasing in rank among the world's S&E article producers: it was 23rd in 1995 and 16th in 2007 (table 5-14).

Across North Africa and the Middle East, only Egypt (2.8% annual growth since 1995), Israel (1.2%), and Iran (25.7%) produced substantial numbers of S&E articles in 2007. Iran's growth rate was the fastest of all nations (see sidebar "S&E Publishing Trends in Iran").

Research Portfolios of Top Article-Producing Countries/Regions

The S&E article output of the United States, the European Union, China, Japan, and the Asia-8 together accounted for 82% of the world total in 2007 (appendix table 5-25). A field-by-field comparison across these five countries/regions provides a snapshot of their research portfolios, and strong differences are evident. China, Japan, and the Asia-8 emphasize the physical sciences more than the United States and the European Union. China's S&E research articles in chemistry and physics accounted for almost one-half of its total article production in 2007 (table 5-15). In Japan, these two fields accounted for 36%, and in the Asia-8, 37%, compared with 17% for the United States and 25% for the European Union. The proportions of all five portfolios in astronomy (≤1.5%) and the geosciences (4.0%–5.5%) were similar.

These portfolios also vary in their emphasis on the life sciences (the biological, medical, agricultural, and other life sciences): the U.S. output in these fields accounted for 57% of its total, compared with 49% for the European Union, 25% for China, 45% for Japan, and 34% for the Asia-8 (table 5-15).

A third strong contrast across the five countries/regions is the emphasis on engineering: S&E research publications with authors in Asia are relatively more heavily concentrated in engineering (China at 16%, Japan at 11%, and the Asia-8 at 19%) than those with authors in the United States (7%) or the European Union (8%).

S&E Publishing Trends in Iran

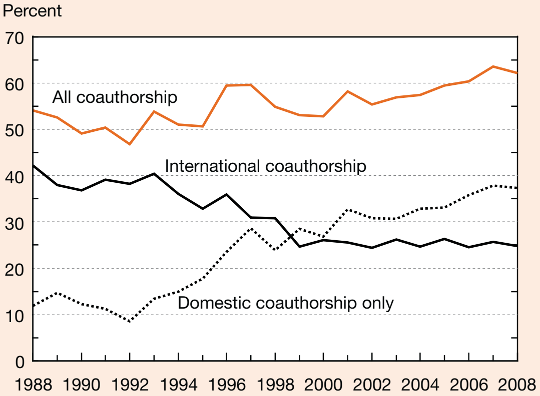
Iran-based authors produced 4,400 articles in 2007, and Iran's S&E publication growth rate has been the fastest in the world. Growth in publications has been strong across many fields, resulting in a 2007 publication portfolio weighted toward chemistry (30% of the total), engineering (15%), the medical sciences (14%), the biological sciences (14%), and physics (14%) (appendix tables 5-25 through 5-38).

Iran has an evolving science policy framework and a growing number of research institutions to carry out the framework (UNCTAD 2005). The country has a growing adult literacy rate (77% in 2003), but its economy is dominated by extraction and export of oil and gas. Current policy envisions a more diversified economy and a transition to development and production of petrochemicals and other high-technology products.

Iran's pattern of international coauthorship has mirrored that of other countries with immature S&E capabilities: they coauthor internationally at very high rates, but these rates decline as domestic capacity builds. Iran's rate of international coauthorship was 42% in 1988 but had declined to 25% in 2008, near the world average of 22% (figure 5-A; see also figure 5-21).

Despite a declining *rate* of international coauthorship Iran's total *number* of international coauthorships has been growing steadily, and coauthorships with each of its main foreign coauthor countries have also been growing. Table 5-B shows Iran's top five coauthoring countries in 2008.

Figure 5-A
Share of Iran's S&E articles coauthored domestically and internationally: 1988–2008



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating institution or country credited one count. Internationally coauthored articles may also have multiple domestic coauthors.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Table 5-B
International coauthorship with Iran, by top five coauthoring countries: 2008

	Articles	
Country	Number	Percent
World	1,514	100.0
United States	346	22.9
United Kingdom	232	15.3
Canada	217	14.3
Germany	129	8.5
France	113	7.5

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to countries on basis of institutional addresses listed on articles. Articles on whole count basis, i.e., each collaborating country credited one count.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters. com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Coauthorship and Collaboration

Coauthored, collaborative articles with authors from different institutions and different countries have continued to increase, indicating increasing knowledge transfer or knowledge sharing among institutions and across national boundaries.[39, 40] The discussion begins with consideration of broad trends in coauthorship for the world as a whole, moves to regional patterns, and ends with an examination of country-level trends, including selected country-to-country coauthorship patterns and indexes of international collaboration. (Indicators of cross-sector coauthorship, which are available only for the United States, are examined below in the section "Trends in Output and Collaboration Among U.S. Sectors." Indicators of collaboration using different data are discussed earlier in this chapter under "Collaborative Research" in the "Doctoral Scientists and Engineers in Academia" section. For a consideration of the limitations of bibliometric techniques in identifying interdisciplinary S&E research, see the sidebar "Can Bibliometric Data Provide Accurate Indicators of Interdisciplinary Research?"

Article Author Names and Institutions

Between 1988 and 2005, the number of S&E articles, notes, and reviews grew by 60%, while the number of institutions and the number of author names on them both grew by more than 100% (NSB 2008, 08-01, figure 5-29). The trend continued in 2008. In all broad fields, the number of

Table 5-15

S&E research portfolios of selected regions/countries, by field: 2007

(Percent)

Field	U.S.	EU	China	Japan	Asia-8
All articles (*n*)	209,695	245,852	56,806	52,896	56,123
Engineering	6.9	8.1	16.0	11.1	19.1
Astronomy	1.4	1.5	0.7	0.8	0.5
Chemistry	7.5	12.0	24.5	16.1	18.0
Physics	9.3	13.4	24.0	19.7	18.9
Geosciences	5.5	5.3	4.3	4.0	4.0
Mathematics	1.9	2.7	3.3	1.3	1.5
Computer sciences	1.1	0.9	1.3	0.4	1.4
Agricultural sciences	1.8	2.4	2.0	2.2	2.4
Biological sciences	25.1	20.6	14.0	21.4	16.5
Medical sciences	27.8	25.2	8.4	21.3	14.9
Other life sciences	2.0	0.9	0.2	0.1	0.4
Psychology	4.3	2.6	0.3	0.7	0.6
Social sciences	5.4	4.3	0.8	1.0	1.6

EU = European Union

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to country on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries, each country receives fractional credit on basis of proportion of its participating institutions. See appendix table 5-23 for countries/economies included in EU and Asia-8. Percents may not add to 100% because of rounding.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board^{TM}; and National Science Foundation, Division of Science Resources Statistics. See appendix tables 5-25 through 5-38.

Science and Engineering Indicators 2010

author names per article increased (table 5-16). The average number of authors per paper was more than five in astronomy, physics, the biological sciences, and the medical sciences. Growth in the average number of coauthors was slowest in the social sciences (from 1.4 authors per paper in 1988 to 1.9 in 2008) and in mathematics (from 1.5 in 1988 to 2.0 in 2008). Unpublished NSF analyses show that in 2008, 90% of all S&E articles had at least two author names.

A closely related indicator, coauthored articles (i.e., articles with authors in different departments or institutions), has also increased steadily. Coauthored articles grew from 40% of the world's total S&E articles in 1988 to 64% in 2008 (figure 5-21). This growth has two parts. Coauthored articles that list only domestic institutions in the byline grew from 32% of all articles in 1988 to 42% in 2008. Articles that list institutions from more than one country, that is, internationally coauthored articles (which also may have multiple domestic institutional authors) grew from 8% to 22% over the same period. The remainder of this section focuses on these internationally coauthored articles.

International Coauthorship From a Regional Perspective

From the perspective of large article-producing countries/regions, interregional coauthorship has increased steadily.[41] From 1998 to 2008, interregional coauthorship increased as a percentage of the total article output of the United States (from 20% to 30%), the European Union (from 21% to 29%), Japan (17% to 26%), and the Asia-8 (22% to 27%) (table 5-17). Notably, China failed to increase on this indicator: as

Table 5-16

Authors per S&E article, by field: 1988, 1993, 1998, 2003, and 2008

Field	1988	1993	1998	2003	2008
All fields	3.1	3.4	3.8	4.2	4.7
Engineering	2.5	2.8	3.1	3.4	3.8
Astronomy	2.5	3.2	3.6	4.5	5.9
Chemistry	3.1	3.3	3.6	3.9	4.3
Physics	3.3	3.8	4.2	4.7	5.3
Geosciences	2.4	2.7	3.2	3.5	4.0
Mathematics	1.5	1.6	1.8	1.9	2.0
Computer sciences	1.9	2.0	2.3	2.6	3.0
Agricultural sciences	2.7	2.9	3.3	3.8	4.3
Biological sciences	3.3	3.7	4.2	4.6	5.3
Medical sciences	3.6	4.1	4.5	5.0	5.6
Other life sciences	2.0	2.1	2.4	2.9	3.2
Psychology	2.0	2.2	2.5	2.8	3.2
Social sciences	1.4	1.5	1.6	1.8	1.9

NOTE: Articles classified by year they entered database rather than year of publication.

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board^{TM}; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Can Bibliometric Data Provide Accurate Indicators of Interdisciplinary Research?

To address the need for indicators of interdisciplinary research (IDR), NSF/SRS commissioned a panel of researchers* to review recent attempts to measure the growth of interdisciplinary S&E research. The panel reviewed 74 publications dealing with IDR. It concluded that, despite increased study of IDR in the literature, existing indicators of IDR based solely on bibliometric data were unsatisfactory for management and policy purposes and relied on an overly simplistic concept of IDR (Wagner, Roessner, and Bobb 2009; Wagner et al. 2009). The panel also found that problems with current data sources and analytical techniques raise questions about the validity of these measures.

The panel concluded that conceptualization of IDR involves both the *outputs* of research and research *processes*: it stressed that both social developments (e.g., new S&E working relationships, new career trajectories, new institutions) and cognitive developments (e.g., new theory, new ways of using existing data, new problem frameworks) are essential markers of IDR. Bibliometric data alone do not capture these dimensions of IDR.

The panel identified an emerging consensus that studies of IDR need measures of *knowledge integration* that could be applied to the work of either a team of researchers or an individual. However, they found limited agreement on what such integration entails and even less agreement on what would count as evidence of it.

The panel also assessed the limitations of current attempts at measurement of IDR, most of which use Thomson Reuters data products. These are organized into a structure based on the discipline of the *journal* in which articles are published. Studies then measure the "cognitive distance" reflected by the diversity of citations in their target data (authors, articles, journals) from the Thomson Reuters journal structure and treat this distance as the measure of IDR.

Alternative analytical techniques are under development. These use statistical and visualization techniques that seek to detect certain hidden structures in the data that may indicate IDR. However, these techniques still require validation. Bibliometric measures will also need to be supplemented by survey data, ethnographic studies, expert review, and other evidence to confirm the degree of interdisciplinarity in research output. Indicators of IDR may also vary depending on user needs. For example, measurements of IDR appropriate for projects, programs, and nations are likely to be different. The panel summarized its conclusions as follows (Wagner, Roessner, and Bobb 2009, p 9-10, 16):

> ♦ The Panel's consensus…is that it is premature to identify one or a small set of indicators or measures of interdisciplinary research…in part, because of a lack of understanding of how current attempts to measure IDR conform to the actual process and practice of interdisciplinary research, and the outcomes resulting from that practice.
>
> ♦ The literature is rich and maturing, but has not reached a point that permits meaningful assessment of IDR, especially for public policy and research management purposes.

---

*The assessment was performed by three researchers at SRI International, Caroline S. Wagner, J. David Roessner, and Kamau Bobb, working with the following experts on interdisciplinarity and visualization: Katy Börner, Indiana University; Kevin W. Boyack, SciTech Strategies, Inc.; Joann Keyton, North Carolina State University; Julie Thompson Klein, Wayne State University; and Ismael Rafols, University of Sussex. These eight researchers are referred to as the "panel" in this sidebar.

a percentage of its total S&E article output, China's interregionally coauthored articles declined from 26% in 1998 to 25% in 2008.

As a percentage of the world's interregionally coauthored articles, the shares of articles with a U.S., European Union, or Japanese institutional author declined slightly, giving way to a rise in the share of articles with an institutional author from China (from 6% to 13%) or the Asia-8 (from 9% to 14%). These changes in share of the world's interregional articles are similar to the changes in each region's share of all the world's articles.

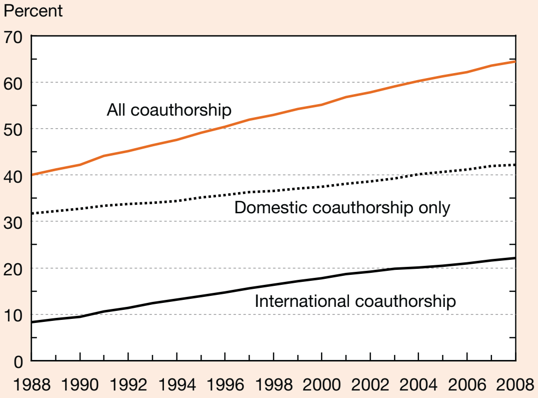
The other regions identified in table 5-17 tend to have a less-developed S&E infrastructure, and scientists and engineers in those regions tend more often to coauthor articles with colleagues in the more scientifically advanced regions/countries. For example, in 2008, 41% of all S&E articles with an institutional author from the Near East/North Africa (which includes Israel) had an author from another region, as did 61% of S&E articles with an institutional author from Sub-Saharan Africa (which includes South Africa). The following sections look more closely at coauthorship patterns of specific countries and country pairs.

International Coauthorship Patterns From a Country Perspective

When the region-level data discussed in the previous section are disaggregated to the country level, a richer picture of international S&E article coauthorship emerges. Table 5-18 displays the international coauthorship rates of countries that had institutional authors on at least 5% or more of the world's internationally coauthored S&E articles in 2008 (see also appendix tables 5-39 and 5-40).

The sheer volume of U.S. internationally coauthored articles dominates these measures: 30% of U.S. articles in 2008

Figure 5-21
Share of world S&E articles coauthored domestically and internationally: 1988–2008



NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating institution or country credited one count. Internationally coauthored articles may also have multiple domestic coauthors.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

were internationally coauthored, and U.S.-based researchers were coauthors of 43% of the world's total internationally coauthored articles. The next highest percentages of the world's coauthored articles were held by Germany and the United Kingdom, each at 19% of the world total.

Even higher rates of international coauthorship are evident among the countries of the European Union and in Switzerland. Both Japan's and the Asia-8's international coauthorship rates have increased over the past 10 years.

What accounts for specific coauthorship relationships? Narin and colleagues (1991) concluded that "the direction of international coauthorship is heavily dependent on linguistic and historical factors." Coauthorship data suggest that geography, cultural relations, and the language of particular pairs or sets of countries play a role (Glänzel and Schubert 2005; Schubert and Glänzel 2006), and these preferences have been evolving over time (Glänzel 2001). In more recent years, European Union policies and incentives that foster intra-European Union, cross-border collaboration are also partly responsible for some high rates of coauthorship. The discussion below in the section "International Collaboration in S&E" identifies strong coauthorship relations in specific country pairs across the world, based on the strength of their coauthorship rates.

Table 5-17
Interregional collaboration on S&E articles: 1998 and 2008
(Percent)

	Share of region's/ country's total article output		Share of world's interregional articles	
Region/country	1998	2008	1998	2008
United States	20	30	57	55
EU	21	29	66	61
Other Western Europe	43	48	12	12
Asia	18	23	25	34
China	26	25	6	13
Japan	17	26	13	11
Asia-8	22	27	9	14
Other Asia	62	65	1	1
Other former USSR	31	42	11	7
Near East/ North Africa	39	41	7	7
Central/ South America	39	40	9	9
Sub-Saharan Africa	47	61	3	4
Other	31	43	20	21

EU = European Union; USSR = Union of Soviet Socialist Republics

NOTES: Interregionally coauthored articles have at least one collaborating institution from indicated region/country and an institution from outside that region/country. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to region/country on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating region/country credited one count. See appendix table 5-23 for countries/economies included in each region. Detail adds to more than 100% because articles may have authors from more than two countries/economies. Asia computed as sum of collaboration among China, Japan, Asia-8, and Other Asia.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

International Coauthorship With the United States

Table 5-19 lists the 31 countries whose institutions appeared on at least 1% of U.S. internationally coauthored articles in 2008. U.S. authors are most likely to coauthor with colleagues from the United Kingdom (13.9%), Germany (12.7%), Canada (12.0%), and China (10.4%—up from 3.5% in 1998).

Table 5-18 shows that the rate at which U.S. researchers participate in international collaboration is below that of many countries with smaller science establishments. However, because of the size of the S&E establishment in the United States, the share of U.S. internationally coauthored articles that were coauthored with any other country is lower than the share of the other country's internationally coauthored articles that were coauthored with U.S. researchers (table 5-19). For example, 3% of U.S. scientists who coauthored internationally in 2008 collaborated with Israeli

Table 5-18
International collaboration on S&E articles, by selected country/economy: 1998 and 2008
(Percent)

	Share of country's/ economy's total article output		Share of world's internationally coauthored articles	
Country/economy	1998	2008	1998	2008
United States	20	30	44	43
EU				
France	38	52	16	14
Germany	36	51	20	19
Italy	38	45	10	9
Netherlands	40	52	7	6
Spain	34	45	6	8
United Kingdom	32	49	19	19
Other Western Europe				
Switzerland	50	65	6	6
Asia				
China	26	25	4	11
Japan	17	26	10	9
Asia-8	23	30	7	12
Other				
Australia	31	45	5	7
Canada	34	46	10	10

EU = European Union

NOTES: Internationally coauthored articles have at least one collaborating institution from indicated country/economy and an institution from outside that country/economy. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count. Countries/economies with less than 5% of 2008 international total omitted. See appendix table 5-23 for countries/economies included in Asia-8, which in this table is treated as a single country. Detail adds to more than 100% because articles may have authors from more than two countries/economies.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

counterparts; the corresponding figure for Israel, with its much smaller scientific infrastructure, is 52%. Again, 51% of scientists and engineers in Canada who coauthored internationally collaborated with U.S. colleagues, but only 12% of U.S. international coauthorship was with colleagues at Canadian institutions;[42] linguistic, geographic, and other ties combine to facilitate these collaborations.

Notable changes in these patterns of U.S. international coauthorship parallel changes in other indicators discussed in this section. As China's total S&E article output grew rapidly, so did its coauthorship with U.S. authors: the U.S. share of China's internationally coauthored articles increased about 6 percentage points over the past decade, and China's share of U.S. internationally coauthored articles increased almost 7 percentage points (table 5-19). U.S. scientists and engineers lost relative share of international coauthorship with some countries/economies, notably India, South Korea, Taiwan, and Japan, as their counterparts in those countries/economies broadened the geographic scope of their collaborative relations.

International Collaboration in S&E

In developing indicators of international collaboration between countries and across regions, researchers have developed statistical techniques that account for unequal sizes in countries' S&E article output and coauthorship patterns (Glänzel and Schubert 2004). One of the simplest is the index of international collaboration (table 5-20), which is defined as the ratio of country A's rate of collaboration with country B divided by country B's rate of total international coauthorship (Narin, Stevens, and Whitlow 1991). Indexes above 1 represent rates of coauthorship that are higher than expected, and indexes below 1 indicate rates of coauthorship that are lower than expected. For example, if country B produces 12% of internationally coauthored articles, and 12% of country A's coauthored articles are with country B, the index of international collaboration is 12%/12% = 1.0. The indexes for all pairs of countries that produced more than 1% of all internationally coauthored articles in 2008 are shown in appendix table 5-41.

Table 5-20 lists the international collaboration index for selected pairs of countries. In North America, the Canada-United States index shows a rate of collaboration that is slightly greater than would be expected based solely on the number of internationally coauthored articles shared by these two countries, and the index has changed little over the past decade. The Mexico-United States index is just about as would be predicted and is also stable.

Collaboration indexes between pairs of countries on opposite sides of the North Atlantic are all low and have changed little over the decade. In Europe, collaboration patterns are mixed, but most have increased over the decade, indicating growing integration across the European Union in terms of S&E article publishing. Among the large publishing countries of Germany, the United Kingdom, and France, collaboration was less than expected but grew in all three countries over the decade.

The Scandinavian countries[43] increased their coauthorship indexes with many countries in Europe (appendix table 5-41), and within Scandinavia, the indexes are among the highest in the world and, overall, have been growing stronger (table 5-20).

Cross-Pacific collaboration patterns are mixed. Japan-United States collaboration fell below the expected value over the decade, while the China-United States index rose to near 1. U.S. collaboration indexes with South Korea and Taiwan declined but remained higher than expected in both cases. Canadian scientists and engineers were less likely than their U.S. neighbors to have coauthored with colleagues in Asia. Mexico's collaboration with Argentina is almost four times higher than expected, at 3.74 in 2008. In South America, the collaboration index of Argentina-Brazil, at 5.32, is one of the highest in the world.

Table 5-19

International coauthorship of S&E articles with the United States, by selected country/economy: 1998 and 2008

(Percent)

Country/economy	1998		2008	
	U.S. share of country's/ economy's international articles	Country/ economy share of U.S.'s international articles	U.S. share of country's/ economy's international articles	Country/ economy share of U.S.'s international articles
World	43.9	na	43.3	na
United Kingdom	29.6	12.5	32.0	13.9
Germany	29.9	13.7	29.7	12.7
Canada	53.2	11.6	51.2	12.0
China	35.8	3.5	42.1	10.4
France	24.7	8.7	26.0	8.3
Japan	45.2	10.4	38.7	7.9
Italy	31.8	7.0	32.5	7.1
Australia	35.1	4.3	33.6	5.2
South Korea	60.6	2.9	53.5	5.0
Spain	24.9	3.4	27.1	4.8
Netherlands	29.9	4.4	30.5	4.5
Switzerland	31.2	4.2	31.6	4.3
Sweden	29.0	3.6	29.2	3.2
Israel	55.1	3.9	52.3	2.8
Brazil	38.1	2.3	38.5	2.8
Russia	24.7	3.9	27.3	2.7
Taiwan	63.4	1.7	53.4	2.5
Belgium	23.1	2.1	24.4	2.3
India	40.6	1.9	34.3	2.3
Denmark	30.5	2.2	30.2	1.9
Mexico	44.5	1.6	44.8	1.7
Poland	25.0	1.8	26.4	1.7
Austria	25.3	1.5	24.5	1.6
Norway	29.1	1.2	29.6	1.4
Finland	27.5	1.5	27.1	1.4
Greece	29.6	0.9	33.4	1.3
New Zealand	34.7	1.0	34.9	1.2
Turkey	38.0	0.6	41.7	1.2
Singapore	28.7	0.4	30.3	1.1
Argentina	35.1	0.9	34.9	1.1
South Africa	31.1	0.7	34.8	1.1

na = not applicable

NOTES: Internationally coauthored articles have at least one collaborating institution from indicated country/economy and an institution from outside that country/economy. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count. Countries/economies ranked on percentage of their share of U.S.'s international articles in 2008; countries/economies with less than 1% of U.S.'s 2008 international articles omitted.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix tables 5-39 and 5-40.

Science and Engineering Indicators 2010

Collaboration indexes within Asia and across the South Pacific between the large article producers are generally higher than expected but with only minor changes over the past decade. Australia's coauthorships are strongly linked to New Zealand, at nearly four times the expected rate of coauthorship. Two strongly coauthoring pairs are South Korea-Japan and Australia-Singapore. India's collaboration index with South Korea grew from 1.61 to 2.19 over the past decade.

Trends in Output and Collaboration Among U.S. Sectors

In the U.S. innovation system, ties between and among universities, industry, and government have been beneficial for all sides. These ties include the flows of knowledge among these sectors, for which research article outputs and collaboratively produced articles are proxy indicators. S&E articles authored at academic institutions have for decades accounted for

Table 5-20
Index of international collaboration on S&E articles, by selected country/economy pair: 1998 and 2008

Country/economy pair	International collaboration index 1998	International collaboration index 2008
North/South America		
Canada–U.S.	1.21	1.18
Mexico–U.S.	1.01	1.03
U.S.–Brazil	0.87	0.89
Argentina–Brazil	4.33	5.32
Mexico–Argentina	2.99	3.74
North Atlantic		
UK–U.S.	0.67	0.74
Germany–U.S.	0.68	0.68
France–U.S.	0.56	0.60
Canada–France	0.63	0.74
Europe		
France–Germany	0.74	0.91
France–UK	0.73	0.87
Germany–UK	0.68	0.86
Belgium-Netherlands	2.50	2.68
Italy–Switzerland	1.51	1.38
Poland–Czech Republic	2.15	3.48
Hungary–Germany	1.23	1.34
Germany–Czech Republic	1.27	1.46
Scandinavia		
Finland–Sweden	3.39	3.98
Norway–Sweden	4.10	3.96
Sweden–Denmark	2.88	3.38
Finland–Denmark	2.36	3.15
Pacific Rim		
Japan–U.S.	1.03	0.89
China–U.S.	0.82	0.97
South Korea–U.S.	1.38	1.23
Taiwan–U.S.	1.44	1.23
China–Canada	0.66	0.73
Japan–Canada	0.59	0.55
Asia/South Pacific		
China–Japan	1.53	1.38
South Korea–Japan	1.99	1.90
Australia–Singapore	1.93	1.70
Australia–China	1.05	1.14
Australia–New Zealand	4.28	3.80
India–Japan	0.94	1.12
India–South Korea	1.61	2.19

UK = United Kingdom

NOTES: International collaboration index is first country's rate of collaboration with second country divided by second country's rate of international coauthorship. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country/economy credited one count.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-41.

Science and Engineering Indicators 2010

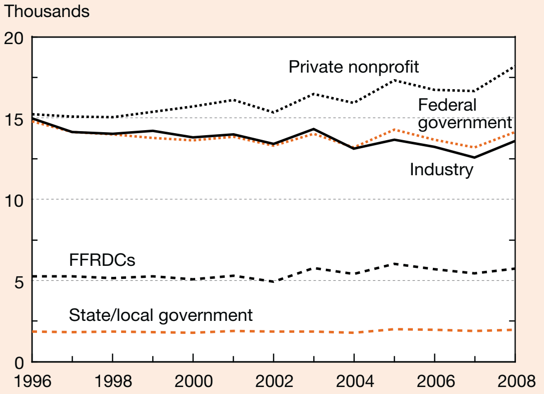
more than 70% of all U.S. articles (76% in 2008) (appendix table 5-42). This section contrasts U.S. academic authorship with nonacademic authorship, including output trends by sector and the extent of coauthorship, both between U.S. sectors and between U.S. sectors and authors abroad.

Article Output by Sector

Total annual S&E articles by authors in U.S. nonacademic sectors changed little over the past decade, ranging from 50,000 to 55,000 articles[44] per year between 1995 and 2008 (appendix table 5-42). The number of articles produced by scientists and engineers in the federal government and in industry was more than 15,000 in 1995 but slowly declined to range between 13,000 and 14,000 each through 2008 (figure 5-22). State and local government authorship, dominated by articles in the medical and biological sciences, remained constant across the decade. Between 1995 and 2008, scientists and engineers in the private nonprofit sector increased their output from about 15,000 to about 18,000.

Federally funded research and development centers (FFRDCs) are research institutions sponsored by federal agencies and administered by universities, industry, or other nonprofit institutions. FFRDCs have specialized research agendas closely related to the mission of the sponsoring agency and may house large and unique research

Figure 5-22
S&E article output of U.S. nonacademic sectors: 1996–2008



FFRDC = federally funded research and development center

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to sector on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple sectors, each sector receives fractional credit on basis of proportion of its participating institutions. Joint and unknown sectors omitted.

SOURCES: Thomson Reuters, SCI and SSCI, http://www.thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-42.

Science and Engineering Indicators 2010

instruments not otherwise available in other research venues. Although authors at FFRDCs published articles in all of the broad S&E fields considered in this chapter, articles in physics, chemistry, and engineering together represented 69% of publication by this sector in 2008, reflecting its specialized research programs. Physics articles accounted for 39% of the FFRDC total (9% of the total for all sectors); engineering articles for 15% (7% of the total for all sectors); and chemistry articles for 16% (8% of the total for all sectors (appendix table 5-42).

The 16 FFRDCs sponsored by the Department of Energy dominated S&E publishing by this sector. Across all fields of S&E, DOE-sponsored labs accounted for 83% of the total for the sector in 2005 (NSB 2008). Scientists and engineers at DOE-sponsored FFRDCs published 96% of the sector's articles in chemistry, 95% in physics, and 90% in engineering (see "S&E Articles From Federally Funded Research and Development Centers," NSB 2008, p 5-47). Nine other federal agencies, including the Departments of Defense, Energy, Health and Human Services, Homeland Security, Transportation, and Treasury; the National Aeronautics and Space Administration; the Nuclear Regulatory Commission; and National Science Foundation also sponsor another 23 FFRDCs (NSF/SRS 2009a).

In contrast, articles published by authors in the private nonprofit sector are primarily in the medical sciences (55% of the sector's articles in 2008) and biological sciences (25%) (appendix table 5-42). Federal government authors show a similar pattern, with 30% in the biological sciences and 27% in the medical sciences.

Trends in Sector Coauthorship

This section considers coauthorship data as an indicator of collaboration at the sectoral level between U.S. institutional authors and between U.S. sectors and foreign institutions.[45] These data show that the growing integration of R&D activities, as measured by coauthorship, is occurring across the full range of R&D-performing institutions internationally as well as domestically.

Between 1998 and 2008, coauthorship within sectors increased for all U.S. sectors.[46] Coauthorship within academia rose from 38% in 1998 to 45% in 2008. FFRDC-FFRDC coauthorship increased 5 percentage points (table 5-21).

U.S. cross-sectoral coauthorships show a mixed pattern between 1998 and 2008. Coauthorship between FFRDCs and industry decreased. (Articles authored by industry physicists have been declining gradually across the period. Since a strong emphasis of FFRDC-authored articles is in physics (39%), it may be that fewer and fewer physicists are available in industry for potential coauthorship with physicists in FFRDCs.)[47] The largest gains in all sectors (6.8–9.8 percentage points) were with coauthors in academia, by far the largest sector with the largest pool of potential S&E coauthors. Cross-sector coauthorship with academic authors was higher in 2008 (54%–74%) than intrasector coauthorship within academia (45%), and cross-sector coauthorship with academia was higher in all sectors than any intrasector coauthorship (table 5-21).

Except for the decline in coauthorship between FFRDCs and industry, the indicators presented in this section hint at increasing integration between and among the different types of U.S. institutions that publish the results of R&D in the scientific and technical literature. Growth in coauthorship has been particularly strong between U.S. authors in academia and in all other sectors. Because of the predominance of the academic sector in S&E article publishing in the United States, academic scientists and engineers have been on the forefront of the integration of S&E research across institutions, both nationally and internationally.

International collaboration increased rapidly in the United States. International coauthorship rates rose by 7–10 percentage points between 1998 and 2008 (table 5-21). Authors at FFRDCs reached the highest rate of collaboration with foreign authors, at 42%, followed by industry and academia at 29% each. Astronomers in most U.S. sectors increased their rates of international coauthorship the most rapidly, and geoscientists, mathematicians, and physicists in most U.S. sectors also increased their collaboration with international colleagues at a higher-than-average pace (NSB 2008, 08-01A, p A5-66).

Trends in Citation of S&E Articles

Citations indicate influence. When scientists and engineers cite the published papers resulting from prior S&E research, they are formally crediting the influence of that research on their own work. Like the indicators of international coauthorship discussed above, cross-national citations are evidence that S&E research is increasingly international in scope. Between 1992 and 2008, international citations grew faster than total citations: 5.8% annually versus 4.6% (figure 5-23). By 2008, international citations were two-thirds of all citations.[48]

Two other trends accompanied the steady growth of international citations in the world's S&E literature: changing shares of total citations across countries and changing shares of highly cited S&E literature. These are discussed in the following sections.

Citation Trends in a Global Context

Shares of the world total of citations to S&E research articles have changed concurrently with shares of the world total of these articles. Appendix table 5-43 shows, for example, that between 1994–96 and 2004–06, the U.S. share of world S&E articles declined from 34% to 29% across all fields;[49] the U.S. share declined in every broad field, although the decline varied in size. Table 5-22 shows the parallel trends for the U.S. share of citations and indicates an even larger decline, from 47% to 38%.

China's share of both total world S&E articles and citations increased over the same period. However, in contrast to the global trend of increasing international citations, China's pattern has been different. Unlike the United States and other large article-producing countries, China's share of international citations *decreased* between 1998 and 2008, from

Table 5-21

U.S. article coauthorship, by sector, foreign coauthorship, and U.S. coauthor sector: 1998 and 2008

(Percent)

		U.S. coauthor sector					
Year/sector	Foreign coauthor	FFRDCs	Federal government	State/local government	Academic institutions	Industry	Private nonprofit
1998							
Federal government	19.7	3.2	17.4	2.0	54.4	9.0	8.5
Industry	19.7	3.3	9.6	1.4	44.8	14.1	8.9
Academic	19.6	2.6	7.8	1.4	37.7	6.0	8.6
FFRDCs	32.9	12.6	8.6	0.2	48.5	8.4	3.4
Private nonprofit	17.8	1.2	8.0	2.3	57.1	8.0	24.3
State/local government	10.9	0.5	13.9	13.5	64.2	8.8	16.2
2008							
Federal government	27.4	4.0	20.5	2.9	62.0	9.5	12.9
Industry	29.2	3.5	10.5	1.9	53.8	17.9	13.5
Academic	28.8	3.2	8.1	1.5	45.2	6.4	10.5
FFRDCs	41.6	17.6	9.7	0.2	58.3	7.6	5.0
Private nonprofit	27.6	1.6	10.3	2.7	63.9	9.7	28.8
State/local government	17.8	0.6	18.3	15.6	74.0	10.8	21.7
1998–2008 change (percentage points)							
Federal government	7.8	0.8	3.1	0.9	7.6	0.5	4.5
Industry	9.5	0.2	0.8	0.5	9.0	3.8	4.6
Academic	9.2	0.6	0.3	0.2	7.5	0.3	1.9
FFRDCs	8.7	5.0	1.1	*	9.8	-0.7	1.6
Private nonprofit	9.7	0.4	2.2	0.5	6.8	1.8	4.5
State/local government	6.9	0.1	4.4	2.1	9.8	2.1	5.5

* = rounds to zero

FFRDC = federally funded research and development center

NOTES: Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered the database, rather than year of publication, and assigned to sector on basis of institutional address(es) listed on article. Articles on whole-count basis, i.e., each collaborating country or sector credited one count. Articles from joint or unknown sectors omitted. Detail may add to more than 100% because articles may have authors from more than two sectors.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board^{TM}; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

64% to 51%, suggesting that much of the use of China's expanding S&E article output—as indicated by citations to those articles—is occurring *within* China.

Trends in Highly Cited S&E Literature

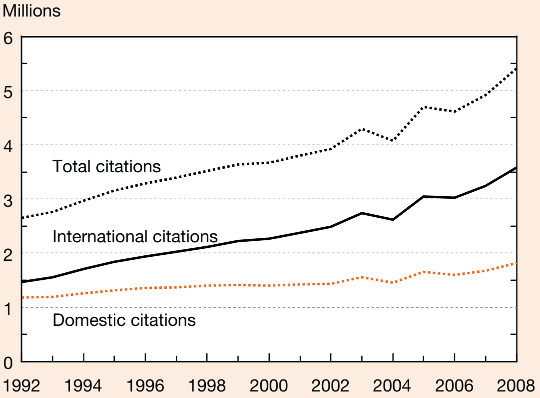
Another indicator of performance of a national or regional S&E system is the share of its articles that are highly cited. High citation rates can indicate that an article has a greater impact on subsequent research than articles with lower citation rates.

Appendix table 5-43 shows citation percentiles for 1998 and 2008 by field for the top five S&E article-producing countries/regions.[50] In that table, a country whose research influence was disproportionate to its output would have higher numbers of articles in higher citation percentiles, whereas a country whose influence was less than its output would suggest would have higher numbers of articles in lower citation percentiles. In other words, a country whose research is highly influential would have higher shares of articles in higher citation percentiles.

This is the case in every field for U.S. articles. In both 1998 and 2008, as displayed in appendix table 5-43, the U.S. share of articles in the 99th percentile was higher than its share in the 95th percentile, and these were higher than its share in the 90th percentile, and so forth, even while U.S. shares of all articles and all citations were decreasing. In 2008, U.S. articles represented 29% of the world total of 2 million articles in the cited period shown; the U.S. authored 52% of the rare 19,500 articles in the 99th percentile and 25% of the 1.2 million articles below the 50th percentile. This broad pattern was unchanged from the 1998 pattern.

Citations to the European Union's S&E articles displayed a different pattern: it had higher percentages of articles in the lower percentiles across all fields of S&E except in the agricultural sciences (appendix table 5-43). Figure 5-24 displays these relationships for all five countries/regions. Only U.S. publications display the preferred relationship of strongly higher proportions of articles in the higher percentiles of article citations; when cited, articles with authors from the European Union, China, Japan, and the Asia-8 are more

Figure 5-23
Total, domestic, and international citations: 1992–2008



NOTES: Citing and cited articles from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication. Citations on fractional-count basis, i.e., for citing and/or cited articles with collaborating institutions from multiple countries, each country receives fractional credit on basis of proportion of its participating institutions. Citation counts based on 3-year period with 2-year lag, e.g., citations for 2008 are references made in articles in 2008 data tape to articles in 2004–06 data tapes.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

often found in the lower citation percentiles. These data are summarized in appendix table 5-44. As the U.S. share of all articles produced declined between 1998 and 2008, its share of articles in the 99th percentile (i.e., the top 1%) of cited articles also declined, particularly in some fields. Shares in the top percentile increased for the European Union, China, Japan, and the Asia-8.

When citation rates are normalized by the share of world articles during the citation period to produce an index of highly cited articles, the influence of U.S. articles is seen to have changed little over the past 10 years. Between 1998 and 2008, the U.S. index of highly cited articles barely changed (from 1.83 to 1.78) (figure 5-25; appendix table 5-44) and remained well above the expected index value of 1. During the same period, the European Union increased its index from 0.73 to 0.89, and China, Japan, and the Asia-8 increased their index values but remained below their expected values. In other words, the United States had 78% more articles than expected in the 99th percentile of cited articles in 2008, and the European Union had 11% fewer than expected. China had 58% fewer articles in the 99th percentile than expected in 2008, and Japan 42% fewer.

The United States experienced notable gains on the index of highly cited articles in engineering and computer sciences (although with relatively low counts in the latter) and a decline in chemistry (appendix table 5-44). The European Union reached its expected value in chemistry, physics, and the agricultural sciences. China achieved an index value of 1 in engineering and mathematics. Japan did not achieve its expected value in any broad field.

Academic Patents, Licenses, Royalties, and Startups

Other indicators of academic R&D outputs reflect universities' efforts to capitalize on their intellectual property in the form of patents and associated activities. The majority

Table 5-22
S&E articles, citations, and international citations, by selected region/country: 1998 and 2008
(Percent)

	Share of world articles		Share of world citations		Share of world/country/economy citations that are international	
Country/region	1998	2008	1998	2008	1998	2008
World	100.0	100.0	100.0	100.0	60.2	66.3
United States	34.0	28.9	46.9	38.3	46.9	51.8
EU	34.6	33.1	32.4	33.2	43.7	49.4
China	1.6	5.9	0.6	4.3	63.6	51.0
Japan	8.5	7.8	6.8	6.3	60.7	68.6
Asia-8	3.6	6.8	1.5	4.6	61.8	65.3

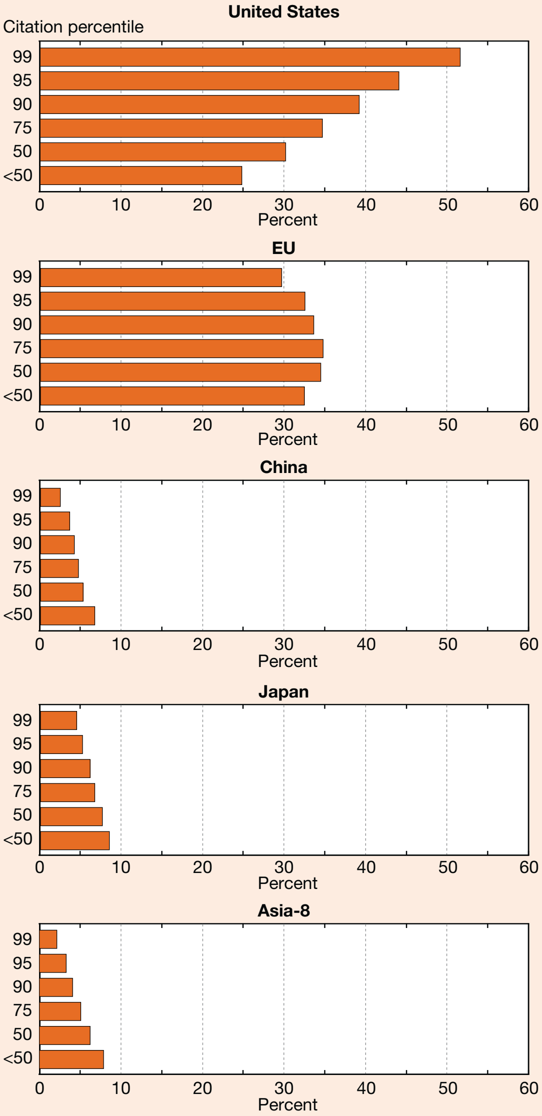
EU = European Union

NOTES: Article/citation counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. See appendix table 5-23 for countries/economies included in EU and Asia-8, which in this table are treated as single countries. Citation counts based on 3-year period with 2-year lag, e.g., citations for 1998 are references made in articles in 1998 data tape to articles in 1994–96 data tapes; data shown are for the 3 years in cited year window.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2010

Figure 5-24
United States, EU, China, Japan, and Asia-8 share of cited papers, by citation percentile: 2008



EU = European Union

NOTES: Article/citation counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. Articles/citations on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. See appendix table 5-23 for countries/economies included in EU and Asia-8. Citation counts based on 3-year period with 2-year lag, e.g., citations for 2008 are references made in articles in 2008 data tape to articles in 2004–06 data tapes. Percentiles approximate because of method of counting citations and always higher than stated.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-43.

Science and Engineering Indicators 2010

of U.S. universities did not become actively involved in the management of their own intellectual property until late in the 20th century, although some were granted patents much earlier.[51] The Bayh-Dole Act of 1980 gave colleges and universities a common legal framework for claiming ownership of income streams from patented discoveries that resulted from their federally funded research. To facilitate the conversion of new knowledge produced in their laboratories to patent-protected public knowledge that can be potentially licensed by others or form the basis for a startup firm, more and more research institutions established technology management/transfer offices (AUTM 2009).

Efforts to encourage links between university-based research and commercial exploitation of the results of that research have been widely studied by researchers. Mowery (2002) notes the strong growth in funding by NIH and the predominance of biomedically related patenting by universities in the 1990s. Branstetter and Ogura (2005) identify a “bio-nexus” in patent-to-paper citations, and Owen-Smith and Powell (2003) explore the effects of an academic medical center as part of the “scientific capacity” of a research university. In a qualitative study of two research universities that would appear to have similar capacities, Owen-Smith and Powell (2001) examine the very different rates of invention disclosure of the two campuses. Stephan and colleagues (2007) found strong differences in patenting activity among university scientists by field of science; a strong relationship between publication activity and patenting by individual researchers; and patenting by university researchers in only a small proportion of the potential population.

The following sections discuss overall trends in university patenting and related indicators through 2007–08.

University Patenting Trends

U.S. Patent and Trademark Office (USPTO) data show that annual patent grants to universities and colleges ranged from 2,950 to 3,700 between 1998 and 2008 (appendix table 5-45). In 2008, just over 3,000 patents were awarded to colleges and universities in the United States.[52] (Data in the next section on invention disclosures and applications suggest that patent grants to academic institutions may increase in the coming years.)

The top 200 R&D-performing institutions, with 96% of the total patents granted to U.S. universities during the 1998–2008 period, dominate among universities and university systems receiving patent protection.[53] College and university patents as a percentage of U.S. nongovernmental patents fell from 5.2% in 1998 to 4.3% in 2008. Among the top R&D-performing institutions that received patents between 1998 and 2008, 19 accounted for more than 50% of all patents granted to these institutions (although these included a few multicampus systems, including the Universities of California and North Carolina).

Between 1998 and 2008, three technology areas dominated U.S. university patenting: chemicals (19%), biotechnology (15%), and pharmaceuticals (14%) (appendix table 5-46). In numbers of patents, all three of these technology areas have declined from previous highs (figure 5-26). The next three highest technology areas over the period were semiconductors and electronics (6%), measurement and control equipment (5%), and computers and peripherals (5%), each accounting for about 200 patents in 2008 (appendix table 5-46).

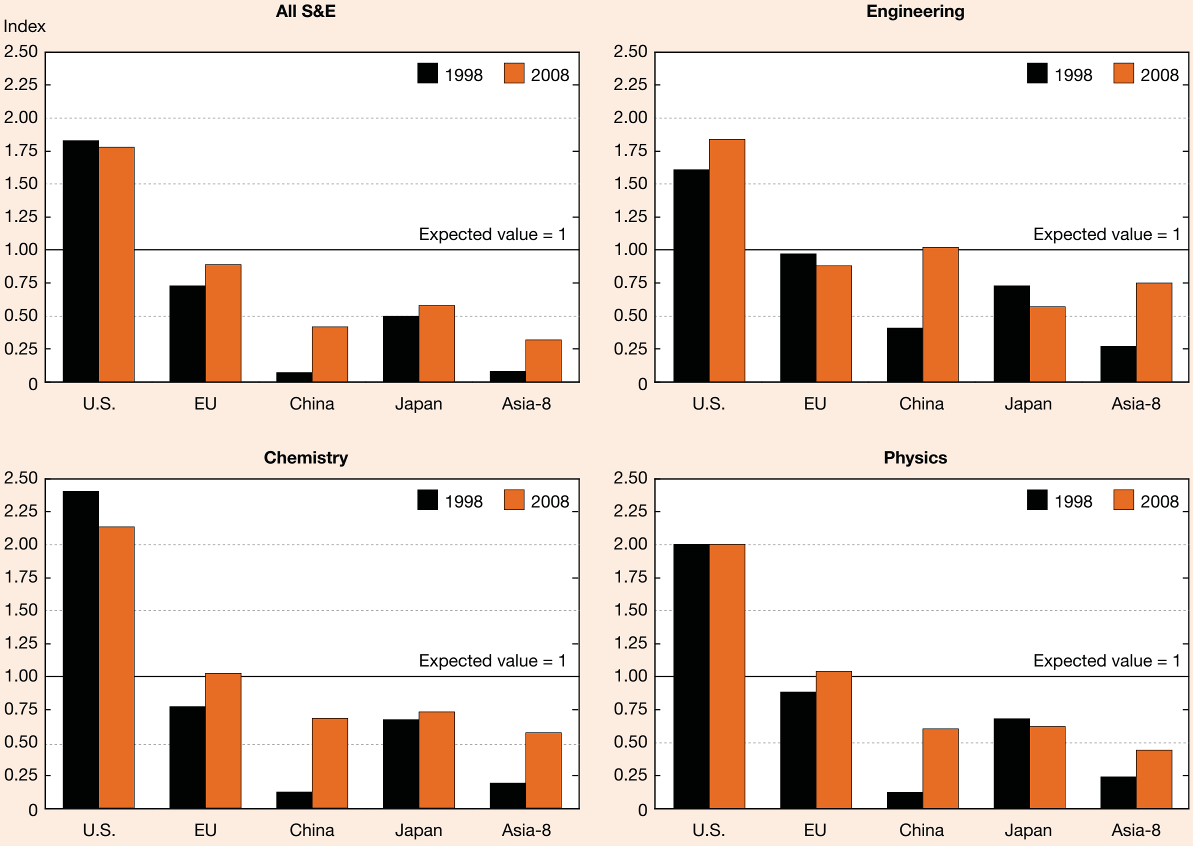
Patent-Related Activities and Income

Data from the Association of University Technology Managers (AUTM) indicate continuing growth in a number of patent-related activities. Invention disclosures filed with university technology management offices describe prospective inventions and are submitted before a patent application is filed. These grew from 13,700 in 2003 to 17,700 in 2007 (notwithstanding a small decline in institutions responding to the AUTM survey over the same period) (appendix table 5-47). Likewise, new U.S. patent applications filed by AUTM respondents also increased, from 7,200 in 2003 to 10,900 in 2007. The AUTM survey respondents reported 348 startup companies formed in 2003 and 510 in 2007. The AUTM 2007 survey also found 3,148 cumulative, operational startup firms associated with U.S. university patenting and licensing activities (AUTM 2009).

Most royalties from licensing agreements accrue to relatively few patents and the universities that hold them, and many of the AUTM respondent offices report negative income. (Thursby and colleagues [2001] note that the objectives of university technology management offices include more than royalty income.) At the same time, large one-time payments to a university can affect the overall trend

Figure 5-25

Index of highly cited articles, by selected field and region/country: 1998 and 2008



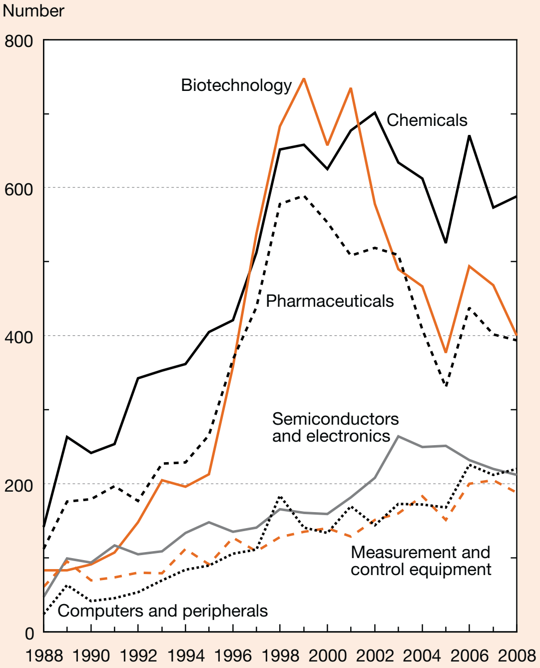
EU = European Union

NOTES: Article/citation counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles/citations classified by year they entered database, rather than year of publication, and assigned to country/economy on basis of institutional address(es) listed on article. See appendix table 5-23 for countries/economies included in EU and Asia-8. Citation counts based on 3-year period with 2-year lag, e.g., citations for 2008 are references made in articles in 2008 data tape to articles in 2004–06 data tapes. Index of highly cited articles is country's share of world's top 1% cited articles divided by its share of world articles for the cited year window.

SOURCES: Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-44.

Science and Engineering Indicators 2010

Figure 5-26
U.S. academic patents, by selected technology area: 1988–2008



NOTES: Data include institutions affiliated with academic institutions, such as university and alumni organizations, foundations, and university associations. The Patent Board™ technology areas constitute an application-oriented classification system that maps the thousands of International Patent Classes (IPCs) at the main group level into 1 of 30 technology areas. If a patent has more than one IPC, only primary IPC is considered in mapping.

SOURCES: The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-46.

Science and Engineering Indicators 2010

in university licensing income. In 2007, the 161 institutions that responded to the AUTM survey reported a total of $1.9 billion in net royalties from their patent holdings (appendix table 5-47).

Between 2003 and 2007, the inventory of revenue-generating licenses and options across all AUTM respondent institutions increased from 9,000 to 12,500 (appendix table 5-47). New licenses and options executed grew over the period from about 3,900 in 2003 to 4,400 in 2007.

Patent-to-Literature Citations

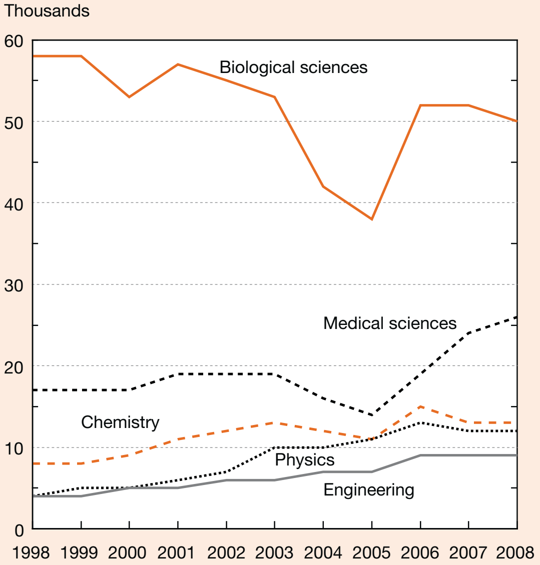
Citations to the S&E literature on the cover pages of issued patents are one indicator of the contribution of research to the development of practical innovation.[54] This indicator of science linkage to practical advance increased sharply in the late 1980's and early 1990's (Narin, Hamilton, and Olivastro 1997), due at least in part to developments in U.S. policy, industry growth and maturation, and court interpretation. At the same time, patenting activity by academic institutions was increasing rapidly, as were patent citations to S&E literature produced across all sectors (NSB 2008, pp. 5-49 to 5-54).

Between 1998 and 2008, growth on this indicator was much slower. Of utility patents awarded to both U.S. and foreign assignees, the number citing S&E articles (11% of total utility patents awarded in 2008) grew 1.4% annually over the 10-year period, compared with 0.7% annually for all utility patents (appendix table 5-48). Much of the growth in S&E citing patents was in patents awarded to non-U.S. assignees: these grew 3.1% annually.

Five broad S&E fields (the biological sciences, the medical sciences, chemistry, physics, and engineering) accounted for 97% of the total citations in these patents (appendix table 5-49 and figure 5-27). Citations to the biological sciences have decreased from their high of 58,000 in 1998 and 1999 but have more recently stabilized at around 50,000 per year. Citations to the medical sciences have increased since 2005 to about 26,000 in 2008.

The data discussed in the previous three paragraphs were heavily influenced by U.S. patents awarded to foreign assignees and references in those patents to non-U.S. S&E articles. Considering only citations to U.S. articles, overall growth in citations has been flat over the past 10 years (appendix table 5-48). Change in citations to articles authored in

Figure 5-27
Citations in U.S. patents to S&E articles, by selected article field: 1998–2008



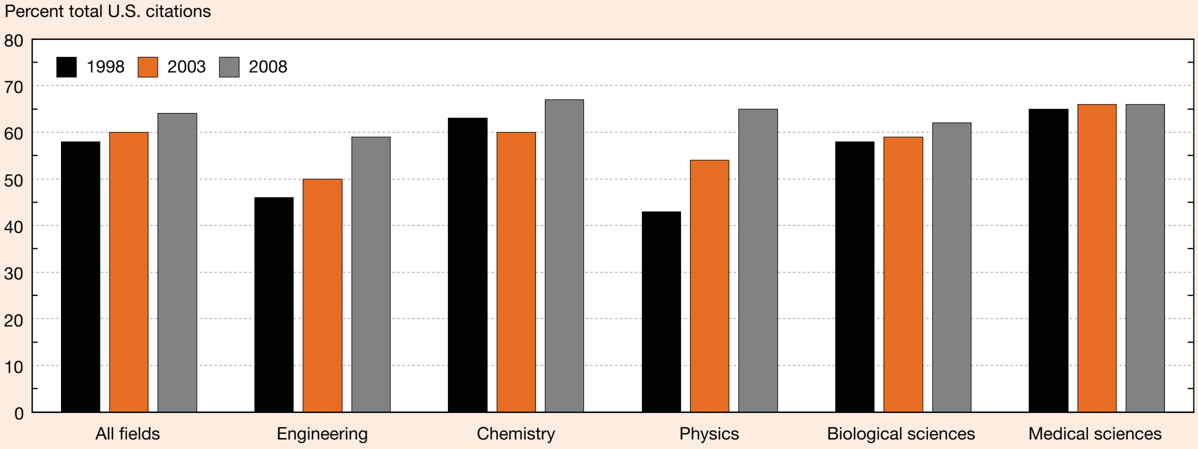
NOTES: Citations are references to S&E articles in journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Citation counts based on a 6-year window with 5-year lag, e.g., citations for 2002 are references in U.S. patents issued in 2002 to articles published in 1992–97.

SOURCES: U.S. Patent and Trademark Office; Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-49.

Science and Engineering Indicators 2010

Figure 5-28

Academic share of U.S. patent citations to U.S. articles, by selected field: 1998, 2003, 2008



NOTES: Citations are references to U.S. S&E articles in journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Citation counts based on a 6-year window with 5-year lag, e.g., citations for 2003 are references in U.S. patents issued in 2003 to articles published in 1993–98.

SOURCES: U.S. Patent and Trademark Office; Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics. See appendix table 5-49.

Science and Engineering Indicators 2010

both the private nonprofit and government sectors has been negative over the period. Growth in citations to academic papers (0.9% annually) and to FFRDC papers (4.6% annually) shows that citations to papers in these two sectors have been replacing declining citations to articles in other sectors. Citations to academic articles account for most of this replacement, despite the slower rate of growth in these citations. Of total citations to U.S. articles in 2008, 64% were to academic articles, compared with 2% to FFRDC articles.

Figure 5-28 summarizes the increasing role of citations to U.S. academic articles in the science linkage to U.S. patents. Across all fields, academic articles made up 58% of total citations to U.S. articles in 1998 and 64% in 2008. Of the five broad fields of S&E that accounted for 97% of all patent citations to U.S. academic articles, increased shares of academic citations were notable in engineering (from 46% to 59%) and physics (from 43% to 65%). These increasing shares of patent citations to U.S. academic S&E articles are parallel to the increasing shares of academic S&E articles as compared with other sectors, as discussed above in the section "Trends in Output and Collaboration Among U.S. Sectors."

Conclusion

U.S. universities and colleges continue to be important performers of U.S. R&D, and particularly basic research. Both the overall academic S&E doctoral workforce and the academic research workforce have continued to increase. Citation data indicate that U.S. scientific publications remain highly influential relative to those of other countries. While the United States continues to produce more S&E articles than any other country, its share of total world articles has declined due to high publication growth rates elsewhere, notably China.

Although funding for academic R&D has been increasing, a number of shifts in funding sources have occurred. After increasing between 2000 and 2004, the federal government's share of funding for academic R&D decreased from 2005 through 2008. In addition, federal funding for academic R&D has either declined in constant dollars or remained flat since 2005. Industry support for academic R&D declined from 2002 to 2004 but rose again through 2008. The state and local government share of support for academic R&D has been generally declining since 1972, and the university share of support for academic R&D has been generally increasing.

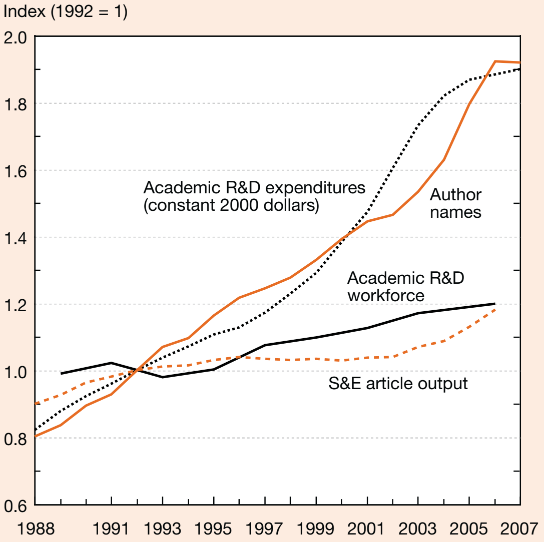
The structure and organization of academic R&D have also changed. (See sidebar "Publications and Resource Inputs.") Research-performing colleges and universities continued to expand their stock of research space, particularly in the biological and medical sciences. The number of academic S&E doctoral researchers has grown over the past couple of decades, with the life sciences accounting for much of the trend. Life scientists accounted for more than a third of academic S&E doctoral researchers in 2006. Increasingly, these researchers are employed in postdoc or other nonfaculty positions. Particularly among life scientists, the number of new doctorate holders has increased greatly while the numbered

Publications and Resource Inputs

The publication of research results in peer-reviewed scientific journals is a key output of scientific research. In the early 1990s, the number of S&E articles published by U.S. academic scientists and engineers in the world's major peer-reviewed journals plateaued while resource inputs—funds and personnel—kept increasing (figure 5-B). With some variations, this trend occurred across different types of institutions and different fields, despite increases in research inputs such as funds and personnel (NSF/SRS 2007).

An examination of relationships among publications, resource inputs, and institutional characteristics in the top 200 academic R&D institutions found that, with the possible exception of S&E faculty and the number of S&E doctoral recipients, inflation-adjusted resources for publications have increased faster than the number of publications. From 1990 to 2001, resource inputs increased per publication, with about 29% more resources consumed per fractional count publication in 2001 than in 1990. This pattern of increasing inputs required to yield the same quantity of publication outputs occurred across the entire U.S. academic system. Possible reasons for the increasing inputs per article include a rise in the complexity of research required for publication; costs for faculty, postdocs, S&E doctoral recipients, and research materials and equipment that are increasing faster than the gross domestic product implicit price deflator; and increased communication costs for collaboration (NSF/SRS 2010, forthcoming). In figure 5-B, the steadily rising number of total author names on articles with at least one academic author is another indicator of the strong growth in research collaboration and article coauthorship noted elsewhere in this chapter.

Figure 5-B
U.S. academic S&E article output, S&E article author names, academic R&D expenditures, and academic R&D workforce: 1988–2007



NOTES: Data for academic workforce available for odd years and 2006; 1992 base year is average of 1991 and 1993 data. Article and author counts are two-year moving average from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Author counts include all authors on any article with one or more U.S. academic institutional addresses.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2007; Survey of Doctorate Recipients, special tabulations; Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/; The Patent Board™; National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-2 and 5-16.

Science and Engineering Indicators 2010

of tenured or tenure-track positions has remained relatively constant since the late 1980s.

Academic R&D is also becoming more international in a number of ways. U.S. academic scientists and engineers are collaborating extensively with colleagues in other countries: In 2008, 29% of journal articles with a U.S. academic author also had at least one coauthor from abroad. The intimate linkage between research and U.S. graduate education, regarded as a model by other countries, helps to bring large numbers of foreign students to the United States, many of whom stay after graduation. Academia has also been able to attract many talented foreign-born scientists and engineers into its workforce, with the percentage of foreign-born full-time doctoral S&E faculty in research institutions approaching half the total in some fields.

Notes

1. See appendix table 5-6 for the fields and subfields included in science and engineering in this section.

2. The academic R&D totals presented here exclude expenditures at federally funded research and development centers (FFRDCs) associated with universities. Those expenditures are tallied separately and are examined in greater detail in chapter 4. FFRDCs and other national laboratories (including federal intramural laboratories) also play an important role in academic research and education, providing research opportunities for both students and faculty at academic institutions and highly specialized shared research facilities.

3. For this discussion, the terms *universities and colleges, higher education*, and *academic institutions* are used interchangeably and include only those schools that grant a

bachelor's or higher degree in science or engineering and spend at least $150,000 for separately budgeted R&D in S&E.

4. For the definitions used in NSF surveys and a fuller discussion of these concepts, see chapter 4 sidebar, "Definitions of R&D."

5. The discussion of federal support for academic R&D includes both obligation data from the funding source (federal agencies) and expenditures data from the performer (universities and colleges).

6. The academic R&D reported here includes separately budgeted R&D and related recovered indirect costs as well as institutional estimates of unrecovered indirect costs associated with externally funded R&D projects, including mandatory and voluntary cost sharing.

7. This funding was required to be obligated by the end of FY 2009; however, the expenditures for these projects will span several years.

8. Performing and funding series may differ for many reasons. For a more detailed discussion of the differences between these two sources, see chapter 4 sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures."

9. Federal grants and contracts and awards from other sources that are passed through state and local governments to academic institutions are credited to the original provider of the funds.

10. This follows a standard of reporting that assigns funds to the entity that determines how they are to be used rather than to the one that necessarily disburses the funds.

11. The medical sciences include fields such as pharmacy, neuroscience, oncology, and pediatrics. The biological sciences include fields such as microbiology, genetics, epidemiology, and pathology. These distinctions may be blurred at times because boundaries between fields often are not well defined.

12. In this section of the chapter and the section "Doctoral Scientists and Engineers in Academia," the broad S&E fields refer to the computer sciences, environmental sciences (sometimes referred to as "earth, atmospheric, and ocean sciences"), life sciences, mathematical sciences, physical sciences, psychology, social sciences, other sciences (those not elsewhere classified), and engineering. The more disaggregated S&E fields are referred to as "subfields." The fourth section of the chapter, "Outputs of S&E Research: Articles and Patents," groups the broad fields and subfields slightly differently (see sidebar "Bibliometric Data and Terminology" and appendix table 5-24).

13. Data reported on non-S&E R&D expenditures are slightly lower-bound estimates for the national totals because NSF did not attempt to estimate for the 2.7% nonresponse rate on this item. Also, only institutions that conducted at least $150,000 of S&E R&D were surveyed. The activities of institutions that do not perform S&E R&D (but may conduct substantial amounts of non-S&E R&D) are not reflected here.

14. Data on non-S&E R&D expenditures have only been collected since FY 2003, and response rates for years prior to 2006 make trend data unreliable.

15. Another hypothesis is that some of the difference may be due to many public universities not having the incentive to negotiate full recovery of indirect costs of research because such funds are frequently returned to the state treasury rather than the institution.

16. Amounts reported as passed through to higher education subrecipients do not precisely equal amounts reported as received by those subrecipients due to differences in timing and in the item response rates for these two survey questions each year.

17. Because of rising capitalization thresholds, the dollar threshold for inclusion in the equipment category has likely changed over time. Generally, university equipment costing less than $5,000 would be classified under the cost category of "supplies."

18. The "bricks and mortar" section of the Survey of Science and Engineering Research Facilities asks institutions to report their research space only. The reported figures therefore do not include space used for other purposes such as instruction or administration. In the cyberinfrastructure section of the survey, however, respondents are asked to identify all of their cyberinfrastructure resources, regardless of whether these resources were used for research or other functions.

19. Research-performing academic institutions are defined as colleges and universities that grant degrees in science or engineering and expend at least $1 million in R&D funds. Each institution's R&D expenditures are determined through the NSF Survey of Research and Development Expenditures at Universities and Colleges.

20. Research space here is defined as the space used for sponsored R&D activities at academic institutions that is separately budgeted and accounted for. Research space is measured in net assignable square feet (NASF), the sum of all areas on all floors of a building assigned to, or available to be assigned to, an occupant for a specific use, such as research or instruction. NASF is measured from the inside faces of walls. Multipurpose space that is at least partially used for research is prorated to reflect the proportion of time and use devoted to research.

21. The S&E fields used in the NSF Survey of Science and Engineering Research Facilities are based on the National Center for Education Statistics (NCES) Classification of Instructional Programs (CIP). NCES updates CIP every 10 years. The S&E fields used in the FY 2007 Survey of Science and Engineering Research Facilities reflect the NCES 2000 CIP update. For a comparison of the subfields in the FY 2005 and FY 2007 surveys, see the S&E Research Facilities: FY 2007 detailed statistical tables.

22. Institutional funds may include operating funds, endowments, tax-exempt bonds and other debt financing, indirect costs recovered from federal grants/contracts, and private donations.

23. The United States is unlike many other countries in the fraction of doctorate holders who are employed in academia. A comparison of 1990–2006 doctorate recipients in 14 countries for which data are available found that in most of these countries, more than half of doctorate holders were employed in academia, compared with 47% for the United States. Only the United States, Austria, and Belgium had substantial fractions employed in the business sector, and the United States had one of the smallest fractions employed in government (OECD 2009).

24. Psychology (also called a behavioral science) is discussed and broken out separately in tables from the social sciences because trends over time and characteristics of doctorate holders in psychology and social sciences differ.

25. The inclusion or exclusion of those on temporary and permanent visas has little impact on the analysis. Data on Pacific Islanders were not collected separately from Asians before 2001. From 1975 to 1999, the Asian category includes Pacific Islanders, but from 2001 to 2006 it does not. In 2006, approximately 200 Pacific Islander doctoral S&E researchers were employed in academia. If combined with Asians, they would constitute less than 1% of the combined category.

26. The Carnegie classification used in that report was the 1994 version.

27. The switch to the American Community Survey as the sampling frame for the National Survey of College Graduates in 2010 and beyond may improve estimates of non-U.S.-trained doctorate holders in future years.

28. Among all S&E doctorate holders employed in academia, this is the case both in fields in which postdocs are prevalent (such as physical sciences and life sciences) and fields in which postdocs are less prevalent (such as computer sciences and mathematics).

29. Interpretation of the data on federal support of academic researchers is complicated by a technical difficulty. Between 1993 and 1997, respondents to the Survey of Doctorate Recipients were asked whether work performed during the week of April 15 was supported by the federal government; in most other survey years, the reference was to the entire preceding year, and in 1985, it was to 1 month. However, the volume of academic research activity is not uniform over the entire academic year. A 1-week (or 1-month) reference period seriously understates the number of researchers supported at some time during an entire year. Thus, the numbers for 1985 and 1993–97 cannot be compared directly with results for the earlier years or with those from the 1999 through 2006 surveys, which again used an entire reference year.

The discussion in this edition of *Indicators* generally compares data for 2006 with data for 1991. All calculations express the proportion of those with federal support relative to the number responding to this question. The reader is cautioned that, given the nature of these data, the trends discussed are broadly suggestive rather than definitive. The reader also is reminded that the trends in the proportion of all academic researchers supported by federal funds occurred against a background of rising overall numbers of academic researchers.

30. Respondents were asked to indicate whether they “Work with an immediate work group or team?”; “Work with others in the same organization (company, university, agency, etc.), but not the same group or team?”; “Work with individuals in other organizations in the U.S.?”; and “Work with individuals located in other countries?”

31. Publication traditions in broad S&E fields differ somewhat. For example, computer scientists often publish their findings in conference proceedings, and social scientists often write books as well as publish in journals. Proceedings and books are poorly covered in the data currently used in this chapter.

32. The U.S. sector identification in this chapter is quite precise; to date, sector identification has not been possible for other countries.

33. European Union data include all member states as of 2007 (see appendix table 5-23 for a list of member countries).

34. The Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Thailand, and Taiwan.

35. For example, Vatican City is not strictly a country; the Union of Soviet Socialist Republics (USSR) and Hong Kong are contained in the data in earlier years, but the USSR no longer exists and Hong Kong data are now reported as part of China. See appendix table 5-23 for a list of the countries represented in the data.

36. Distributions of data in which a small percentage of cases accounts for a significant amount of the total value across all cases belong to a group of statistical distributions collectively referred to as *power law distributions* (Adamic 2000). Other phenomena with such distributions include, e.g., earthquakes (among a large number of earthquakes only a few have great power) and Internet traffic (visits to a relatively small number of sites account for a very large proportion of visits to all sites).

37. For example, Montenegro appeared in the data in 2006 for the first time as an independent country; the tiny Pacific island nation of Niue appeared in 2007 for the first time because a coauthor from that country appeared in the data.

38. See also NSB 2008, table 5-21, for detail on field level ranks and changes in rank since 1995.

39. Coauthorship data are a broad, though limited indicator of collaboration among scientists. Previous editions of *Indicators* discussed possible underlying drivers for increased collaboration, including scientific advantages of knowledge- and instrument-sharing, decreasing costs of travel and communication, national policies, and so forth (NSB 2006). Katz and Martin (1997), Bordons and Gómez (2000), and Laudel (2002) analyze limitations of coauthorship as an indicator of research collaboration. Other researchers have continued using these data (Adams et al. 2005; Gómez, Fernández, and Sebastián 1999; Lundberg et al. 2006; Wuchty, Jones, and Uzzi 2007; Zitt, Bassecoulard, and Okubo 2000).

40. The reader is reminded that the data on which these indicators are based give the nationality of the institutional addresses listed on the article. Authors themselves are not associated with a particular institution and may be of any nationality. Therefore the discussion in this section is based on the nationality of institutions, not authors, and makes no distinction between nationality of institutions and nationality of authors.

41. The coauthorship data discussed in this paragraph are restricted to coauthorship across the regions/countries identified in table 5-17; that is, collaboration between or among countries of the European Union, e.g., is ignored. *Intraregional* coauthorship is discussed in the following sections.

42. Readers are reminded that the *number* of coauthored articles between any pair of countries is the same; each country is counted once per article in these data. However, countries other than the pairs discussed here may also appear on the article.

43. Finland is included here as one of the Scandinavian countries; Iceland is not.

44. Article counts in this section are based on the year in which the article appeared in the database, not on the year of publication, and therefore are not the same counts as in the earlier discussion of total world article output.

45. Identification of the sector of the non-U.S. institution is not possible with the current data set.

46. Readers are reminded that coauthors from different departments in an institution are coded as different institutions.

47. Referring to the declining share of industry's basic research articles in physics, the National Science Board (NSB) noted, "Most of this decline is accounted for by widespread restructuring of a few large corporations during this period, including closure, downsizing, or reorientation of large central research laboratories. Increased globalization, intensified competition, and commercial priorities may have contributed to the decline in publishing by companies and their researchers" (NSB 2008, p 6-36).

48. This chapter uses the convention of a 3-year citation window with a 2-year lag, e.g., 2008 citation rates are from references in articles contained in the tape for 2008 to articles contained in the 2004, 2005, and 2006 tapes of the Thomson Reuters Science Citation Index and Social Sciences Citation Index databases. Analysis of the citation data shows that, in general, the 2-year citing lag captures the 3 peak citation years for most fields, with the following exceptions: in astronomy and physics, the peak citation years are generally captured with a 1-year lag, and in computer sciences, psychology, and the social sciences with a 3-year lag.

49. The reader is reminded that articles in this section are counted by the year they entered the database, not by year of publication. Therefore article counts, and percentages based on them, are different from the data presented earlier in this section.

50. Percentiles are specified percentages below which falls the remainder of the articles, e.g., the 99th percentile identifies the number of citations 99% of the articles failed to receive. For example, across all fields of science, 99% of articles from 2004 to 2006 failed to receive at least 22 citations in 2008. Matching numbers of citations with a citation percentile is not precise because all articles with a specified number of citations must be counted the same. Therefore, the citation percentiles discussed in this section and used in appendix tables 5-43 and 5-44 have all been counted conservatively, and the identified percentile is in every case higher than specified, i.e., the 99th percentile is always greater than 99%, the 95th percentile is always greater than 95%, and so forth. Actual citations/percentiles per field vary widely because counts were cut off to remain in the identified percentile. For example, using this method of counting, the 75th percentile for engineering contained articles with three to four citations in 2004 through 2006, whereas the 75th percentile for the biological sciences contained articles with five to eight citations.

51. For an overview of these developments in the 20th century, see Mowery (2002).

52. It is unclear whether the recent downturn in patents granted to universities/colleges is a result of changes in USPTO processing. For example, in its Performance and Accountability Report Fiscal Year 2008, USPTO reported an increase in average processing time ("patent average total pendency") from 29.1 months in 2005 to 32.2 months in 2008 (USPTO 2008).

53. The institutions listed in appendix table 5-45 are slightly different from those listed in past volumes, and data for individual institutions may be different. In appendix table 5-46, an institution is credited with a patent even if it is not the first assignee, and therefore, some patents may be double counted. Several university systems are counted as one institution, and medical schools may be counted with their home institution. Universities also vary in how they assign patents, e.g., to boards of regents, individual campuses, or entities with or without affiliation with the university.

54. Patent-based data must be interpreted with caution. Year-to-year changes in the data may reflect changes in USPTO processing times (so-called patent pendency rates). Likewise, industries and companies have different tactics and strategies for pursuing patents, and these may also change over time.

Patent citations to S&E research discussed in this section are limited to the citations found on the cover pages of successful patent applications. These citations are entered by the patent examiner, and may or may not reflect citations given by the applicant in the body of the application. Patent cover pages also contain references to scientific and technical materials not contained in the article data used in this chapter, e.g., other patents, conference proceedings, industry standards, etc. Analyses of the data referred to in this section found that nonjournal references on patent cover pages accounted for 19% of total references in 2008. The journals/articles in the SCI/SSCI database used in this chapter—a set of relatively high-impact journals—accounted for 83% of the journal references, or 67% of the total science references, on the patent covers.

Glossary

Academic doctoral S&E workforce: Includes those with a U.S. doctorate in an S&E field employed in 2- or 4-year colleges or universities in the following positions: full and associate professors (referred to as *senior faculty*); assistant professors and instructors (referred to as *junior faculty*); postdocs; other full-time positions such as lecturers, adjunct faculty, research associates, and administrators; and part-time positions of all kinds.

Academic institution: In the "Financial Resources for Academic R&D" section of this chapter, an academic institution is generally defined as an institution that grants a bachelors' or higher degree in science or engineering and that has spent at least $150,000 for separately budgeted R&D in S&E within the fiscal year being measured. Elsewhere in the chapter, this term encompasses any accredited institution of higher education.

Underrepresented minority: Demographic category including blacks, Hispanics, and American Indians/Alaska Natives, groups considered to be underrepresented in academic institutions.

References

Adamic L. 2000. Zipf, Power-laws, and Pareto—A Ranking Tutorial. Palo Alto: Information Dynamics Lab, HP Labs. http://www.hpl.hp.com/research/idl/papers/ranking/ranking.html. Accessed 19 June 2009.

Adams J, Black G, Clemmons R, Stephan P. 2005. Scientific teams and institutional collaborations: Evidence from U.S. universities, 1981–1999. *Research Policy* 34:259–85.

Association of American Universities. 2006. University Research: Understanding its Role. http://www.aau.edu/research/university_research.aspx?id=6896. Accessed 4 February 2009.

Association of University Technology Managers (AUTM). 2009. *AUTM Licensing Activity Survey Full Report, FY 2007.* Tieckelmann R, Kordal R, Flanigan S, Glavicic-Théberge T, Bostrom D, editors. http://www.autm.net/ AM/Template.cfm?Section=Licensing_Surveys_AUTM. Accessed 18 May 2009.

Benderly B. 2004. The incredible shrinking tenure track. *Science Career Magazine.* Washington, DC: American Association for the Advancement of Science. http://sciencecareers.sciencemag.org/career_development/previous_issues/articles/3150/the_incredible_shrinking_tenure_track. Accessed 19 June 2009.

Bordons M, Gómez I. 2000. Collaboration networks in science. In: Cronin B, Atkins HB, editors. *The Web of Knowledge: A Festschrift in Honor of Eugene Garfield.* Medford, NJ: Information Today, Inc. p 197–213.

Brainard J, Borrego A. 2003. Academic pork barrel tops $2-billion for the first time. *The Chronicle of Higher Education* 50(5):A18. http://chronicle.com/weekly/v50/i05/05a01801.htm. Accessed February 2009.

Brainard J, and Hermes JJ. 2008. College's earmarks grow, amid criticism. *The Chronicle of Higher Education* 54(29):A1. http://chronicle.com/free/v54/i29/29a00101.htm. Accessed February 2009.

Branstetter L, Ogura Y. 2005. Is academic science driving a surge in industrial innovation? Evidence from patent citations. National Bureau of Economic Research working paper 11561. http://www.nber.org/papers/w11561. Accessed 27 June 2009.

Check E. 2007. More biologists but tenure stays static. *Nature* (448):848–49. http://www.nature.com/nature/journal/v448/n7156/full/448848a.html. Accessed 21 June 2009.

Committee on Science, Engineering, and Public Policy (COSEPUP). 2007. *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering.* Washington, DC: National Academies Press.

Fox MF. 2005. Gender, family characteristics, and publication productivity among scientists. *Social Studies of Science* 35(February):131–50.

Garrison HH, McGuire K. 2008. Education and employment of biological and medical scientists: Data from national surveys (updated November 2008). Bethesda, MD: Federation of American Societies for Experimental Biology. http://opa.faseb.org/pages/PolicyIssues/training_datappt.htm. Accessed 19 June 2009.

Ginther D. 2001. Does science discriminate against women? Evidence from academia, 1973–97. Federal Reserve Bank of Atlanta working paper 2001-02. http://www.frbatlanta.org/invoke.cfm?objectid=83FD23CB-9AF0-11D5-898400508BB89A83&method=display. Accessed 19 June 2009.

Glänzel W. 2001. National characteristics in international scientific co-authorship relations. *Scientometrics* 51(1):69–115.

Glänzel W, Schubert A. 2004. Analyzing scientific networks through co-authorship. In: Moed HFM, Glänzel W, Schmoch U, editors. *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies on S&T Systems.* Dordrecht, The Netherlands: Kluwer Academic Publishers. p 257–76.

Glänzel W, Schubert A. 2005. Domesticity and internationality in co-authorship, references and citations. *Scientometrics* 65(3):323–42.

Gómez I, Fernández MT, Sebastián J. 1999. Analysis of the structure of international scientific cooperation networks through bibliometric indicators. *Scientometrics* 44(3):441–57.

Hosek SD, Cox AG, Ghosh-Dastidar B, Kofner A, Ramphal N, Scott J, Berry SH. 2005. Gender differences in major federal external grant programs. Santa Monica, CA: RAND. http://www.rand.org/pubs/technical_reports/2005/RAND_TR307.pdf. Accessed 19 June 2009.

Katz J, Martin B. 1997. What is research collaboration? *Research Policy* 26:1–18.

Laudel G. 2002. Collaboration and reward. What do we measure by co-authorships? *Research Evaluation* 11(1):3–15.

Long JS, editor; Panel for the Study of Gender Differences in Career Outcomes of Science and Engineering Ph.D.s; Committee on Women in Science and Engineering; National Research Council. 2001. *From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers.* Washington, DC: National Academies Press.

Lundberg J, Tomson G, Lundkvist I, Skår J, Brommels M. 2006. Collaboration uncovered: Exploring the adequacy of measuring university-industry collaboration through co-authorship and funding. *Scientometrics* 69(3):575–89.

Merton RK. 1973. *The Sociology of Science: Theoretical and Empirical Investigations.* Storer NW, editor. Chicago: University of Chicago Press.

Mowery D. 2002. The changing role of universities in the 21st century U.S. R&D system. In: Teich A, Nelson D, Lita S, editors. *AAAS Science and Technology Policy Yearbook 2002.* Washington, DC: American Association for the Advancement of Science. p 253–71.

Narin F, Stevens K, Whitlow E. 1991. Scientific co-operation in Europe and the citation of multinationally authored papers. *Scientometrics* 21(3):313–23.

Narin F, Hamilton K, Olivastro D. 1997. The increasing linkage between U.S. technology and public science. *Research Policy* 26:317–30.

National Research Council (NRC). 2005. *Bridges to Independence: Fostering the Independence of New Investigators in Biomedical Research.* Washington, DC: National Academies Press.

National Research Council (NRC). 2009. *Gender Differences at Critical Transitions in the Careers of Science, Engineering and Mathematics Faculty.* Washington, DC: National Academies Press.

National Science Board (NSB). 2006. *Science and Engineering Indicators 2006.* Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A).

National Science Board (NSB). 2008. *Science and Engineering Indicators 2008.* Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 08-01; volume 2, NSB 08-01A).

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2004. Gender differences in the careers of academic scientists and engineers. NSF 04-323. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2006. Academic institutions of minority faculty with S&E doctorates. NSF 06-318. Joan Burrelli. Arlington VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2007. Changing U.S. output of scientific articles: 1988–2003. NSF 07-320. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2008. Thirty-three years of women in S&E faculty positions. NSF 08-308, Joan Burrelli. Arlington, VA.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009a. Federally funded R&D centers. Master government list. http://www.nsf.gov/statistics/ffrdc. Accessed 14 August 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2009b. *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2009.* NSF 09-305. Arlington, VA. http://www.nsf.gov/statistics/wmpd/. Accessed 19 June 2009.

National Science Foundation, Division of Science Resources Statistics (NSF/SRS). 2010. U.S. academic scientific publishing. Arlington, VA. Forthcoming.

Organisation for Economic Co-operation and Development (OECD). 2009. 1990–2006 Earned doctorates: Where and how are they used? Results of the First Data Collection on Careers of Doctorate Holders. Paris. Forthcoming.

Owen-Smith J, Powell W. 2001. To patent or not: Faculty decisions and institutional success at technology transfer. *Journal of Technology Transfer* 26:99–114.

Owen-Smith J, Powell W. 2003. The expanding role of university patenting in the life sciences: Assessing the importance of experience and connectivity. *Research Policy* 32:1695–1711.

Rosser S, Daniels JZ, Wu L. 2006. Institutional factors contributing to the dearth of women stem faculty: Classification and status matter; location doesn't. *Journal of Women and Minorities in Science and Engineering* 12(1):79–93.

Schubert A, Glänzel W. 2006. Cross-national preference in co-authorship, references and citations. *Scientometrics* 69(2):409–28.

Stephan P, Gurmu S, Sumell A, Black G. 2007. Who's patenting in the university? Evidence from the survey of earned doctorates. *Economics of Innovation and New Technology* 16(2):71–99.

Thursby J, Jensen R, Thursby M. 2001. Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities. *Journal of Technology Transfer* 26:59–72.

United Nations Conference on Trade and Development (UNCTAD). 2005. *Science, Technology and Innovation Policy Review. The Islamic Republic of Iran*. http://stdev.unctad.org/docs/iranstip.doc. Accessed 22 May 2009.

U.S. Patent and Trademark Office (USPTO). 2008. Performance and Accountability Report Fiscal Year 2008. http://www.uspto.gov/web/offices/com/annual/2008/index.html. Accessed 19 June 2009.

Wagner C, Roessner JD, Bobb K. 2009. SRS Task Order 45: Indicators of Interdisciplinary S&E Research. Final Report. Unpublished report to National Science Foundation.

Wagner C, Roessner JD, Bobb K, Klein J, Boyack K, Keyton J, Rafols I, Börner K. 2009. Evaluating the Output of Interdisciplinary Scientific Research: A Review of the Literature. Unpublished report to National Science Foundation.

Wuchty S, Jones B, Uzzi B. 2007. The increasing dominance of teams in production of knowledge. *Science* 316:1036–39.

Zitt M, Bassecoulard E, Okubo Y. 2000. Shadows of the past in international collaboration: Collaboration profiles of the top five producers of science. *Scientometrics* 47(3):627–57.

Chapter 6
Industry, Technology, and the Global Marketplace

List of Sidebars

List of Tables

List of Figures

Highlights

Knowledge- and Technology-Intensive Industries in the World Economy

The U.S. economy had the highest concentration among major economies of knowledge- and technology-intensive (KTI) industries, a key part of the global economy.

- ♦ KTI industries, including knowledge-intensive (KI) service and high-technology (HT) manufacturing industries, have become a major part of the global economy, providing almost 30% of global economic output in 2007.
- ♦ The U.S. economy had the highest concentration of KTI industries among major economies. These industries accounted for 38% of U.S. gross national product (GDP) in 2007. China's KTI industries created 23% of GDP in 2007, up from 21% in 1992.
- ♦ Labor productivity growth has been higher in China and the Asia-9 than in the developed economies. (The Asia-9 includes India, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.) Despite China's 8% annual growth over the past 15 years and 4% growth in the countries and economies of the Asia-9, their absolute productivity levels remain far below those of their developed counterparts.
- ♦ U.S. per capita income in 2007 was about 25% higher than that of Japan and 40% higher than the European Union (EU) average. The per capita income of China and the Asia-9 has grown far faster than that of the three developed economies—the United States, the EU, and Japan.

Trends in Knowledge- and Technology-Intensive Industries

The United States is the largest producer of privately provided KTI service and manufacturing industries.

- ♦ KTI industries contributed $15.7 trillion to the world economy: $5.0 trillion in largely location-bound education and health services, $9.5 trillion in tradable services, and $1.2 trillion in HT manufacturing.
- ♦ The United States is the largest provider of commercial KI service industries (business, financial, and communications). The U.S. world share edged up from 32% in 1995 to 34% in 2007.
- ♦ China's share of global commercial KI service industries rose from 2% in 1995 to 5% in 2007, led by nearly 20% average annual growth of its communications industry. India's communications industry also grew rapidly.
- ♦ In HT manufacturing industries, 90% of global value added was accounted for by the United States (30%), the EU (25%), China (14%), and Japan and the Asia-9 (about 10% each).
- ♦ China's share of HT manufacturing industries more than quadrupled, rising from 3% in 1997 to 14% in 2007, surpassing the Asia-9 in 2006 and Japan in 2007.

Information and Communications Services and Manufacturing

The United States is the largest provider of information and communications technology (ICT) service and manufacturing industries.

- ♦ The United States and the EU are the largest producers of ICT service and manufacturing industries (27% share each of global value added).
- ♦ China's share of ICT global value added rose sharply from 4% to 12% between 1995 and 2007. Japan's share declined steeply from 22% to 9% over the decade.

U.S. and Global Trade in Knowledge- and Technology-Intensive Goods and Services

The United States lost market share in global HT exports, whereas China became the largest single country exporting HT goods.

- ♦ The U.S. share of global HT exports declined from 21% in 1995 to 14% in 2008, largely because of a fall in ICT goods exports.
- ♦ China's share of global HT goods exports more than tripled, from 6% in 1995 to 20% in 2008, making it the single largest exporting country for HT products.
- ♦ The U.S. trade balance of HT products shifted from surplus to deficit, starting in the late 1990s. In 2000, the deficit was $32 billion in current dollars; in 2008, the deficit widened to $80 billion. The deficit in ICT goods alone was almost $120 billion in 2008.
- ♦ China's trade position in HT products moved from balance to surplus, starting in 2001, and rapidly increased from less than $13 billion in 2003 to almost $130 billion in 2008, driven by trade in ICT goods. The Asia-9's trade surplus also increased over the past decade from less than $50 billion to more than $220 billion, an increase entirely due to an expansion of its surplus in information technology (IT) goods.
- ♦ China's rise as the world's major assembler and exporter of many electronic goods is reflected by a sharp increase in China's share of imports of ICT goods from the United States, the European Union, and Japan.
- ♦ Trade data indicate that assembly of ICT goods has shifted to China and that the Asia-9 has become a major supplier of components and inputs. Its share of China's ICT imports jumped from 40% to 70% in a decade; China's share of the Asia-9's exports nearly quadrupled,

intra-Asia trade is up, and Japan's export data also show a pronounced shift toward China.

U.S. Trade Positions

The United States has maintained a surplus in trade of commercial KI services, but its surplus in advanced technology products turned into a deficit earlier in this decade.

- U.S. trade in commercial KI service industries has been in surplus for the past decade and grew from $21 billion in 1997 to $47 billion in 2007.
- U.S. trade in advanced technology products generated an initial deficit in 2002 that widened to $56 billion by 2008. The deficit in the manufacturing component of ICT alone reached more than $100 billion, with smaller deficits in the life sciences and optoelectronics. Aerospace and electronics generated surpluses of $55 billion and $25 billion, respectively.
- The largest U.S. trade deficit in advanced technology products was $66 billion with China, its largest trading partner country, followed by $19 billion with the Asia-9 and $8 billion with Japan. ICT deficits were higher: $75 billion with China, $44 billion with the Asia-9, and $9 billion with Japan.
- The United States had a $7-billion surplus with the EU in 2008; aerospace, the life sciences, and ICT manufacturing constituted the largest share of advanced technologies trade with this region.

Foreign Direct Investment

U.S. overseas investment in KTI industries was more than $900 billion, and direct investment in the United States in these industries was almost $600 billion.

- U.S. overseas investment in commercial KI service industries stood at $834 billion and HT manufacturing industries at $121 billion by 2008.
- Financial services had the largest share of commercial KI service industries by far (76%), followed by business services (22%) and communications (2%). Among HT manufacturing industries, communications and semiconductors (44%) and pharmaceuticals (30%) had the largest shares.
- Direct investments in the United States in commercial KI service industries stood at $390 billion in 2008; direct investment in U.S. HT manufacturing industries stood at $187 billion.
- Financial services had the largest share (64%) of foreign direct investment in commercial KI service industries, followed by business services (23%) and communications (13%). Among HT manufactures, the largest shares were in pharmaceuticals and in communications and semiconductors.

Trade in Intangible Assets

The United States runs a surplus with the rest of the world in trade of intangible assets, including patent licensing fees and use of trade secrets.

- Investment and trade in intangible assets such as copyrights, trademarks, and patents is sizeable. In 2007, the United States had a surplus of nearly $60 billion in trade of intangible assets, which has grown steadily over the past two decades.
- An important component of the surplus in U.S. intangible assets is generated by industrial processes ($19 billion), which include licensing fees for patents and use of trade secrets. U.S. exports in this category were $37 billion in 2007.
- The EU is the United States' largest trading partner for industrial processes (nearly 50% share), followed by Japan (19%). More than half of the U.S. surplus is with the EU ($10 billion), and it has smaller surpluses with the Asia-9, China, and Latin America. The U.S. has a deficit of $3 billion with Japan.

Patents

The United States, the EU, and Japan have similar shares of economically valuable patents, accounting for a combined 90% share of the total.

- Inventions for which patent protection is sought in three of the world's largest markets—the United States, the EU, and Japan—are presumed to be of higher-than-average value. The United States, the EU, and Japan have similar shares of high-value patents, accounting for nearly 90% of the total. The Asia-9's share increased from 1% in 1997 to 6% in 2006, accounted for almost entirely by South Korea.
- The United States is the leading source of U.S. Patent and Trademark Office (USPTO) patent applications; however, foreign-based inventors, attracted by the size and openness of the U.S. market, have traditionally provided almost half of these applications.
- In 2008 the U.S. share of patent applications declined to 51%, with gains for second- and third-ranked Japan and the EU. The Asia-9's share in 2008 was flat at 10% compared to 2007, but double its level of a decade ago, driven by growth in applications from South Korea and Taiwan. India's and China's patent applications grew but remained modest, with India's share below and China's share barely above 1%. Trends are similar in patents granted.

Angel and Venture Capital Funding in the United States

Investment in angel and venture capital, an important source of financing for HT small businesses, fell in 2008 after several years of increases.

- Angel investors provided \$19 billion in financing in 2008, compared with \$26 billion in 2007—the first decline since 2002. Health services received the largest share of investment (16%), followed by software (13%), retail (12%), and biotechnology (11%).
- U.S. venture capitalists invested \$28.1 billion in 2008—an 8% decline, compared with the level in 2007. Computer software had the largest share of investment from 2007 to 2008 (18%), followed by biotechnology (16%) and industrial/energy (13%), possibly reflecting opportunities in green and renewable energy.

Introduction

Chapter Overview

Economists increasingly emphasize the central role of knowledge, particularly R&D and other activities to promote science and technology, in a country's economic success. Information and communications technology (ICT), for example, is widely regarded as a transformative technology that has altered lifestyles and the way business is conducted across a wide range of sectors.

This chapter examines some of the downstream effects of R&D on the United States and the global marketplace. One key area is the creation of knowledge- and technology-intensive (KTI) industries and the diffusion and application of new technologies throughout other industries. Technology-intensive manufacturing and knowledge-intensive service industries have become an important and growing part of the United States' and other economies.

The globalization of the world economy and the vigorous pursuit of national innovation policies by developing countries have led to the rise of new centers of high-technology manufacturing and knowledge-intensive service industries. The United States continues to be a world leader in both, but Asian and other developing countries have become major producers and exporters and are building up their indigenous capability. The rise of these new centers of activity and the increasing fragmentation of production across borders and firms have stimulated foreign investment and trade.

Innovation is closely associated with technologically led economic growth, and observers regard it as important for advancing living standards. The measurement of innovation is an emerging field, and current data and indicators are limited. However, activities related to the commercialization of inventions and new technologies are regarded as important components of innovation indicators. Such activities include patenting, the creation and financing of new high-technology firms, and investment in intangible goods and services.

Chapter Organization

This chapter is organized into four sections. The first section discusses the increasingly prominent role of KTI industries in regional/national economies around the world. The focus is on the United States, the European Union (EU), Japan, China, and a set of emerging Asian countries/economies (the Asia-9).[1] The time span starts in the early 1990s, roughly from the end of the Cold War, to the present.

The second section describes the global spread of KTI industries and analyzes regional and national shares of worldwide production. It discusses shares for the KTI industry groups as a whole and for particular services and manufacturing industries within them. Because technology is increasingly essential for non-high-technology industries, some data on the latter are presented as well.

The third section examines indicators of increased interconnection of KTI industries in the global economy. Data on patterns and trends in global trade in KTI industries make up the bulk of this section. It presents bilateral trade data to provide a rough indication of the internationalization of the supply chains of high-technology manufacturing industries, with a special focus on the Asian region. The section also presents data on U.S. trade in advanced technology products, examining trends in U.S. trade with major economies and in key technologies. Domestic and foreign production and employment of U.S. multinationals in KTI industries are presented as indicators of the increasing involvement of these economically important firms in cross-border activities. To further illustrate the effects of globalization on the United States, the section presents data on U.S. and foreign direct investment abroad, showing trends by region and by KTI industries.

The last section presents innovation indicators and examines U.S. trade in intangible goods. It next examines patterns in country shares of high-value patents. A discussion of U.S. high-technology small businesses includes data on the number of high-technology small business startups and existing firms, employment, and venture and angel capital investment by industry. The last section also presents World Bank indicators of the knowledge capability of the United States and other major economies, which may have bearing on their current ability and future capacity to innovate.

Data Sources, Definitions, and Methodology

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The sidebar, "Comparison of Data Classification Systems Used," shows the classification systems used in this chapter in tabular format.

Knowledge- and Technology-Intensive Industries in the World Economy

Science and technology are widely regarded as important for the growth and competitiveness of all industries and for national economic growth. The Organisation for Economic Co-operation and Development (OECD 2001 and 2007) has identified 10 categories of service and manufacturing industries—collectively referred to as *KTI industries*—that have a particularly strong link to science and technology.[2] Although a number of other taxonomies exist, they do not allow examination of worldwide production and trade data.

♦ Five knowledge-intensive service industries incorporate high technologies either in their services or in the delivery of their services. They include financial, business, and communications services (including computer software development and R&D), which are generally commercially traded. They also include education and health services, which are primarily government provided and location bound.

♦ The five high-technology manufacturing industries include aerospace, pharmaceuticals, computers and office

Comparison of Data Classification Systems Used

System	Type of data	Basis	Coverage	Data source	Data preparation
High-technology manufacturing industries	Production and value added	Industry by International Standard Industrial Classification	Aerospace, pharmaceuticals, office and computing equipment, communications equipment, scientific instruments	United Nations Commodity Trade Statistics and IHS Global Insight	IHS Global Insight, proprietary special tabulations
Knowledge-intensive service industries	Industry production (revenues from services), in current dollars	Industry by International Standard Industrial Classification	Business, financial, communications, health, and education services	United Nations Commodity Trade Statistics and IHS Global Insight	IHS Global Insight, proprietary special tabulations
Trade in high-technology products	Product exports and imports, in current dollars	Product by technology area, harmonized code, country of origin and destination	Aerospace, pharmaceuticals, office and computing equipment, communications equipment and scientific instruments	United Nations Commodity Trade Statistics and IHS Global Insight	IHS Global Insight, proprietary special tabulations
U.S. trade in advanced technology products	U.S. product exports and imports, in current dollars	Product by technology area, harmonized code, country of origin and destination	Biotechnology, life sciences, optoelectronics, information and communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons, nuclear technology, software	U.S. Census Bureau, Foreign Trade Division	U.S. Census Bureau, Foreign Trade Division, special tabulations
U.S. trade in commercial knowledge-intensive services	U.S. exports and imports, in current dollars	Type of service, country of origin	Business, financial, and communications services	U.S. Bureau of Economic Analysis	U.S. Bureau of Economic Analysis
Globalization of U.S. multinationals	Value added and direct investment position, in current dollars	North American Industry Classification, in country of origin and destination	Business, financial, and communications services, aerospace, pharmaceuticals, office and computing equipment, communications equipment, scientific instruments manufacturing	U.S. Bureau of Economic Analysis	U.S. Bureau of Economic Analysis
U.S. trade in intangibles	U.S. receipts and payments, in current dollars	Type of intangibles and industrial processes	Total intangibles and industrial processes	U.S. Bureau of Economic Analysis	U.S. Bureau of Economic Analysis
Patents	Number of patents for inventions, triadic patents (invention with patent granted or applied for in U.S., European, and Japanese patent offices)	Technology class, country of origin	More than 400 U.S. patent classes, inventions classified according to technology disclosed in application	U.S. Patent and Trademark Office (USPTO) and Organisation for Economic Co-operation and Development (OECD)	USPTO, The Patent Board, and OECD
Angel capital	Funds invested by U.S. angel investors	Technology	Biotechnology, electronics, financial services, health care, industrial/energy, information technology, media, telecommunications	Center for Venture Research, University of New Hampshire	Center for Venture Research, University of New Hampshire
Venture capital	Funds invested by U.S. venture capital funds	Technology area defined by data provider	Biotechnology, communications, computer hardware, consumer related, industrial/energy, medical/health, semiconductors, computer software, Internet specific	National Venture Capital Association	Thomson Financial Services, special tabulations

machinery, communications equipment, and scientific (medical, precision, and optical) instruments.[3] These industries spend a high proportion of their revenues on R&D, and their products contain or embody technologies developed from R&D. Aerospace comparisons will reflect, in part, government funding for military aircraft, missiles, and spacecraft and differences in national commercial and civilian flight regulations. Global comparisons of pharmaceuticals gross domestic product (GDP) shares or market revenues may be influenced by differing national regulations covering foreign pharmaceuticals.

- Information and communications technology (ICT) is a subset of KTI industries. It consists of two high-technology manufacturing industries—(1) computers and office machinery and (2) communications equipment and semiconductors—and two knowledge-intensive service industries—(1) communications and (2) computer services—that are classified under business services. ICT is used in a wide variety of economic sectors and is considered an important driver of economic growth.

The OECD classification of knowledge-intensive service and high-technology manufacturing industries is an imprecise measure for a number of reasons. For example, high-technology manufacturing and knowledge-intensive service industries may produce non-high-technology products or non-knowledge-intensive services, and technologically advanced manufacturing industries are excluded if they do not spend a high proportion of their revenues on R&D.

This section examines the prominence of KTI industries in the global economy. The value added of these industries as a share of GDP is presented as an indicator of their relative importance in the major and world economies (see sidebar, "Industry Data and Terminology," for a discussion of value added and other measures). Selected data are presented on the economic wealth and productivity growth of these economies, with particular focus on the United States and other economies that are knowledge and technology intensive.

KTI industries have become a major part of the global economy. Value added of these industries was almost $16 trillion in 2007, representing 29% of world GDP compared with a 26% share 15 years ago (figure 6-1; appendix tables

Industry Data and Terminology

The industry production and trade data used in this chapter come from a proprietary data set developed by IHS Global Insight that covers a consistent set of industries across 70 countries. IHS Global Insight's data set uses data from the United Nations, the Organisation for Economic Co-operation and Development, and other sources, combined with IHS Global Insight's proprietary forecasting and estimation for missing data in some developing countries.

Two measures of industry activity are used in this chapter: *value added* and *exports and imports*. Value added and exports and imports are expressed in current (not adjusted for inflation) dollars. These measures are not compatible with past editions of this chapter, which expressed value added and exports and imports in constant (adjusted for inflation) dollars.

Value added, a measure of industry production, is the amount contributed by the country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Value added is credited to regions or countries on the basis of where the company reported the activity. This is likely to be an imperfect measure because globalization and fragmentation of production may mean that the activity occurred in a different region or country than was reported by the company. In addition, companies have different reporting and accounting conventions for crediting and allocating production performed by their subsidiaries or companies in foreign countries.

Value added of a company's activity is assigned to a single manufacturing or service industry on the basis of the largest share of the company's shipment of goods or delivery of services. This method of categorizing company activity is imperfect because an industry classified as manufacturing may include services, and a company classified as being within a service industry may include manufacturing or directly serve a manufacturing company. Furthermore, the single-industry classification is not a good measure for companies that have diversified activities in many categories of industry.

Exports and imports are valued as the sum (gross) of value added contributed by all countries, firms, or other entities involved in production. This measure is not compatible with the value-added measure of industry production. Exports and imports are credited to the country where the product was "substantially transformed" into final form. This is an imperfect measure for exports produced in multiple countries because the assigned country may not be the same location where the most value added took place.

Exports and imports are assigned to a single product category by the exporter or customs agent on the basis of the primary content of the good. This method is imperfect because the product may contain other products. The trade product classification is not directly compatible with the industry classification of company production. For example, exports classified as semiconductor products may have originated from a company classified as being in the computer industry.

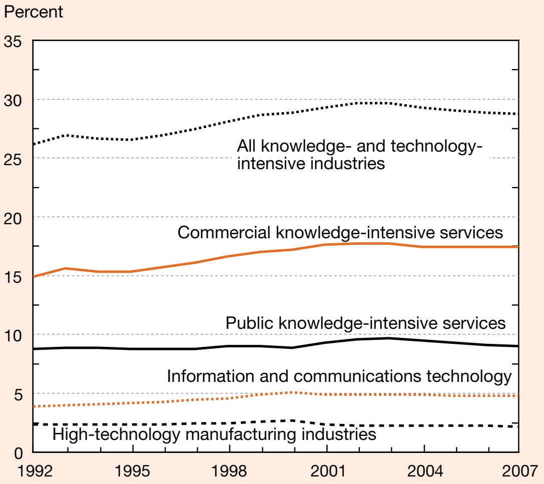
6-1 and 6-2). The share increased during the past decade before leveling off in 2002. The increase in the worldwide share of KTI industries was concentrated in five regional/national economies, which conduct nearly 90% of global R&D—the United States, the EU, Japan, the Asia-9, and China.[4]

The United States had the highest concentration of KTI industries (38% of GDP in 2007), 4 percentage points higher compared with its level in 1992 (figure 6-2; appendix tables 6-1 and 6-2). The percentage point increase in the corresponding shares of the EU and Japan was similar, reaching 30% and 28%, respectively, in 2007.

China's KTI industries increased their share of GDP from 21% to 23% (figure 6-2; appendix tables 6-1 and 6-2). The Asia-9's share climbed from 19% to 22% during this period. The shares of three Asia-9 countries/economies—the Philippines, South Korea, and Taiwan—rose by about 10 percentage points, reaching a 25% to 30% share of their GDP in

Figure 6-1

Global output of knowledge- and technology-intensive industries as a share of global GDP: 1992–2007



GDP = gross domestic product

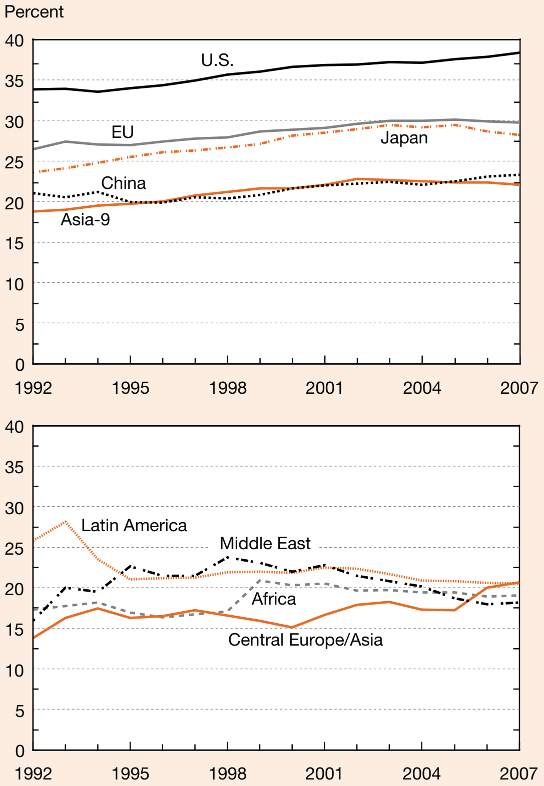
NOTES: Output of knowledge- and technology-intensive industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries include knowledge-intensive services and high-technology manufacturing industries classified by Organisation for Economic Co-operation and Development (OECD). Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Information and communications technology, classified by OECD, includes two knowledge-intensive services—communications services and computer and related services (part of business services)—and two high-technology manufacturing industries—communications and semiconductors and computers and office machinery.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 6-2

Output of knowledge- and technology-intensive industries as a share of GDP, by selected region/country: 1992–2007



EU = European Union; GDP = gross domestic product

NOTES: Output of knowledge- and technology-intensive industries on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries classified by Organisation for Economic Co-operation and Development and include knowledge-intensive services and high-technology manufacturing industries. Knowledge-intensive services include business, financial, communications, education; and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Africa includes Cameroon, Egypt, Kenya, Morocco, Nigeria, Senegal, South Africa, Tunisia, and Zimbabwe. Central Europe/Asia includes Russia, Turkey, and Ukraine. Latin America includes Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Jamaica, Mexico, Panama, Peru, Uruguay, and Venezuela. Middle East includes Iran, Israel, Jordan, Kuwait, and Saudi Arabia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

2007, significantly higher than the Asia-9 average. India's share was 18% in 2007, 3 percentage points higher than it was 15 years ago.

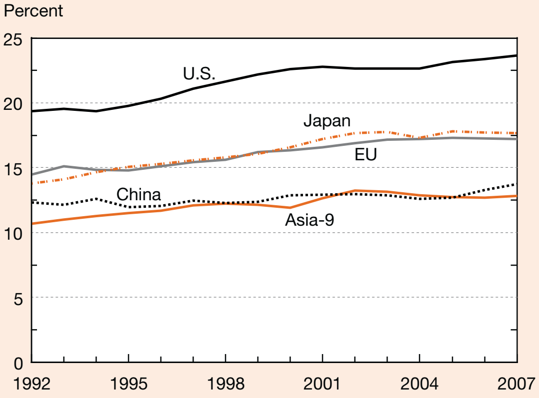
An increase in the intensity of the Asia-9 and China's KTI industries coincided with liberalization of their economies, increases in R&D expenditures, and adoption of policies to encourage high-technology industry production and trade. The KTI shares of other developing economies in Latin America, Africa, Central Europe/Asia, and the Middle East have grown little or have stagnated and are comparatively low (appendix tables 6-1 and 6-2).

Value added of commercial knowledge-intensive services amounted to $10 trillion in 2007, representing about 60% of the value added of all KTI industries (appendix table 6-3). Commercial knowledge-intensive services increased their share of world economic activity from 15% to 17% over the 15-year period, driving the increase in the KTI share of world GDP (figure 6-1; appendix tables 6-2 and 6-3). Value added of U.S. commercial knowledge-intensive services increased from 19% of U.S. GDP to 24%, the highest share of the knowledge-based economies (figure 6-3). The EU and Japan experienced a similar percentage point increase in the commercial knowledge-intensive share of their GDP. The share for China and the Asia-9 increased by 1 to 2 percentage points, reaching 14% and 13%, respectively, in 2007. Their considerably lower shares reflect their stage of development.

As a share of the global economy, ICT value added rose from 4% in 1992 to 5% in 2007 (figure 6-1; appendix tables 6-2 and 6-4). ICT shares in the developed economies edged up or remained steady (figure 6-4). China's ICT value-added

Figure 6-3

Output of commercial knowledge-intensive services as a share of GDP, by selected region/country: 1992–2007



EU = European Union; GDP = gross domestic product

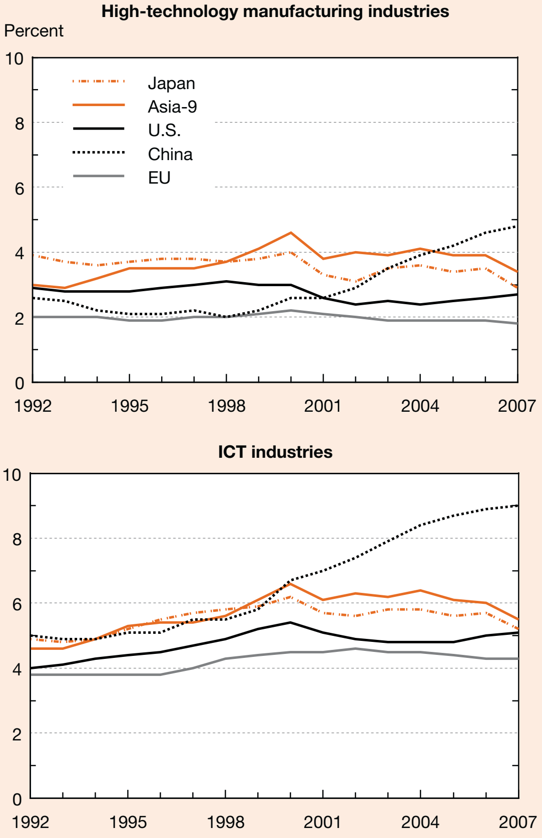
NOTES: Output of commercial knowledge-intensive services on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge-intensive services classified by the Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, communications, and financial services. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 6-4

Output of high-technology manufacturing and ICT industries as a share of GDP, by selected region/country: 1992–2007



EU = European Union; GDP = gross domestic product;
ICT = information and communications technology

NOTES: Output of high-technology manufacturing and ICT industries on value-added basis. High-technology manufacturing industries and ICT industries classified by Organisation for Economic Co-operation and Development. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. ICT industries include communications services, computer and related services, communications and semiconductors, and computers and office machinery. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

share of its GDP doubled, climbing from 5% in 1992 to 9% in 2007. The Asia-9's share was steady at 5% during this period. A major factor in the rise of China's ICT intensity is that it became a major world exporter of ICT goods. The trend of the high-technology manufactures' share in the five economies was similar to that for ICT (figure 6-4; appendix table 6-5).

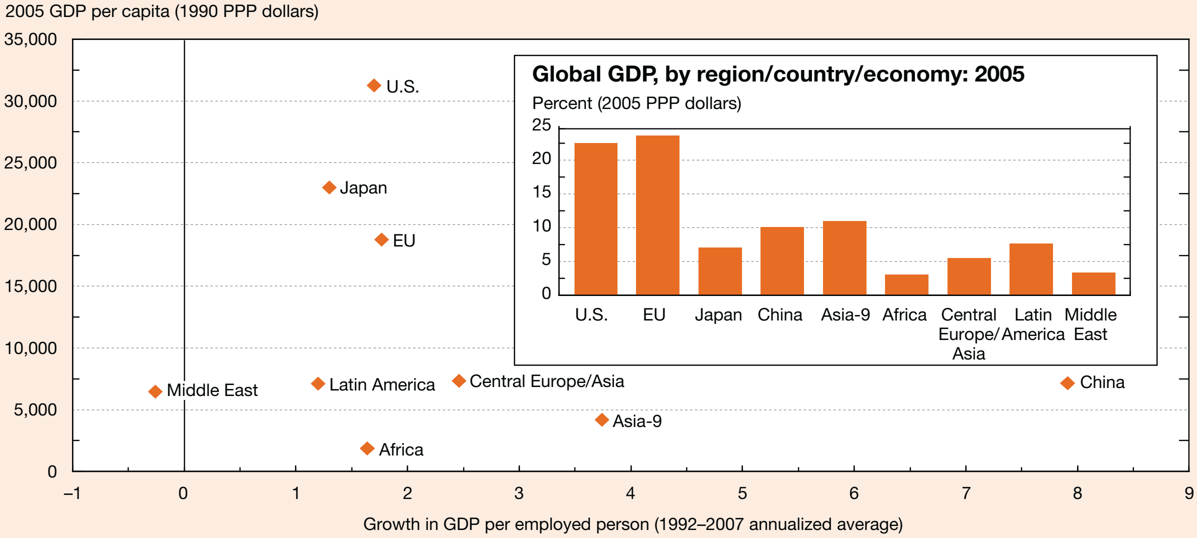
The relatively high and growing intensity of KTI industries in the United States, the EU, Japan, China, and the Asia-9 coincided with elevated living standards, as measured by GDP per capita. The United States, the EU, and Japan account for about half of the world's economic activity and also have the highest living standards (figure 6-5; appendix table 6-6). The United States has the highest per capita income among these economies ($31,260 in 1990 purchasing power parity [PPP][5]), 26% higher than Japan and 40% higher than the EU. The Asia-9 and China, each with economic production approximately the size of Japan's, have far lower per capita incomes. However, per capita income varies widely in the Asia-9. The per capita income of India, Indonesia, the Philippines, and Vietnam is less than $4,500 (1990 PPP), whereas South Korea, Singapore, and Taiwan have standards of living similar to that of the EU.

China and the Asia-9 have made remarkable progress in raising their living standards over the past decade and a half. China's per capita income grew at an annual average rate of almost 8%, resulting in per capita income more than tripling since 1992 (figure 6-6; appendix table 6-6). The Asia-9 economies grew at an annual average rate of 4%, resulting in almost a doubling of per capita income. Singapore, South Korea, and Taiwan grew slightly faster than the Asia-9 average, resulting in living standards rising from middle to high income. India's per capita income doubled from $1,300 to $2,800, propelled by 5% growth during this period. The per capita income of other developing economies has grown at half the rate (or less) of the Asia-9.

Many economists and policymakers regard productivity growth as the single most important factor in maintaining and advancing living standards. Standard productivity measures, such as labor or multifactor output per hour, are not available for many countries. A proxy measure—GDP per employed person—is used here, spanning 1992 to 2007 (appendix table 6-7).[6]

Labor productivity growth was much lower for the developed economies than the developing economies, but productivity levels were much higher (appendix table 6-7). Labor productivity growth rates for the United States, the EU, and Japan averaged less than 2% annually (1.7%, 1.8%, and 1.3%, respectively) (figure 6-5). In contrast, China's labor productivity grew at an estimated 8% annual rate.

Figure 6-5
Macroeconomic indicators, by region/country/economy: 1992–2007



EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: Africa includes Algeria, Angola, Burkina Faso, Cameroon, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Central Europe/Asia includes Albania, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Russia, Serbia and Montenegro, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. China includes Hong Kong. Latin America includes Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Peru, Puerto Rico, St. Lucia, Trinidad and Tobago, Uruguay, and Venezuela. Middle East includes Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen.

SOURCE: The Conference Board, Total Economy Database (January 2009), http://www.conference-board.org/economics, accessed 15 January 2009.

Science and Engineering Indicators 2010

Productivity growth of the Asia-9 economies averaged roughly 4%, ranging from India's 5% to 3-4% for Singapore, South Korea, and Taiwan.

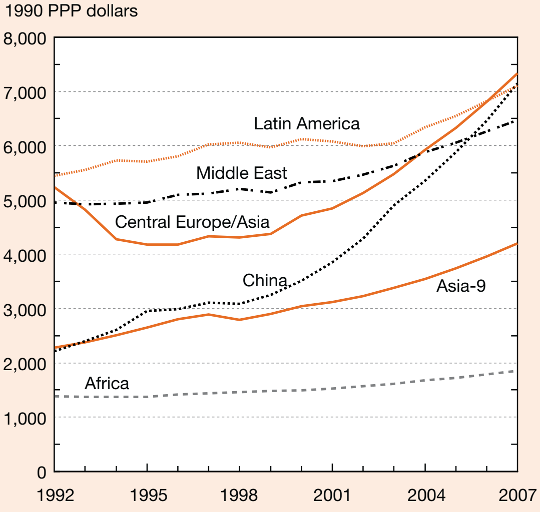
Despite impressive gains, productivity levels in China and the Asia-9 remain far below those of the United States, the EU, and Japan (figure 6-7; appendix table 6-7). China's gap with the United States decreased by 10 percentage points from 1992 to 2007 but remains at one-fifth the U.S. level. The Asia-9's gap narrowed slightly to 16% (from 12%) of the U.S. level. However, the labor productivity levels of Singapore, South Korea, and Taiwan are equivalent to those of the EU and Japan.

ICT has been identified by many economists and policymakers as vital for national economic growth and the competitiveness of all industries.[7] Bresnahan and Trajtenberg (1995) and others have identified ICT as a "general-purpose technology" that has the potential for pervasive use in a wide range of sectors because (1) it can be used with a variety of inputs and technologies and (2) it is subject to falling prices that stimulate further demand and use.[8] ICT is regarded as crucial for the growth of today's knowledge-based economies in much the same way that earlier general-purpose technologies (the steam engine, metal forging, and automatic machinery) were crucial for growth during the Industrial Revolution. Thus, adoption and diffusion of ICT may be an important indicator of future economic and productivity growth and of a country's capacity to innovate.

Three ICT indicators are presented here:

- **ICT intensity:** ICT spending as a share of GDP
- **The World Bank's Knowledge Economy Index (KEI):** a measure of per capita diffusion and adoption of ICT[9]

Figure 6-6
GDP per capita for developing economies: 1992–2007



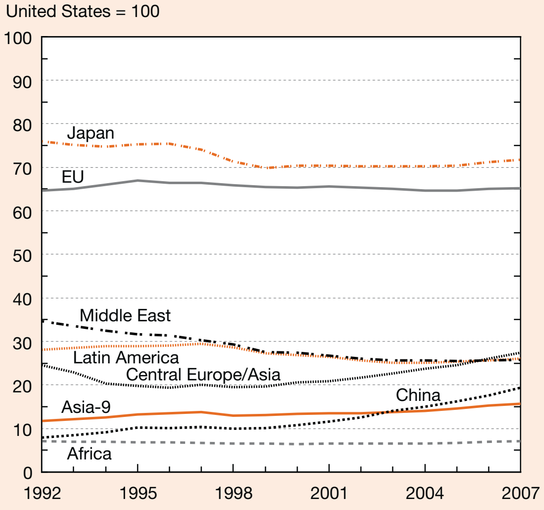
GDP = gross domestic product; PPP = purchasing power parity

NOTES: Africa includes Algeria, Angola, Burkina Faso, Cameroon, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Central Europe/Asia includes Albania, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Russia, Serbia and Montenegro, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. China includes Hong Kong. Latin America includes Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Peru, Puerto Rico, St. Lucia, Trinidad and Tobago, Uruguay, and Venezuela. Middle East includes Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (January 2009), http://www.conference-board.org/economics, accessed 15 January 2009.

Science and Engineering Indicators 2010

Figure 6-7
GDP per employed person, by region/country/economy: 1992–2007



EU = European Union; GDP = gross domestic product

NOTES: Value for each region expressed as percentage of U.S. value. Africa includes Algeria, Angola, Burkina Faso, Cameroon, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Central Europe/Asia includes Albania, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Russia, Serbia and Montenegro, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. China includes Hong Kong. EU includes all 27 member states. Latin America includes Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Jamaica, Mexico, Peru, Puerto Rico, St. Lucia, Trinidad and Tobago, Uruguay, and Venezuela. Middle East includes Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen.

SOURCE: The Conference Board, Total Economy Database on Output and Labor Productivity (January 2009), http://www.conference-board.org/economics, accessed 15 January 2009.

Science and Engineering Indicators 2010

- **National share of global ICT spending:** a measure of the scale of the economy's demand for global ICT products and services.

The United States ranks highest in the share of global ICT spending, scores highest in the KEI index, and ties with China in having the highest ratio of ICT spending to GDP (figure 6-8). The EU and Japan score nearly as high in the KEI index but have a lower intensity of ICT spending than the United States. China and the Asia-9 have greater ICT intensity and a higher share of global ICT spending than other developing regional/national economies. However, China and the Asia-9 score lower in the KEI index compared with Latin America, the Middle East, and Central Europe/Asia. ICT index scores vary widely within the Asia-9: The developed economies score at the same level as the United States, but India and other developing economies score at only half the Asia-9 average.

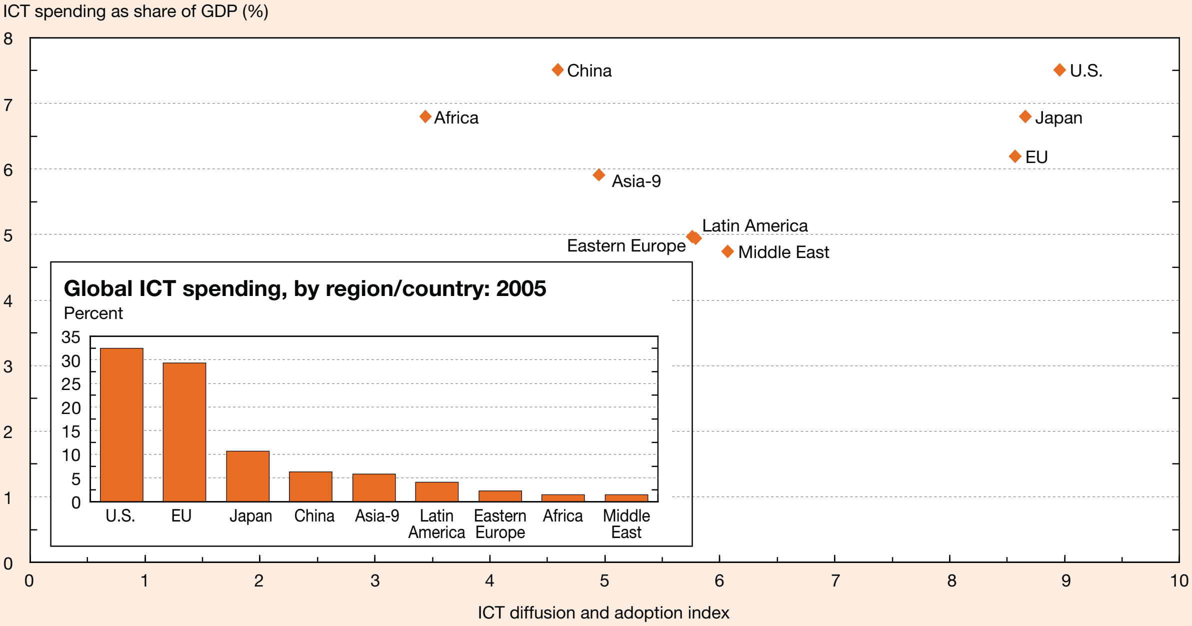
The relatively low standing of China and the Asia-9 in the KEI index, despite their relatively high share of global ICT spending, may be due to China's and India's very large populations and because China and some Asia-9 countries/economies are net exporters of ICT goods. The benefit that China and some of the Asia-9 derive from ICT exports may come at the cost of not using cheaper and more powerful ICT products throughout their domestic economy and populace.[10]

Worldwide Distribution of Knowledge- and Technology-Intensive Industries

As national and regional economies change, the worldwide centers of KTI industries shift in importance. Shifts take place both for this entire group of industries and for individual service and manufacturing industries within the group.

The global value-added output of knowledge-intensive service industries and high-technology manufacturing

Figure 6-8
Indicators of ICT adoption and intensity: 2005



EU = European Union; GDP = gross domestic product; ICT = information and communications technology

NOTES: ICT diffusion and adoption index composed of three variables: telephone, computer, and Internet usage per capita. For more information on key variables, see source World Bank, Knowledge Assessment Methodology. Regions/countries/economies ranked in order of scores on each variable, and scores normalized on 0–10 scale against all regions/countries/economies. Top 10% of performers receive normalized score between 9 and 10, decile receives normalized scores between 8 and 9, and so on. Scores for regions weighted by country/economy share of region's economic activity according to World Bank's GDP on 2005 purchasing power parity basis. Africa includes Angola, Burkina Faso, Cameroon, Egypt, Ghana, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Tunisia, Uganda, and Zimbabwe. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Central Europe/Asia includes Albania, Armenia, Azerbaijan, Belarus, Croatia, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Russia, Tajikistan, Turkey, and Ukraine. China includes Hong Kong. EU excludes Malta. Latin America includes Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay, and Venezuela. Middle East includes Bahrain, Iran, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, and Yemen.

SOURCE: World Bank, Knowledge Assessment Methodology, http://web.worldbank.org/WBSITE/EXTERNAL/WBI/WBIPROGRAMS/KFDLP/EXTUNIKAM/0,,menuPK:1414738~pagePK:64168427~piPK:64168435~theSitePK:1414721,00.html, accessed 2 October 2009; and World Information Technology and Services Alliance (WITSA), Digital Planet 2008, http://www.witsa.org/v2/, accessed 7 November 2009.

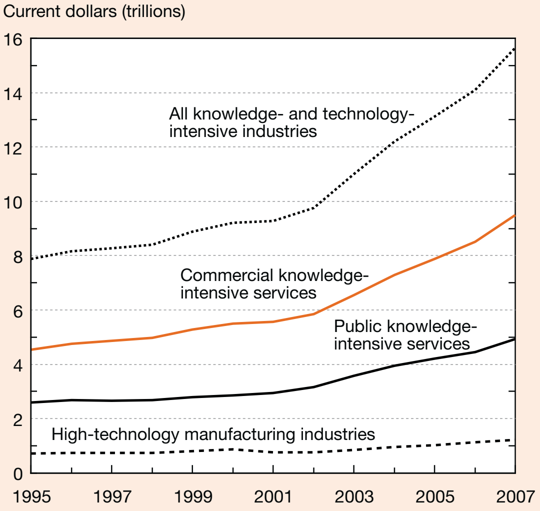
Science and Engineering Indicators 2010

industries accounted for an estimated $15.7 trillion in 2007, of which $5.0 trillion was for the largely location-bound, publicly funded knowledge-intensive services: $2.8 trillion for health and $2.2 trillion for education (figure 6-9; appendix tables 6-8 and 6-9). The total for tradable knowledge-intensive services and high-technology manufactures amounted to $10.7 trillion—$9.5 trillion for services and $1.2 trillion for manufacturing—out of an estimated total world economic output of $54.8 trillion (IMF 2009).

Health and Education Services

The health and education sectors generated an estimated global value added of $2.8 and $2.2 trillion, respectively, in 2007 (appendix tables 6-8 and 6-9). International comparison of these two sectors is complicated by variations in the size and distribution of each country's population and the degree of government involvement and regulation. As a result, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

Figure 6-9
Global value added of knowledge- and technology-intensive industries: 1995–2007



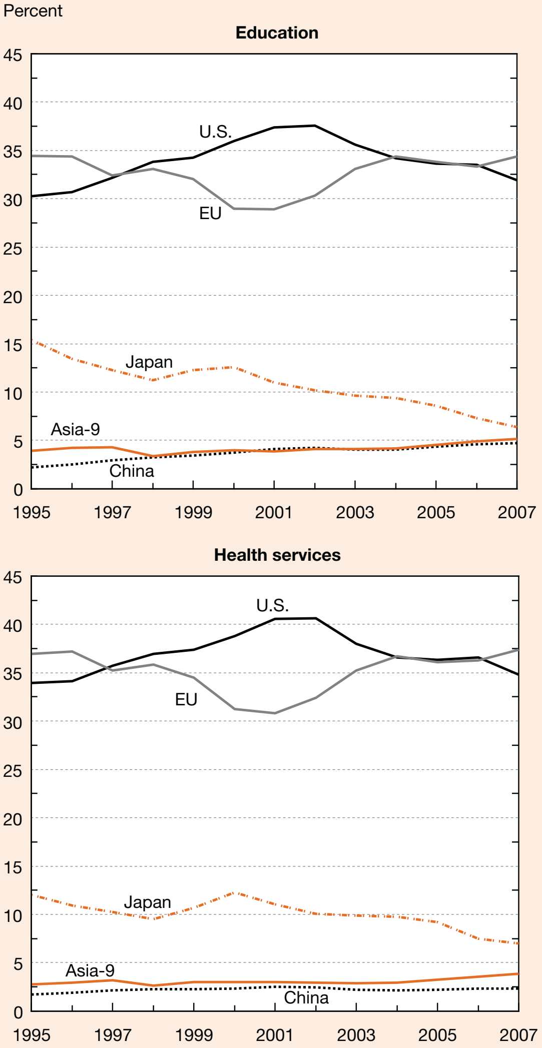
NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries include knowledge-intensive services and high-technology manufacturing industries classified by Organisation for Economic Co-operation and Development. Knowledge-intensive services include business, financial, communications, education, and health. Commercial knowledge-intensive services include business, financial, and communications services. Public knowledge-intensive services include education and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

The health sector of the United States, which has more private sector involvement than many countries, is the second largest in the world as measured by share of global value added (35%), behind the EU's 37% share (figure 6-10; appendix table 6-9). The U.S. and EU shares fluctuated considerably over the past decade but were roughly stable at

Figure 6-10
Global value added of education and health services, by selected region/country/economy: 1995–2007



EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-9 Includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

the beginning and end of the period. Japan's world share fell from 12% in 1995 to 7% in 2007. China's share was stable and the Asia-9's share rose from 3% to 4% during this period.

The United States is also the second largest provider of education at a 32% share, placing it behind the EU's 34% share, with little change in these shares over the period (figure 6-10; appendix table 6-8). Third-ranked Japan's share declined from 15% in 1995 to 6% in 2007, China's share rose from 2% to 5%, and the Asia-9's share rose from 4% to 5%, largely because of strong growth in education spending in India, the Philippines, South Korea, Taiwan, and Thailand. Gains by China, India, and other Asian countries coincided with the rapid expansion of university enrollments and graduation of new degree holders. (See "Global Trends in Higher Education in S&E" in chapter 2 for a discussion of trends in S&E higher education in Asia and other regions/countries/economies.)

Commercial Knowledge-Intensive Service Industries

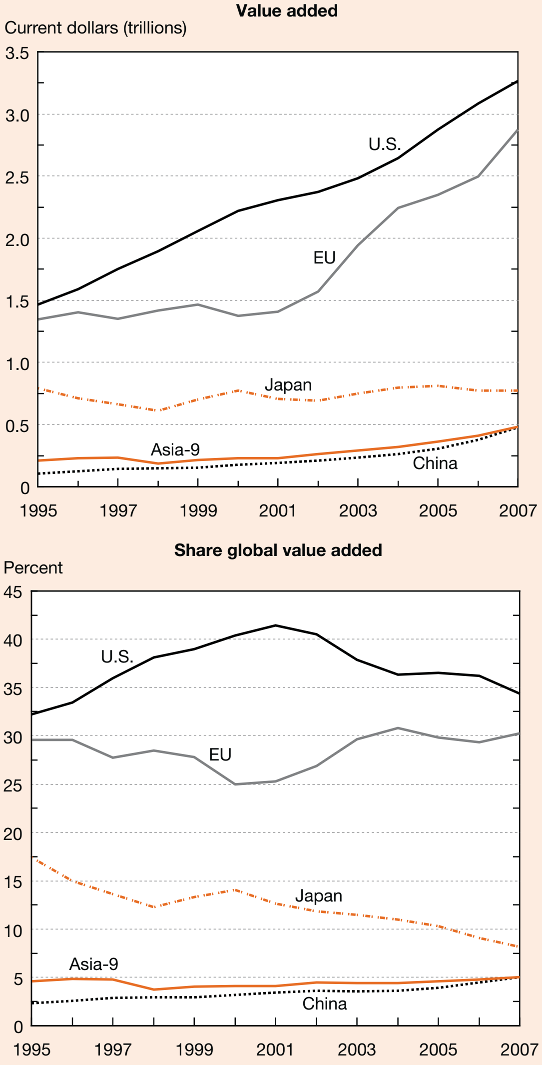
Business services is the largest of the three commercial knowledge-intensive service industries ($5.1 trillion value added); it includes computer and data processing services and commercial R&D services (appendix table 6-10). Financial services, the next largest industry, generated $3.2 trillion (appendix table 6-11). Communications ($1.3 trillion), the smallest of the knowledge-intensive industries, is arguably the most technology driven of the commercial knowledge-intensive services (appendix table 6-12).

Worldwide, the volume of commercial knowledge-intensive services more than doubled over a decade, from $4.5 trillion in 1995 to $9.5 trillion in 2007 (appendix table 6-3). The United States remains the largest provider of commercial knowledge-intensive services, with $3.3 trillion of the value added globally in 2007 (figure 6-11). The EU maintained second place at $2.9 trillion, trailed by Japan with $0.8 trillion. The volume of value added for commercial knowledge-intensive services in China and the Asia-9 is growing but remains low, at half a trillion dollars each.

Three distinct growth patterns marked the commercial knowledge-intensive service industries of these regions. However, trends in these services are probably influenced by the level and growth of per capita income and changing consumption patterns of these economies rather than by advances in technology. The United States, the EU, and the Asia-9 grew at a pace similar to the world average (appendix table 6-3). (Fluctuations in growth for the U.S. and the EU during the past decade may partially reflect fluctuations in the dollar/euro exchange rate.[11]) Japan's output stagnated over the decade, causing its world share to drop from 17% in 1995 to 8% in 2007 (figure 6-11). China's output expanded more than two times the world's average growth rate but began from a low base, reaching 5% of the 2007 world total.

The same patterns can be seen in the individual service industries, with the shares for the United States and the EU consistently near 25% of global value added, steeply

Figure 6-11
Value added of commercial knowledge-intensive services, by selected region/country/economy: 1995–2007



EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge- and technology-intensive industries classified by Organisation for Economic Co-operation and Development and include knowledge-intensive services and high-technology manufacturing industries. Knowledge-intensive services include business, financial, communications, education; and health. High-technology manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

declining shares for Japan, and modest to rapid growth from low bases for China (moving from 2%–3% to 4%–7% of the world total over the decade) and the Asia-9, depending on the industry (figure 6-12; appendix tables 6-10 through 6-12). Within the EU, the Eastern European countries and Ireland generally grew at least twice as fast as the EU average in all three industries. Among the Asia-9 countries/economies, India was the second largest producer behind South Korea; its share rose from 0.8% to 1.4% as a result of strong growth in all three industries.

In other developing regions, Central Europe/Asia's commercial knowledge-intensive services expanded more than twice as fast as the world's average growth rate, led by growth in Russia and Turkey (appendix table 6-3). Its share of global value added increased from 1% to 3% because of strong growth in business and financial service industries. The Middle East expanded slightly faster than the world average rate, led by very rapid growth by Iran. Although Latin America grew at the world average, Mexico's output expanded 50% faster than the world average and Brazil's output more than doubled between 2003 and 2007 because of strong growth in business services and communications (appendix tables 6-10 through 6-12).

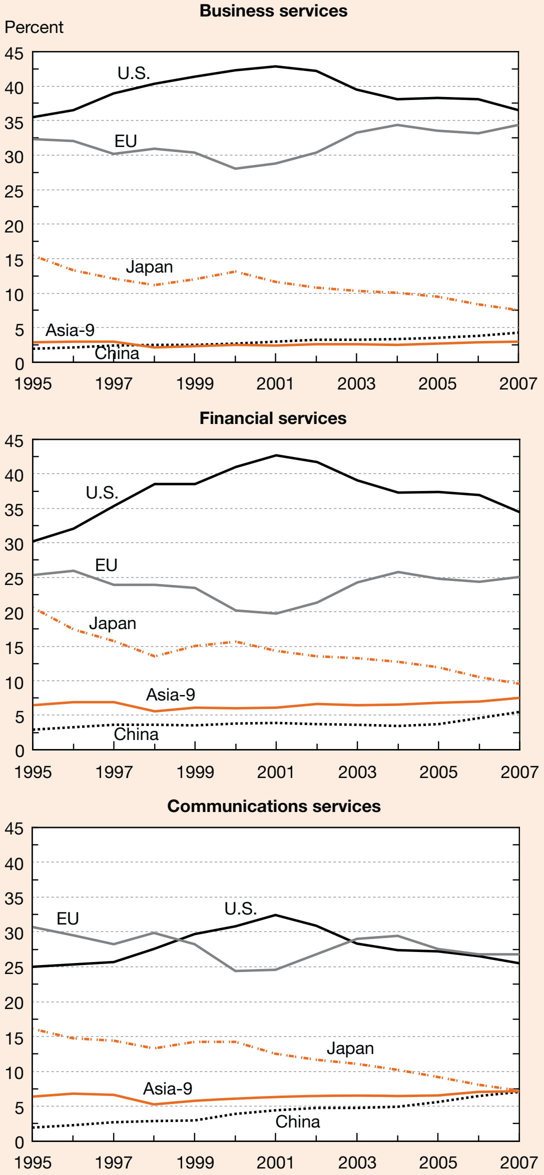
High-Technology Manufacturing Industries

Five manufacturing industries constitute the high-technology manufacturing sector, as defined by the OECD. In decreasing order of 2007 global value added, they are communications and semiconductors ($445 billion), pharmaceuticals ($319 billion), scientific instruments ($189 billion), aerospace ($153 billion), and computers and office machinery ($114 billion) (appendix tables 6-13 through 6-17).

The United States, the EU, Japan, China, and the Asia-9 dominate high-technology manufacturing industries. In 2007, their collective shares accounted for 90% of the $1.2 trillion global total (figure 6-13; appendix table 6-5). U.S. high-technology manufacturers continued to rank first with $374 billion value added, followed by the EU at $306 billion and China at $167 billion. However, the EU ranks first in domestic consumption of high-technology manufactured goods, followed by the United States (see sidebar, "Consumption of High-Technology Manufactured Goods"). Since 1995, the high-technology share of total U.S. manufacturing has increased modestly from 17% to 21% (appendix tables 6-5 and 6-18). In contrast, for all manufacturing industries, the EU is the global leader (29% of value added) and the United States ranks second (20%).

From 1995 to 2007, high-technology manufacturing output rose faster (69%) than total manufacturing (59%) (appendix tables 6-5 and 6-18). The United States, the EU, and the Asia-9 experienced growth in high-technology manufacturing close to the world average, whereas Japan's output declined, resulting in a drop in its world share from 27% to 11% (figure 6-13). China's growth in high-technology manufacturing output greatly exceeded the world average, expanding ninefold over the decade, from $19 billion to $167

Figure 6-12
Global value added of commercial knowledge-intensive services, by selected region/country/economy: 1995–2007

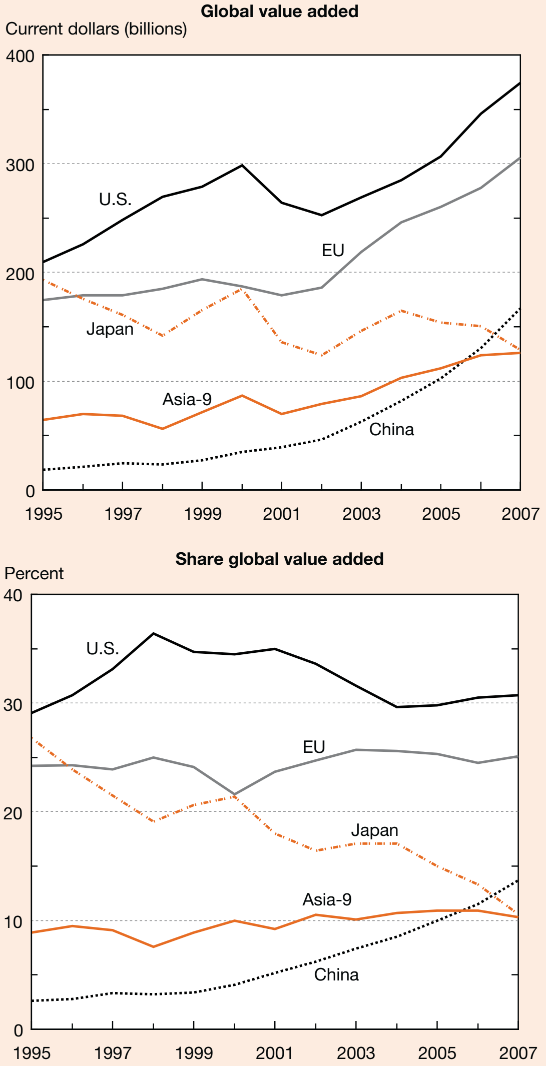


NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health. Commercial knowledge-intensive services exclude education and health. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 6-13
Value added of high-technology manufacturing industries, by selected region/country/economy: 1995–2007



EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Consumption of High-Technology Manufactured Goods

Production of high-technology goods feeds both domestic demand and foreign markets. A broad measure of domestic use is provided by adding domestic sales to imports and subtracting exports. However, use so defined encompasses two different concepts: consumption of final goods and capital investment for further production (intermediate goods). Available data series do not permit the examination of these two concepts separately.

Patterns of the world's use of high-technology manufactures have changed considerably over the past decade. The U.S. share of domestic use, so defined, fell from 28% in 1995 to 25% in 2004 and has largely stayed at that level (figure 6-A). The EU's share stayed broadly the same at 26%–27% over the decade; it overtook the United States in 2003 to become the leading consumer of high-technology goods. Japan's share declined by more than half, from 21% to 8%; the Asia-9's share stayed essentially stable at 10% during this period.

China's share surged from 4% in 1995 to 16% in 2007. The Chinese trend underscores the difficulty of teasing out final consumption from use as intermediate goods. The strong rise in the Chinese trend is considered by many observers to reflect the rising flow of intermediate goods—often previously produced in China—from other Asian manufacturing centers into China for further assembly and ultimate export.

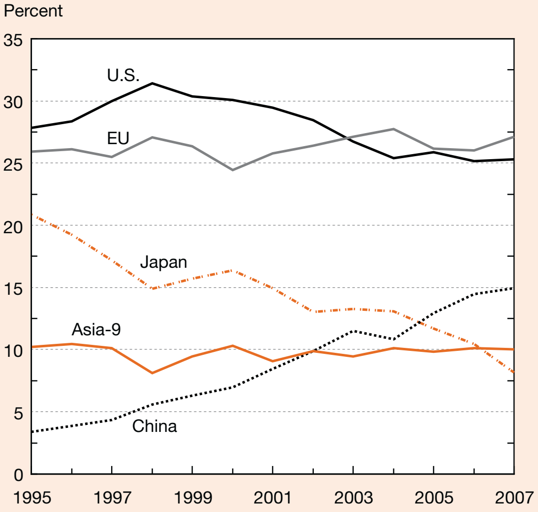
billion, and its world share more than quadrupled from 3% to 14%. The high-technology share of the Chinese manufacturing sector jumped from 7% to 13% during this period. These country patterns were broadly similar to the output growth trends in domestic consumption of high-technology manufactured goods and knowledge-intensive services (figures 6-11 and 6-A).

In 2007, the United States was the world leader in global value added in three high-technology manufacturing industries: communications and semiconductors (29%), pharmaceuticals (32%), and aerospace (52%) (figure 6-14; appendix tables 6-13, 6-14, and 6-16). The United States ranked behind the EU in scientific instruments (19% vs. 44%) and well behind China in computers and office machinery (25% vs. 39%) (appendix tables 6-15 and 6-17).

The U.S. share of global value-added in high-technology manufacturing remained roughly stable over the decade (figure 6-13; appendix tables 6-5 and 6-18). (Fluctuations in U.S. growth may be partially due to changes in the value of the U.S. dollar.) The U.S. share of global value added was relatively stable in the aerospace, communications and

Figure 6-A

Global apparent consumption of high-technology manufacturing industry output, by selected region/country/economy: 1995–2007



EU = European Union

NOTES: Apparent consumption is sum of domestic production and inputs less exports. High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

semiconductors, computers and office machinery, and pharmaceutical industries (figure 6-14; appendix tables 6-14 through 6-17). The U.S. share in scientific instruments, however, fell significantly from 29% to 19% during this period.

Anecdotal evidence suggests that assembly of computers and semiconductors shifted from the United States to China and other Asian countries, contributing to China's vigorous expansion of its output in these industries. However, U.S.-based firms such as Dell and Apple continued to grow and to be highly profitable, deriving much of their profits from high-value activities such as logistics, design, and marketing that remained in the United States (see Dedrick, Kraemer, and Linden 2008, and sidebar, "Tracing the Geography of the Value Chain of Products").

The EU's share stayed roughly stable in three industries: pharmaceuticals (31%), communications and semiconductors (15%), and aerospace (27%) (figure 6-14; appendix tables 6-13, 6-14, and 6-16). The EU increased its share of scientific instruments by 6 percentage points to 44% over the decade but experienced a significant decline in computers and office machinery (appendix tables 6-15 and 6-17). Output of several Eastern European member countries—the Czech Republic, Hungary, Poland, and the Slovak Republic—grew much more rapidly in these industries than output of other member countries. This is consistent with evidence that these countries have become assembly centers for high-technology industries based in more developed EU economies (Kaminski and Ng 2001).

The communications and semiconductors and computers and office machinery industries drove China's rapid expansion of high-technology manufacturing, coinciding with China becoming the world's low-cost assembler and exporter of these goods. China's communications and semiconductors industry grew nearly sixfold over the decade, its world share climbing from 4% to 15% (figure 6-14 and appendix table 6-13). Its computer industry grew at 45% annually between 1995 and 2007; its world share jumped from 1% to almost 40% over the same period (appendix table 6-17).

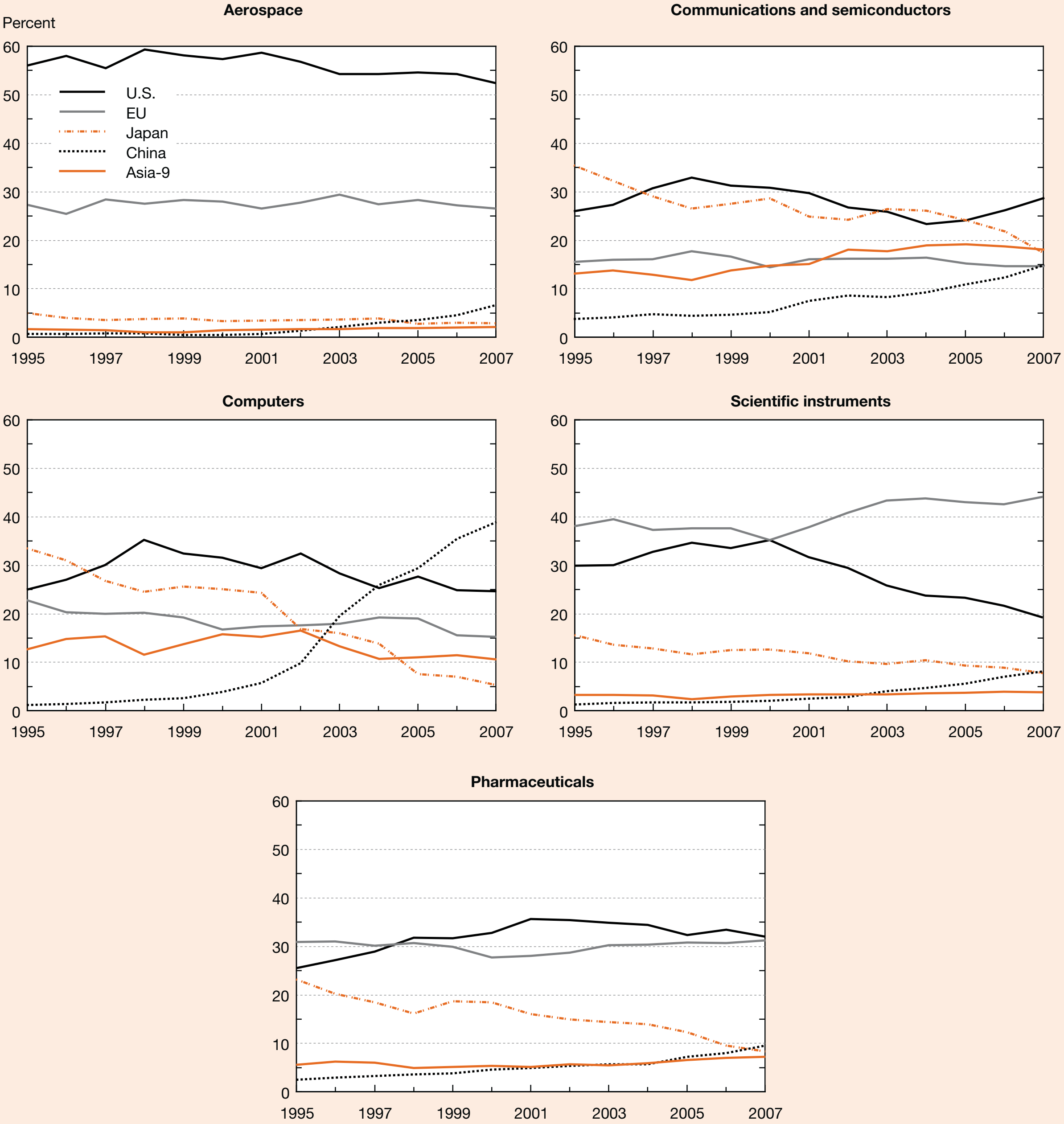
China's growth in other high-technology industries was also rapid—China at least quadrupled its world share in pharmaceuticals, scientific instruments, and aerospace (figure 6-14 and appendix tables 6-14, 6-15, and 6-16).

Japan's share loss, driven primarily by the communications and semiconductors and the computers and office machinery industries, also extended to the other three high-technology industries (figure 6-14 and appendix tables 6-13 through 6-17). This broad downward trend may reflect its lengthy economic stagnation and the shift of production to China and other Asian economies. The Asia-9's share of global value added edged up from 9% to 10%, reaching parity with Japan in 2007 (figure 6-13; appendix table 6-5). South Korea had very strong growth in communications and semiconductors, moving its share of global value added from 4% to 10% (appendix table 6-13).

India has a very limited high-technology manufacturing industry, but its value added grew more than twice as fast as the Asia-9's average (appendix table 6-5). India's growth was concentrated in pharmaceuticals, with gains in scientific instruments—industries in which the United States and other multinationals have established a presence in India (appendix tables 6-14 and 6-15).

In other developing regions, high-technology manufacturing output in Central Europe/Asia grew more than twice the world average over the 1995–2007 period, led by growth in Russia and Turkey (appendix table 6-5). The Middle East also gained, driven by Israel and Iran. Growth in both of these regions was led by scientific instruments and pharmaceuticals; communications and semiconductors also contributed to the Middle East's gain (appendix tables 6-13, 6-14, and 6-15). Latin America grew at a rate near the world average, the second slowest of the developing regions. However, Mexico, an important assembly center for high-technology goods, grew two times faster than the world average during this period, led by pharmaceuticals and communications and semiconductors. Brazil's growth was stagnant between 1995 and 2003; however, it has grown rapidly since 2003, surpassing Mexico in 2005 to become the

Figure 6-14
Global value added of selected high-technology manufacturing industries, by selected region/country/economy: 1995–2007



EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Tracing the Geography of the Value Chain of Products

Several studies sponsored by the Sloan Foundation have attempted to estimate the value-added contribution of countries involved in the production of several electronic goods, including the Apple iPod and the Hewlett-Packard laptop computer. These studies essentially show that the big returns accrue to the firms and countries that harbor special design, engineering, and marketing expertise.

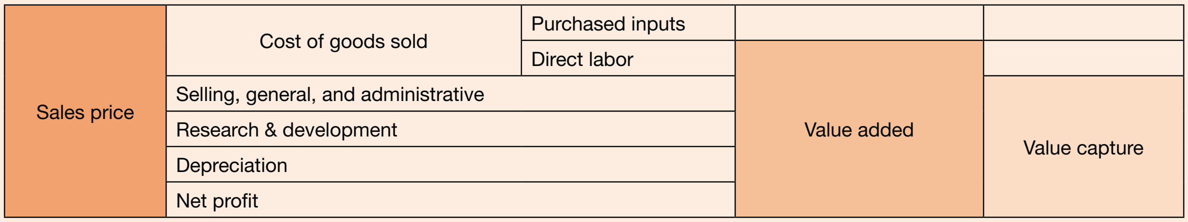
Because value-added data are not readily available at the product or firm level, these studies estimate the *value capture* of these goods. Value capture does not count the cost of direct labor (figure 6-B) which, when included, could raise a country's share (if direct labor was performed in the country) or lower it (if direct labor was performed in another country). Thus, the estimates shown must be regarded as broadly indicative only.

The Apple iPod study estimates that the United States receives the largest share of value capture based on the factory price (39%), largely reflecting Apple's gross profit (36%) (table 6-A). The study sorts iPod components into key and low-cost generic items. Key inputs account for 37% of the wholesale price, and value capture is estimated for their manufacturers. The estimated U.S. share is 3%, raising the total U.S. share to 39%. Asia's key inputs share is estimated at 14%, with Japan capturing 12% because of the expensive hard drive manufactured by Toshiba. (If direct labor costs were available, Japan's share of value added would be arguably lower because Toshiba manufactures its hard drives in China and the Philippines.) The value capture of the generic inputs is estimated at 10%, of which 3% is estimated as the value capture from manufacture of these components.

China, the location of final assembly, receives an estimated 2% share of the Apple iPod's value capture (table 6-A). The study estimates that China's value capture is very small because final assembly of an iPod requires about 10 minutes and the minimum monthly wage for a worker is about $100. Because final assembly of the iPod and other electronic goods yields little value for China, the authors claim that trade statistics are misleading because the U.S. trade deficit with China increases by about $150 plus the cost of shipping for every iPod sold in the United States, whereas the value added by China is estimated at only a few dollars. Table 6-A summarizes similar data for the Hewlett-Packard laptop computer.

(continued on next page)

Figure 6-B
Components of value added and value capture



NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Value capture is value added excluding the cost of direct labor.

SOURCE: Dedrick J, Kraemer KL, Linden G, Who Profits from Innovation in Global Value Chains? A Study of the iPod and notebook PCs, Personal Computing Industry Center, University of California–Irvine (2008), http://pcic.merage.uci.edu/papers.asp., accessed 7 November 2009.

Science and Engineering Indicators 2010

largest Latin American producer. Brazil's aerospace industry grew by sevenfold and its computer industry registered strong gains.

Information and Communications Technology Industries

ICT as discussed here comprises both the communications and computer services industries and the computer, communications, and semiconductors manufacturing industries. In 2007, ICT generated an estimated total of $2.6 trillion in global value—$2.0 trillion in communications and computer services, and $0.6 trillion in the manufacturing industries (appendix table 6-4).

In 2007, the United States and the EU tied as the largest ICT producers (about $700 billion), followed by second-ranked China ($315 billion). Japan and the Asia-9 converged in a range of approximately $205–$230 billion (figure 6-15; appendix table 6-4).

The U.S. and EU shares fluctuated over the decade but showed little change in 2007 compared with a decade ago (figure 6-15; appendix table 6-4). Japan's share fell steeply during this period, mirroring its downward trends in share in both high-technology and knowledge-intensive industries. China's share tripled from 4% to 12% because of strong gains across all ICT industries. The Asia-9's share was flat during this period, although India's share rose

Table 6-A

Contribution of value capture for Apple iPod and HP laptop computer, by country/economy of origin: 2005

(Percent)

Product, country/economy, and manufacturer	Activity	Share factory price
Apple video iPod		
U.S.	Design/marketing, manufacturing of components	38.7
Apple (gross profit)	Design/marketing	35.7
U.S. contract manufacturer	Manufacturing of components	3.0
Japan	Manufacturing of components	12.0
South Korea	Manufacturing of components	0.4
Taiwan	Manufacturing of components	2.0
China	Final assembly	1.8
Hewlett-Packard laptop computer		
U.S.	Design/marketing, operating system/chip, manufacturing of components	47.0
HP (gross profit)	Design/marketing	28.0
Microsoft and Intel	Operating system and chip	18.0
U.S. contract manufacturer	Manufacturing of components	1.0
Japan	Manufacturing of components	7.0
South Korea	Manufacturing of components	1.0
Taiwan	Manufacturing of components	2.0
NA	Final assembly	NA

NA = not available

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Value capture is value added excluding the cost of direct labor.

SOURCE: Dedrick, J, Kraemer, KL, Linden G, "Who Profits from Innovation in Global Value Chains? A Study of the iPod and notebook PCs," Personal Computing Center, University of California–Irvine (2008), http://pcic.merage.uci.edu/papers.asp., accessed 27 May 2009.

Science and Engineering Indicators 2010

from 0.5% to 1.1%, driven by gains in communications and computer services.

In other developing regions, Central Europe/Asia and Latin America increased their world share by 1 percentage point over the decade, reaching 4% and 5%, respectively, in 2007 because of strong growth in ICT service industries (appendix table 6-4).

Industries That Are Not Knowledge or Technology Intensive

Science and technology are used in many industries besides high-technology manufacturing and services. Services not classified as knowledge intensive incorporate technology in their services or in the delivery of their services but at a lower intensity compared with the knowledge-intensive services discussed above. Manufacturing industries not classified as high technology by the OECD use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacture, and/or perform or rely on R&D in applicable scientific fields. In addition, some industries not classified as either manufacturing or services use or incorporate science and technology to varying degrees in their products and processes (see sidebar, "Trends in Industries Not Classified as Services or Manufacturing").

Non-Knowledge-Intensive Commercial Services

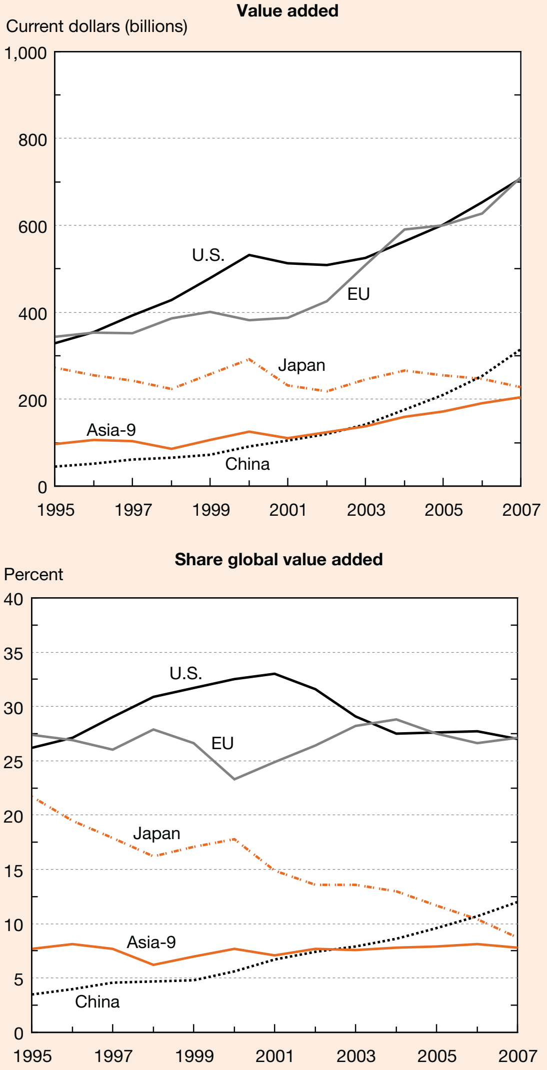
Commercial services not classified as knowledge intensive include the wholesale and retail, restaurant and hotel, transportation and storage, and real estate industries. The United States leads the EU by a slim margin, as measured by share of global value added (29%) in the wholesale and retail industry—the largest of these industries ($5.9 trillion)—and is the second-ranked provider in the other three industries (table 6-1). Allowing for fluctuations, the national/regional shares remained stable or showed slight upward trends except for Japan, whose shares fell in all of these industries.

Non-High-Technology Manufacturing Industries

Non-high-technology manufacturing industries are divided into three categories, as classified by the OECD: medium-high technology, medium-low technology, and low technology. These industries include motor vehicle manufacturing and chemicals production, excluding pharmaceuticals (medium-high technology), rubber and plastic production and basic metals (medium-low technology), and paper and food product production (low technology).

The share trends in all of these industry segments are the same as for high technology—share losses for the United States and larger share losses for Japan, stable or slight declines for the EU, stable or slight increases for the Asia-9, and strong share gains across all segments for China.

Figure 6-15
Value added of ICT industries, by selected region/country/economy: 1995–2007



EU = European Union; ICT = information and communications technology

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Information and communications technology classified by Organisation for Economic Co-operation and Development and includes communications services, computer and related services, communications and semiconductors, and computers and office machinery. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

- **Medium-high-technology industries:** These industries produced $2.1 trillion in global value added in 2007. The U.S. share fell from 23% to 17% between 1995 and 2007 (table 6-2), and the EU share remained roughly stable (32%). Japan's share fell from 24% to 13%, China's more than quadrupled from 3% to 13%, and the Asia-9's share rose from 7% to 9%.
- **Medium-low-technology industries:** The U.S. and EU shares of these industries ($2.5 trillion global value added) fell 3 percentage points each over the decade, reaching 16% and 28%, respectively (table 6-2). Japan's share fell from 24% to 10%, its steepest loss among these three segments.
- **Low-technology industries:** These industries produced $2.6 trillion in global value added in 2007. The U.S. and EU shares fell slightly (table 6-2). The Asia-9's share remained stable, as opposed to its small gains in the other two segments.

Trade and Other Globalization Indicators

In the modern world economy, production is more often globalized (i.e., value is added to a product in more than one nation) than in the past and less often vertically integrated (i.e., conducted under the auspices of a single company and its subsidiaries). These trends have affected all industries, but their impact has been particularly strong in electronic, ICT, and other KTI manufacturing and service industries. The broader context is the rapid expansion of these industrial and services capabilities in many developing countries, both for export and internal consumption.

Global high-technology trade volume has risen faster than global production, indicating the growing importance of international suppliers of intermediate goods that are then used in the assembly of the final products purchased by the consumer. Data on multinational companies and cross-border investment likewise indicate growing interconnection among the world's economies.

This discussion of trade trends in high-technology manufactured products focuses on the United States, the EU, Japan, the Asia-9, and China. Europe and East Asia have a substantial volume of intraregional trade that is treated differentially in this section. Intra-EU exports are excluded because the EU is an integrated trading bloc with common external trade tariffs and few restrictions on intra-EU trade. Trade between China and Hong Kong is excluded because it is essentially intracountry trade. The substantial intra-Asia-9 trade is included because the group is not an integrated economy. Analytically, this allows delineation of a developing Asia-9/China supplier and manufacturing zone of high-technology goods that are largely destined for export to the EU, the United States, and Japan.

Trade data are an imperfect indicator of where value is added to a product. When the United States imports an ICT

Trends in Industries Not Classified as Services or Manufacturing

Agriculture, construction, mining, and utilities are not classified as either manufacturing or service industries and are not categorized by their level of technology or knowledge intensity. However, these industries are dependent on or use science and technology. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining is dependent on earth sciences, and utilities rely on advances in energy science.

The United States ranks first in mining, second in construction and utilities behind the EU, and fourth in agriculture as measured by share of global value added among the five major economies (table 6-B). The U.S. share rose from 18% to 22% in construction over the decade, and its share in the other three industries remained stable. The EU's share rose or was steady in construction and utilities but fell substantially in mining and agriculture. Japan's share fell sharply in all of these industries. China had gains across all industries, particularly agriculture and utilities. The Asia-9's shares were stable or slightly higher.

Table 6-B
Share of global value added for selected industries, by region/country/economy: Selected years, 1995–2007
(Percent distribution)

Industry and region/country/economy	1995	1997	1999	2001	2003	2005	2007
Agriculture							
Global value added (current $billions)	1,113.3	1,150.1	1,033.4	1,003.9	1,167.6	1,390.0	1,835.8
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	8.4	9.6	9.1	9.8	9.8	9.6	9.1
EU	21.9	19.4	19.5	18.1	18.7	16.8	15.8
Japan	9.2	6.6	7.9	6.9	6.1	5.0	3.6
China	13.1	15.2	17.3	19.0	18.0	20.3	21.3
Asia-9	19.4	19.3	19.3	18.8	18.9	18.9	19.5
All other countries	28.0	30.0	26.9	27.4	28.5	29.5	30.7
Construction							
Global value added (current $billions)	1,626.4	1,587.7	1,591.6	1,607.5	1,846.3	2,311.3	2,775.2
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	17.6	21.3	25.5	29.2	26.9	26.2	22.0
EU	30.0	27.5	28.3	26.8	31.7	31.9	34.3
Japan	26.8	21.6	21.1	18.2	15.1	12.5	9.4
China	3.2	4.1	4.5	4.9	5.2	5.6	6.7
Asia-9	7.9	8.6	6.2	6.0	6.7	7.5	8.4
All other countries	14.6	16.9	14.4	14.9	14.3	16.3	19.3
Mining							
Global value added (current $billions)	469.7	552.0	462.6	600.4	748.3	1,305.1	1,695.3
United States	15.8	16.8	18.5	19.8	19.2	17.1	16.2
EU	15.4	12.2	13.0	11.5	10.5	8.5	7.6
Japan	1.9	1.2	1.2	0.9	0.6	0.3	0.3
China	7.2	9.4	11.6	10.3	10.8	9.6	10.2
Asia-9	7.9	7.6	7.9	7.6	7.4	6.8	7.0
All other countries	51.9	52.8	47.8	49.9	51.5	57.6	58.6
Utilities							
Global value added (current $billions)	718.9	693.8	700.1	687.3	795.7	961.7	1,149.7
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	25.2	25.9	26.5	29.4	27.6	24.9	24.5
EU	26.6	25.6	24.5	21.2	25.2	25.7	26.0
Japan	25.4	21.8	23.4	22.4	19.3	16.3	12.6
China	2.7	3.9	5.0	5.5	6.0	9.2	10.3
Asia-9	5.1	5.7	5.5	5.9	6.1	5.8	6.1
All other countries	15.0	17.1	15.1	15.6	15.8	18.1	20.5

EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Table 6-1
Global value added for selected service industries, by region/country/economy: Selected years, 1995–2007
(Percent distribution)

Service industry and region/country/economy	1995	1997	1999	2001	2003	2005	2007
Wholesale and retail							
Global value added (current $billions)	3,575.8	3,601.9	3,683.1	3,717.3	4,242.7	5,020.3	5,899.8
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	27.2	30.4	32.9	34.9	32.7	30.8	28.8
EU	27.0	25.7	25.9	24.4	27.8	27.7	28.4
Japan	23.5	18.9	18.7	16.5	14.5	13.4	10.8
China	2.2	2.9	3.1	3.6	3.9	4.1	4.6
Asia-9	5.8	6.2	5.6	5.9	6.1	6.8	7.6
All other countries	14.3	15.9	13.8	14.6	15.1	17.2	19.9
Real estate							
Global value added (current $billions)	2,570.2	2,606.8	2,755.7	2,889.0	3,371.9	3,929.9	4,623.7
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	31.7	34.8	36.9	40.5	37.8	36.3	34.3
EU	31.6	30.0	29.3	26.9	31.4	32.6	35.0
Japan	21.9	17.7	18.1	16.8	15.3	13.9	11.3
China	1.4	1.7	1.9	2.2	2.4	2.7	3.3
Asia-9	3.2	3.5	3.1	3.1	3.1	3.3	3.5
All other countries	10.2	12.2	10.7	10.6	10.0	11.2	12.5
Transport and storage							
Global value added (current $billions)	1,207.6	1,206.2	1,237.8	1,255.9	1,452.9	1,775.4	2,147.4
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	18.7	21.0	23.2	23.6	21.8	20.5	19.0
EU	29.9	29.1	29.7	28.0	32.1	31.7	32.3
Japan	23.2	17.4	17.1	15.4	13.8	11.8	9.4
China	3.8	4.7	5.5	7.0	6.6	7.4	8.1
Asia-9	6.6	7.0	6.4	6.5	6.9	7.6	8.3
All other countries	17.8	20.8	18.0	19.5	18.9	21.0	22.9
Restaurants and hotels							
Global value added (current $billions)	706.8	734.1	787.1	806.2	934.3	1,116.1	1,336.3
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	26.3	29.4	31.0	33.0	31.2	29.9	28.4
EU	29.4	28.7	29.4	27.8	32.1	32.6	33.7
Japan	21.6	17.4	17.0	15.2	14.0	12.5	10.4
China	2.7	3.5	3.7	4.3	4.2	4.8	5.6
Asia-9	6.1	6.3	5.2	5.5	5.6	5.9	6.6
All other countries	13.8	14.7	13.7	14.2	12.9	14.2	15.3

EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

good that is assembled in China from components that, in turn, are imported from other Asian economies, China's value added may be small because its contribution is limited to final assembly of the good (Koopman, Wang, and Wei 2008). Much of the value added may originate from Asian, EU, or U.S. firms that manufactured the components or conducted design, marketing, software development, and other activities. The factory price and shipping cost of the good, however, would be fully credited to China's exports and U.S. imports. Accurately apportioning value added is fraught with difficulties (see sidebar, "Tracing the Geography of the Value Chain of Products").

Trade of High-Technology Goods

A country's success in exporting its goods to other countries is one measure of its comparative economic advantage—the goods it produces are provided not just to its local market but are also competitive in a world market.

The gross value of global exports of high-technology products—communications and semiconductors, computers and office machinery, pharmaceuticals, scientific instruments, and aerospace—reached $2.9 trillion in 2008, up from $915 billion in 1995 (appendix table 6-19).[12] (See sidebar, "Product Classification and Determination of Country of Origin of Trade Goods" for discussion on how trade goods

Table 6-2

Global value added for manufacturing industries, by selected technology level and region/country/economy: Selected years, 1995–2007

(Percent distribution)

Manufacturing technology level and region/ country/economy	1995	1997	1999	2001	2003	2005	2007
Medium high							
Global value added (current $billions)	1,394.7	1,343.5	1,313.1	1,251.6	1,462.2	1,747.8	2,127.1
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	22.5	24.9	26.7	26.6	23.3	19.3	17.4
EU	31.5	31.0	31.2	29.7	32.7	31.9	32.3
Japan	23.9	20.4	20.6	19.0	17.5	16.9	13.3
China	2.7	3.6	3.5	5.0	7.1	10.2	13.4
Asia-9	6.5	6.7	5.9	6.7	7.2	8.1	8.6
All other countries	12.9	13.4	12.1	13.1	12.3	13.7	15.0
Medium low							
Global value added (current $billions)	1,352.5	1,325.3	1,277.5	1,257.9	1,464.9	1,981.5	2,518.8
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	19.1	22.0	23.8	24.0	20.7	19.3	16.1
EU	31.2	29.5	30.2	28.3	30.3	28.0	28.1
Japan	23.8	19.9	18.9	17.5	15.6	13.5	9.8
China	3.5	3.9	4.1	5.6	7.4	10.0	14.2
Asia-9	7.6	8.2	7.4	7.6	8.1	9.0	9.5
All other countries	14.8	16.5	15.5	17.0	17.8	20.1	22.3
Low							
Global value added (current $billions)	1,809.3	1,766.6	1,792.2	1,743.3	1,942.2	2,229.1	2,549.7
All countries	100.0	100.0	100.0	100.0	100.0	100.0	100.0
United States	24.7	26.9	30.2	31.3	28.7	26.1	23.0
EU	31.5	30.2	29.5	27.3	30.4	29.7	29.8
Japan	18.8	14.8	15.0	13.9	12.1	10.7	8.3
China	2.9	4.1	4.0	5.1	6.3	8.7	11.9
Asia-9	6.0	6.3	5.7	5.7	5.8	6.0	6.5
All other countries	16.1	17.7	15.7	16.7	16.8	18.7	20.4

EU = European Union

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Technology level of manufacturing classified by Organisation for Economic Co-operation and Development on basis of R&D intensity of output. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Industry Service database, special tabulations (2009).

Science and Engineering Indicators 2010

are classified.) Removing intrabloc (within the EU) and intracountry (China to Hong Kong) exports reduces these totals to $732 billion in 1995 and an estimated $2.3 trillion in 2008—base figures for the analyses that follow (figure 6-16). Among the five high-technology products, the world export value was greatest in communications and semiconductors (45% of the total) followed by computers (20%), giving the ICT products about two-thirds of the total (figure 6-17; appendix tables 6-20 through 6-24).

The threefold increase in exports was greater than the rise in global production of these industries over the period, from $2.0 trillion to $4.0 trillion (figure 6-16). This probably reflects the broadened geographic base of high-technology manufacturing overall, the expansion of multinational firms' production to overseas venues, and the shift of production from vertically integrated firms to greater reliance on international external suppliers.

Global Trade Balance Trends in High-Technology Manufactures

The expansion of high-technology trade has led to changes in the relative positions of the developed and developing countries (figure 6-18; appendix table 6-19). Measured in relative volume of exports, the U.S. position has declined from 21% in 1995 to 14% in 2008, reflecting broad drops in exports of U.S. ICT goods (communications and semiconductors and computers and office machinery), which account for nearly 45% of the nation's high-technology exports (figure 6-19; appendix tables 6-19 through 6-21). (See sidebar, "Product Classification and Determination of Country of Origin of Trade Goods," for discussion of how exports are credited to countries.) Japan's share declined steadily over the period, from 18% to 8%, again largely because of declining exports of ICT goods. The EU's high-technology export share remained approximately stable at 16%–18%.

Amidst a great increase in world exports, China's share surged from 6% to 20% over little more than a decade,

Product Classification and Determination of Country of Origin of Trade Goods

The characteristics of goods in international trade are determined from a product perspective. Data on product trade are first recorded at the country's ports of entry. Each type of product is assigned a product trade code by the customs agent according to the harmonized system.[*] Exporters generally identify the product being shipped and include its proper code. Because many imported products are assessed an import duty and these duties vary by product category, a customs agent for the receiving country inspects or reviews the shipment to make the final determination of the proper product code and country of origin. The value of products entering or exiting U.S. ports may include the value of components, inputs, or services classified in different product categories or originating from other countries than the country of origin.

Data on international product trade assign products to a single country of origin. For goods manufactured with international components, the country of origin is determined by where the product was "substantially transformed" into its final form. For example, a General Motors car that was assembled in the United States with components imported from Germany and Japan and that is destined for export to Canada will be labeled "Made in the USA." The country where the product was "substantially transformed" may not be the location where the most value was added.

---

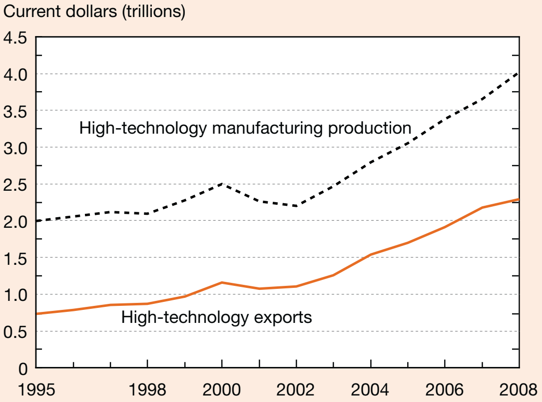
[*] The Harmonized Commodity Description and Coding System, or Harmonized System (HS), is a system for classifying goods traded internationally that was developed under the auspices of the Customs Cooperation Council. Beginning on 1 January 1989, HS numbers replaced previously adhered-to schedules in more than 50 countries, including the United States.

making it the largest single exporting country for high-technology manufactured goods (figure 6-18; appendix table 6-19). The Asia-9 region has maintained its position at more than a quarter of the total. However, this largely reflects the rise of a manufacturing supplier zone around China that is focused on ICT goods (see "Trends in the Geographic Distribution of Bilateral High-Technology Trade," later in this chapter).

Notable differences are apparent in the export performance of these countries and regions for the five products (figure 6-19; appendix tables 6-20 through 6-25). The United States and Japan have been losing export shares in most industries, with the exception of the U.S. aerospace share, which has fluctuated at about 50%. EU shares have held approximately steady, with strong market shares for pharmaceuticals, aerospace, and scientific instruments. China's market shares have grown substantially since 2000,

Figure 6-16

Global production of high-technology manufacturing industries and exports of high-technology products: 1995–2008



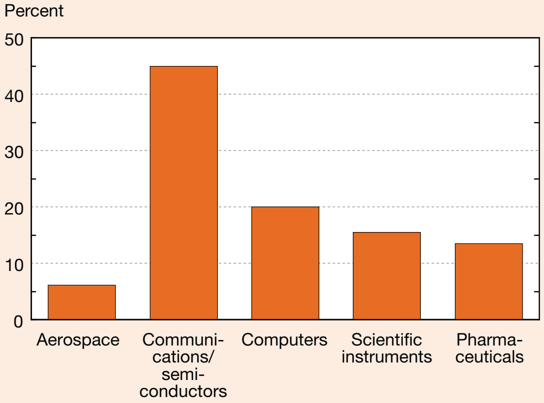
NOTES: Production is gross revenue, which includes purchases of domestic and imported materials and inputs. High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. High-technology manufacturing production on industry basis. High-technology exports on product basis.

SOURCE: IHS Global Insight, World Industry Service and World Trade Service databases, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 6-17

Distribution of global exports of high-technology products: 2008

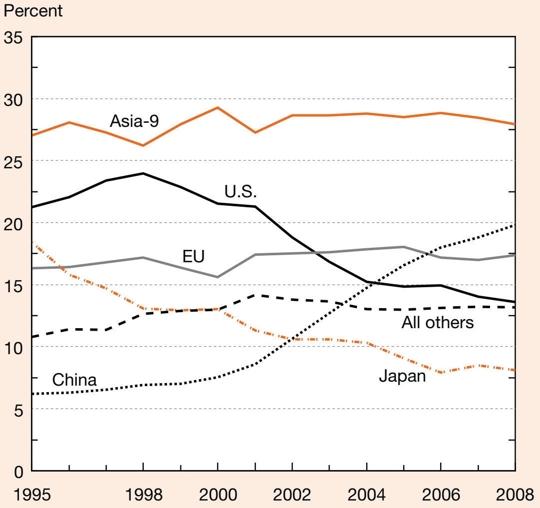


NOTES: High-technology exports on product basis and include aerospace, communications and semiconductors, computers and office machinery, scientific instruments and measuring equipment, and pharmaceuticals.

SOURCE: IHS Global Insight, World Industry Service and World Trade Service databases, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 6-18
Global exports of high-technology products, by selected region/country/economy: 1995–2008



NOTES: High-technology products include aerospace, communications and semiconductors, computers and office machinery, scientific instruments and measuring equipment, and pharmaceuticals. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. China's exports exclude exports between China and Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. EU exports exclude exports among EU member countries.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

capturing almost 40% of the world export market in computers and office machinery and showing strong growth in semiconductors export shares (but negligible shares in aerospace and pharmaceuticals). The Asia-9 region accounts for large shares of semiconductor and computer exports and, together with China, captured more than 60% of the world export market share in these industries.

Throughout the 1980s and into the mid-1990s, the United States consistently exported more high-technology products than it imported, in contrast to deficits recorded for other U.S. manufacturing products.[13] A growing U.S. import volume in the late 1990s shifted the U.S. high-technology trade balance from surplus to deficit (figure 6-20 and appendix table 6-19). In 2000, the deficit was $32 billion in current dollars; by 2008, the deficit had widened to $80 billion.

ICT goods are driving the U.S. high-technology trade deficit: In 2008, the ICT industries ran a deficit of almost $120 billion in current dollars (figure 6-20; appendix table 6-26). The emergence of large deficits in these products reflected rising domestic demand, which coincided with a broad shift in location of the production of ICT goods to developing countries, largely in Asia. This, in turn, stimulated imports of ICT goods from these countries. Pharmaceuticals contributed a further $21 billion to the overall 2008 deficit (appendix table 6-23).

U.S. trade in aerospace products registered a trade surplus of $50 billion in 2008, continuing its trend of surpluses for the past two decades; trade in scientific instruments added a smaller surplus of $9 billion (appendix tables 6-22 and 6-24).

The EU high-technology trade balance remained roughly stable, with a deficit of about $20 to $50 billion over this period (figure 6-20; appendix table 6-19). However, the EU ICT deficit grew from $38 billion in 1995 to $117 billion in 2008, reflecting the same underlying structural shift (appendix table 6-26). Rising surpluses in aerospace, pharmaceuticals, and scientific instruments offset the increasing ICT deficit (appendix tables 6-22 through 6-24).

The trade positions of China and the Asia-9 also changed substantially. China's trade position, which had been in balance for much of the 1980s and 1990s, moved to a surplus after 2001 (figure 6-20; appendix table 6-19) and rapidly increased from less than $13 billion in 2003 to almost $130 billion in 2008, driven by the ICT goods trade (appendix table 6-26). The Asia-9's trade surplus grew from about $50 billion to more than $220 billion over the past decade, entirely due to an expansion of its surplus in ICT goods (however, see the next section). Japan's surplus showed little change, despite its loss of market share in production of high-technology industries.

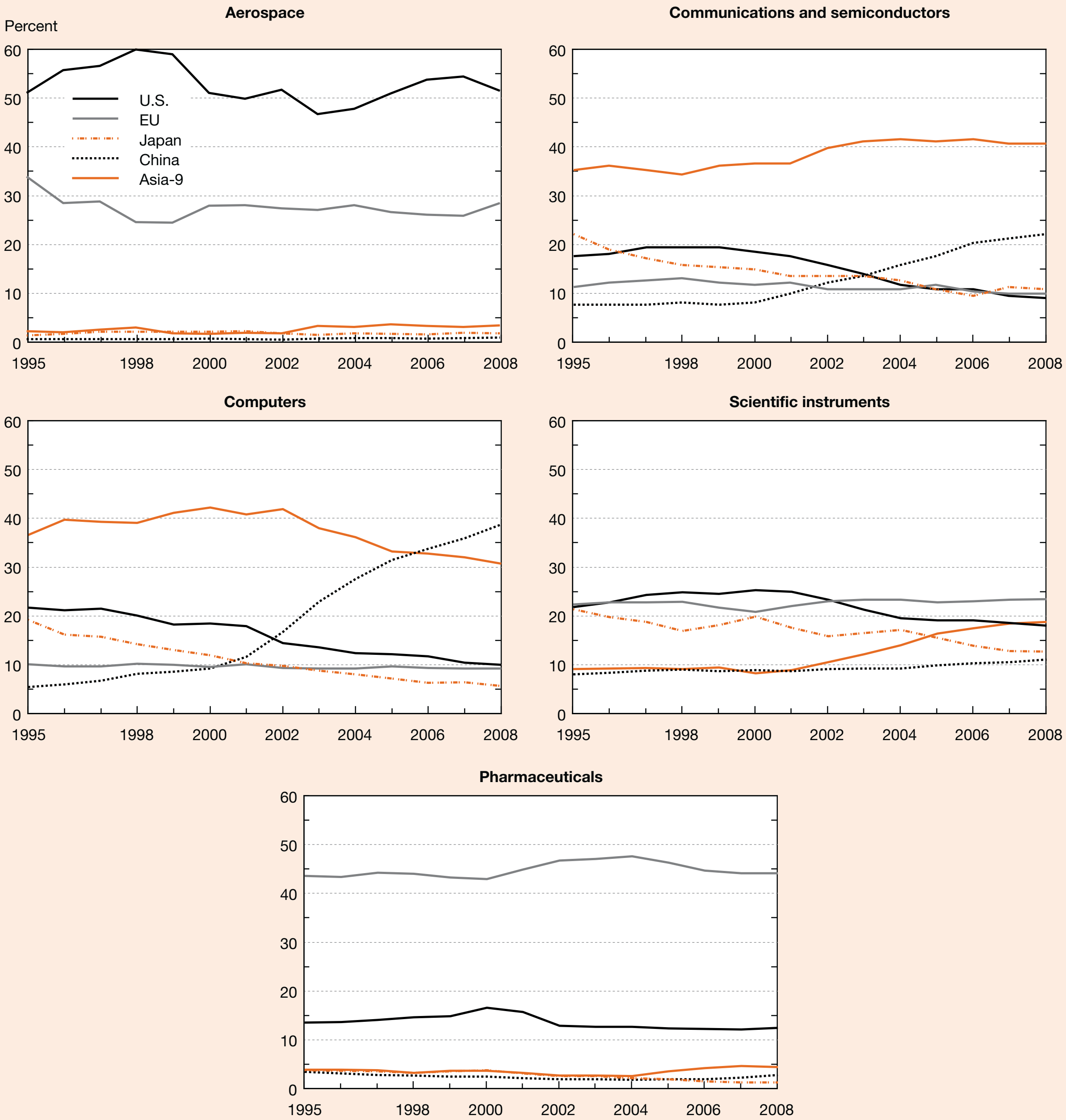
Geographic Distribution of Bilateral High-Technology Trade

The shift in trade in global high-technology manufactures over the past decades (i.e., the shift away from the developed regional/national economies to China and the Asia-9) was accompanied by a pronounced shift in the distribution of bilateral trade among these and the three other economies—the United States, the EU, and Japan. Trade in ICT goods, the largest single category of high-technology industry goods, illustrates these shifting patterns.

Final assembly of ICT goods and components shifted—from the United States, the EU, Japan, and developed economies among the Asia-9—toward China early in this decade, and some assembly work has subsequently shifted from China to the less-developed Asia-9 economies (Athukorala and Yamashita 2006, Ng and Yeats 2003, Rosen and Wing 2005). This discussion examines trends in bilateral trade distribution of ICT goods.

The rise of China as the world's major assembler and exporter of many electronic goods is reflected by a sharp increase in China's share of ICT imports in the United States, the European Union, and Japan (figure 6-21; appendix tables 6-27 through 6-29). China's share of these economies' ICT imports was 40%–50% in 2008, compared with 10% or less in 1995. Data on China's bilateral exports show that about 65% of its ICT exports were shipped to the United States, Japan, and the EU, suggesting that most of China's exports are finished products destined primarily for developed countries (figure 6-22; appendix table 6-30). The trends for China's

Figure 6-19
Region/country/economy share of global exports of selected high-technology products: 1995–2008



EU = European Union

NOTES: High-technology products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

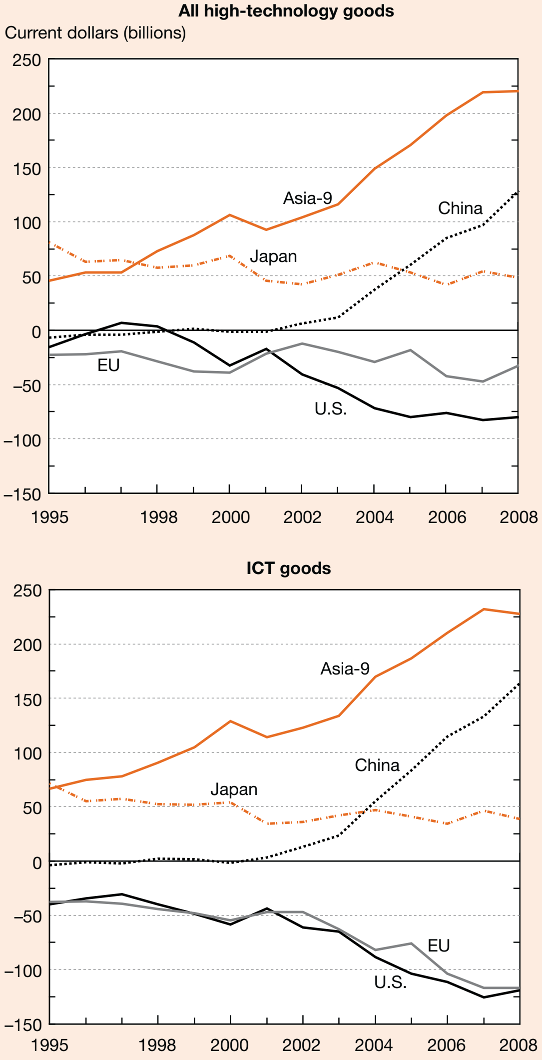
Science and Engineering Indicators 2010

ICT exports by share of developed economy showed little change over time.

Trends in data regarding China's imports and the Asia-9's exports of ICT goods suggest that much of final assembly has shifted to China, with the Asia-9 acting as key suppliers of components and inputs. The Asia-9's share of China's ICT imports rose from 40% in 1995 to 71% in 2008 (figure 6-22; appendix table 6-30). Imports from Taiwan increased

Figure 6-20

Trade balance of high-technology and ICT products, by selected region/country/economy: 1995–2008



EU = European Union; ICT = information and communications technology

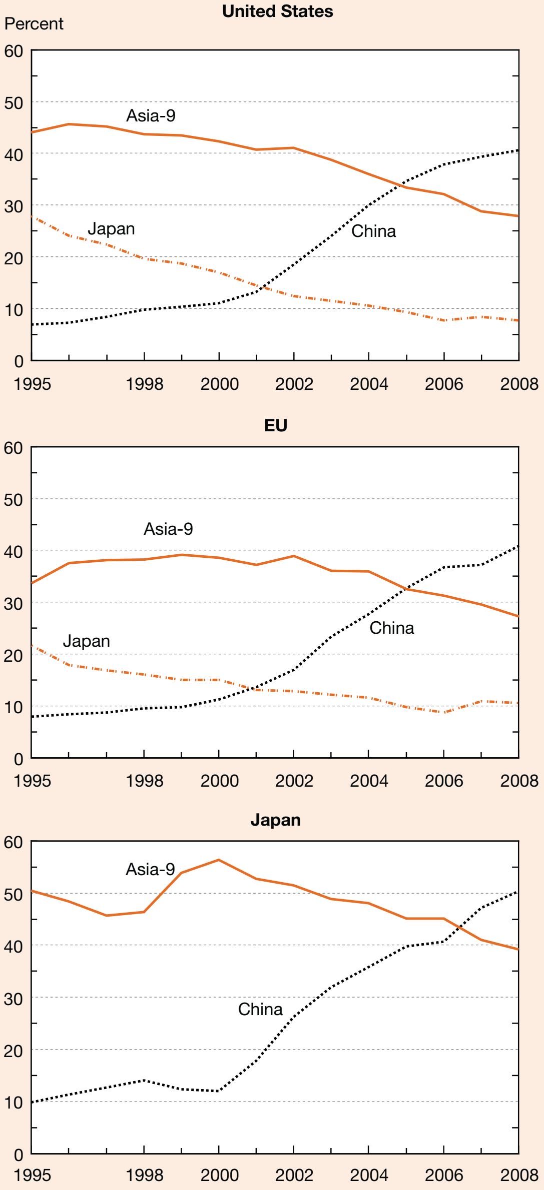
NOTES: High-technology products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, scientific instruments and measuring equipment. ICT products include communications services, computer and related services, communications and semiconductors, and computers and office machinery. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

Figure 6-21

United States', EU's, and Japan's imports of ICT products, by share of selected region/country/economy of origin: 1995–2008



EU = European Union; ICT = information and communications technology

NOTES: ICT products include communications and semiconductors and computers and office machinery. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

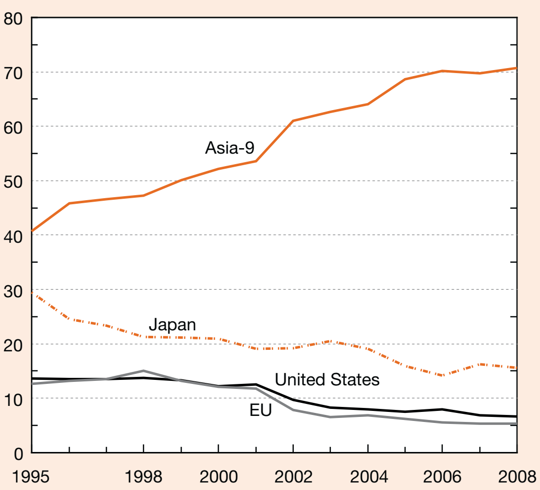
the most, from 11% to 23% of China's total ICT imports. South Korea's and the Philippines' shares also increased by about 5 percentage points each, reaching 14% and 5%, respectively; Singapore's share was stable. However, Japan's share of China's imports fell from 30% to 16%.

Japan's ICT export data show a pronounced shift toward China, rising from a 10% share of its ICT export goods to 28% since 1995 (figure 6-23; appendix table 6-29). The share of Japanese exports to the United States fell sharply over the period, from 36% to 15%; its share to the Asia-9

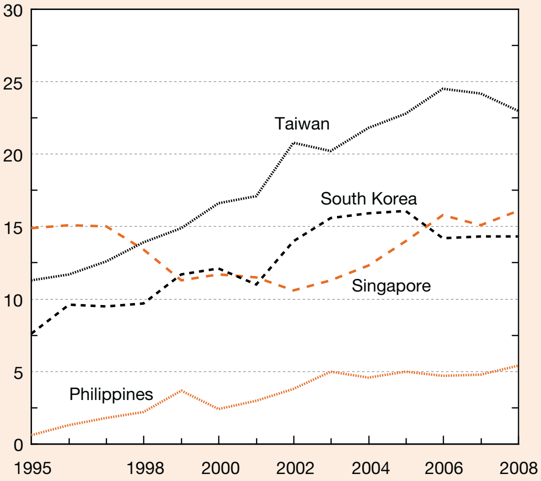
Figure 6-22

China's imports of ICT products, by share of selected region/country/economy of origin: 1995–2008

Major country/economy



Asian economy



EU = European Union; ICT = information and communications technology

NOTES: ICT products include communications and semiconductors and computers and office machinery. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Luxembourg, Malta, and Slovenia.

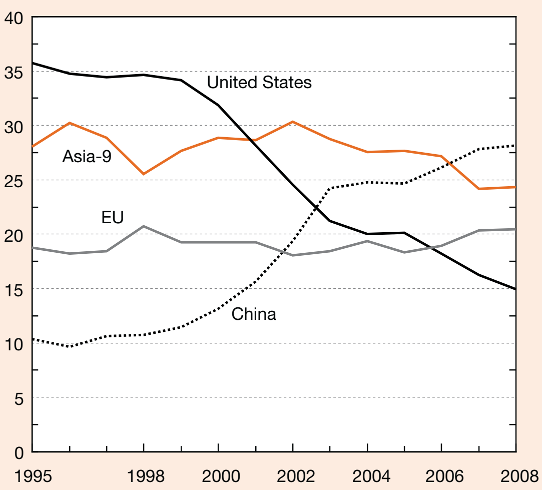
SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

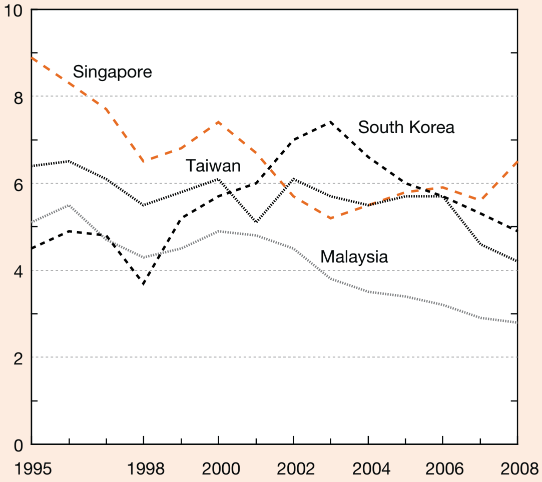
Figure 6-23

Japan's exports of ICT products, by share of selected region/country/economy of destination: 1995–2008

Major country/economy



Asian economy



EU = European Union; ICT = information and communications technology

NOTES: ICT products include communications and semiconductors and computers and office machinery. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

was steady at about 25% (figure 6-21; appendix tables 6-27 and 6-31). These patterns are consistent with reports that Japanese (and Taiwanese) manufacturers began exporting components for assembly in plants they established in China. U.S. purchases of ICT goods from Japan may have been supplanted by goods assembled in and shipped from China for Japanese and Taiwanese firms.

The Asia-9's bilateral export data are consistent with China's import data showing the rise of the Asia-9 as a major supplier to China's ICT manufacturing industries. China's share of the Asia-9's exports nearly quadrupled from 8% to 31% over the decade (figure 6-24; appendix table 6-31). China's share growth was strongest in the exports of South Korea (from 8% to 30%), Taiwan (from 12% to 43%), Singapore (from 10% to 29%), and the Philippines (from 5% to 38%) (figures 6-24 and 6-25; appendix tables 6-32 through 6-35). The share of Asia-9's ICT exports going directly to the United States or the EU fell sharply during this period (appendix tables 6-27 and 6-28).

The data indicate that the Asia-9 countries/economies have come to be assemblers and exporters of both intermediate and finished ICT goods, the former going to China and other Asia-9 destinations, the latter largely to the United States, the EU, and other developed nations. The intra-Asia-9 share of Asia-9 ICT imports rose from 36% to 46% over the past decade (figure 6-26; appendix table 6-31), coinciding with a sharp increase (from 7% to 26%) in imports from China. This is consistent with the Asia-9 countries/economies importing components from China for final or intermediate assembly and re-exporting them back to China for final assembly and export.

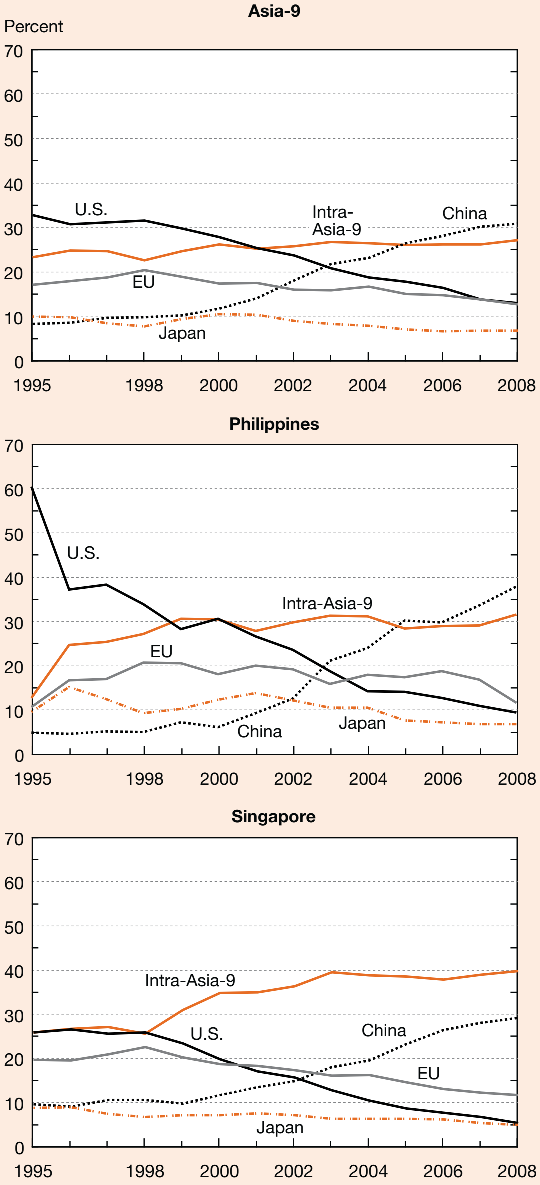
The Asia-9 countries/economies—particularly Malaysia, South Korea, Taiwan, and Singapore—remain substantial suppliers of ICT goods to the EU and the United States (about 30% each) and to Japan (39%) (figure 6-24; appendix tables 6-31 and 6-33 through 6-36).

Exports of Medium- and Low-Technology Manufactured Products

The U.S. export performance in products associated with less knowledge intensity and less use of R&D provides a context for its high-technology status. In these industries, the United States has historically had lower world export shares, although some convergence, which largely reflects declines in the U.S. high-technology share, has been evident since the late 1990s.

The U.S. share of world exports in medium-high-technology products (i.e., motor vehicles, chemicals, railroad equipment) was 14% in 2008, which was equal to its share in high-technology industries (table 6-3) and which placed it fourth behind the EU (24%, excluding intra-EU trade) and Japan and the Asia-9 (15% each). The U.S. and EU shares have remained stable over the past decade, whereas Japan's share has fallen from 22% to 15%. China, ranked fifth, has rapidly expanded its share of global exports from 4% to 13% (excluding trade between China and Hong Kong).

Figure 6-24
Asia-9, Philippines, and Singapore's exports of ICT products, by share of selected region/country/economy of destination: 1995–2008



Asia-9

Philippines

Singapore

EU = European Union; ICT = information and communications technology

NOTES: ICT products include communications and semiconductors and computers and office machinery. Intra-Asia-9 is trade among Asia-9 countries/economies. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

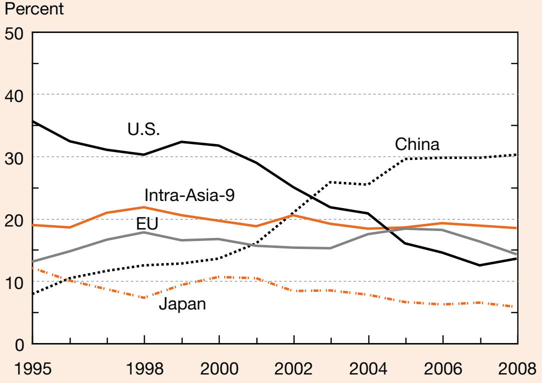
SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

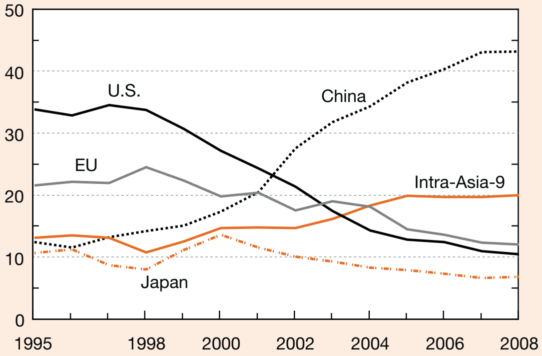
Figure 6-25

South Korea's, Malaysia's, and Taiwan's exports of ICT products, by share of selected region/country/economy of destination: 1995–2008

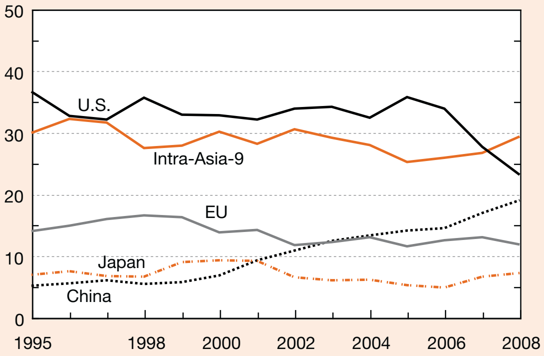
South Korea



Taiwan



Malaysia



EU = European Union; ICT = information and communications technology

NOTES: ICT products include communications and semiconductors and computers and office machinery. Intra-Asia-9 is trade among Asia-9 countries/economies. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

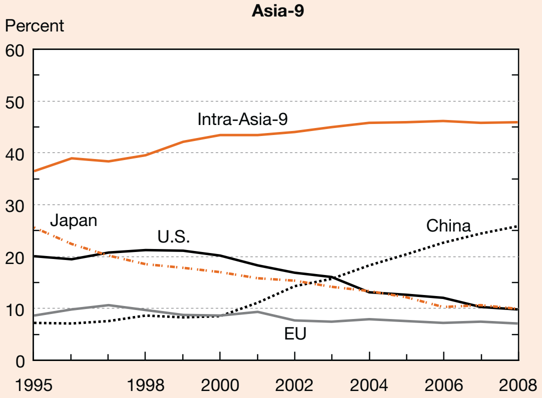
SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

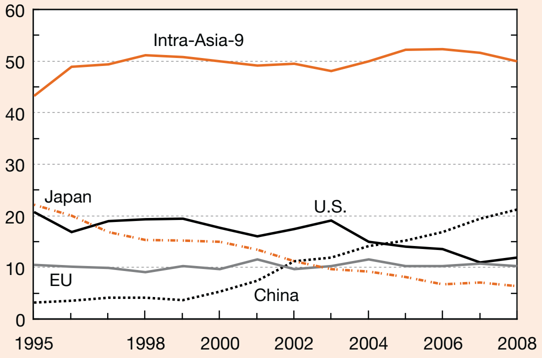
Figure 6-26

Asia-9's, Malaysia's, and Singapore's imports of ICT products, by share of selected region/country/economy of origin: 1995–2008

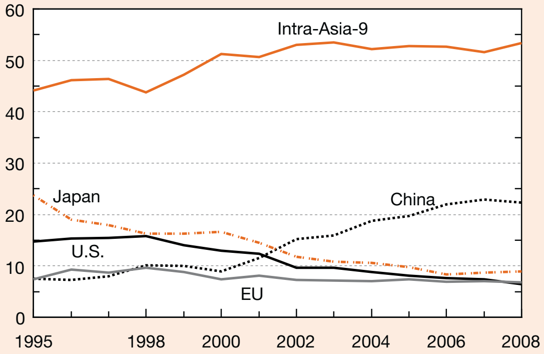
Asia-9



Malaysia



Singapore



EU = European Union; ICT = information and communications technology

NOTES: ICT products include communications and semiconductors and computers and office machinery. Intra-Asia-9 is trade among Asia-9 countries/economies. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (15 January 2009).

Science and Engineering Indicators 2010

Table 6-3
Exports of manufactured products, by selected technology level and region/country/economy: Selected years: 1995–2008
(Percent distribution)

Manufacturing technology level and region/country/economy	1995	1998	2001	2004	2006	2008
Medium high						
Global exports (current $billions)	630.4	697.0	805.7	1,171.6	1,477.8	1,812.0
All countries	100.0	100.0	100.0	100.0	100.0	100.0
United States	17.3	18.0	16.8	14.0	14.2	14.1
EU	25.5	25.2	24.4	24.6	23.4	23.7
Japan	21.7	19.2	17.4	17.2	16.0	15.2
China	3.9	4.9	6.5	8.8	10.8	12.8
Asia-9	11.3	10.6	12.2	14.9	15.1	15.2
All other countries	20.2	22.2	22.6	20.6	20.5	19.0
Medium low						
Global exports (current $billions)	396.2	413.4	480.5	816.2	1,258.6	1,769.3
All countries	100.0	100.0	100.0	100.0	100.0	100.0
United States	10.8	12.3	11.8	8.3	8.2	8.4
EU	20.7	20.1	17.7	16.9	16.1	15.8
Japan	13.2	11.2	9.1	8.2	6.9	6.6
China	5.2	6.0	7.1	9.4	10.5	12.7
Asia-9	15.8	17.2	16.9	18.5	18.6	18.0
All other countries	34.3	33.2	37.6	38.7	39.6	38.5
Low						
Global exports (current $billions)	559.7	561.0	626.4	818.9	993.3	1,235.7
All countries	100.0	100.0	100.0	100.0	100.0	100.0
United States	14.5	14.7	14.0	11.8	11.9	12.0
EU	20.7	20.5	19.1	19.7	18.4	18.3
Japan	3.8	3.8	3.6	3.0	2.7	2.5
China	12.1	13.6	15.3	17.9	20.3	21.8
Asia-9	20.1	18.3	18.5	16.8	16.5	16.2
All other countries	28.8	29.1	29.5	30.9	30.1	29.3

EU = European Union

NOTES: Global exports exclude intra-EU exports and exports between China and Hong Kong. EU exports exclude intra-EU exports, and China exports exclude exports between China and Hong Kong. Manufacturing technology level classified by Organisation for Economic Co-operation and Development. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Luxembourg, Malta, and Slovenia. Percents may not add to 100% because of rounding.

SOURCE: IHS Global Insight, World Trade Service database, special tabulations (2009).

Science and Engineering Indicators 2010

The United States also ranks fourth (8%) in share of world exports in medium-low-technology products (table 6-3), behind the EU and the Asia-9 (16% and 18%, respectively) and China (13%). U.S. export share in low-technology products in 2008 (at 12%) also placed it fourth behind China (22%), the EU (18%), and the Asia-9 (16%). In both of these industry groups, China's world export share expanded greatly since the mid-1990s but not to the same degree as for high-technology exports.

U.S. Trade in Advanced Technology Products

The Census Bureau has developed a classification system for internationally traded products that embody new or leading-edge technologies. This classification system has significant advantages for determining whether an industry and its products are high technology and may be a more precise and comprehensive measure than the industry-based OECD classification.

This system allows a highly disaggregated, focused examination of technologies embodied in U.S. imports and exports. It categorizes trade into 10 major technology areas:

- **Advanced materials**—the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- **Aerospace**—the development of aircraft technologies, such as most new military and civil airplanes, helicopters, spacecraft (excluding communications satellites), turbojet aircraft engines, flight simulators, and automatic pilots.
- **Biotechnology**—the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses.
- **Electronics**—the development of electronic components (other than optoelectronic components), including

integrated circuits, multilayer printed circuit boards, and surface-mounted components (such as capacitors and resistors) that improve performance and capacity and, in many cases, reduce product size.

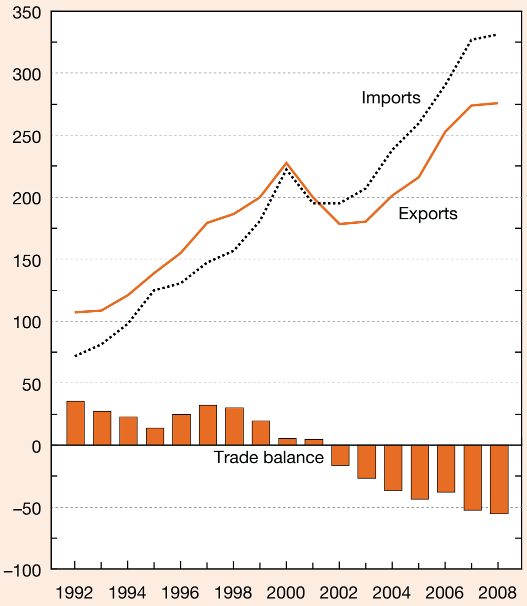
- **Flexible manufacturing**—the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Information and communications**—the development of products that process increasing amounts of information in shorter periods of time, including computers, video conferencing, routers, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software.
- **Life sciences**—the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing techniques, have led to new products that help control or eradicate disease.
- **Optoelectronics**—the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- **Nuclear**—the development of nuclear production apparatus (other than nuclear medical equipment), including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges. (Nuclear medical apparatus is included in the life sciences rather than this category.)
- **Weapons**—the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.

U.S. trade in advanced technology products is an important component of overall U.S. trade, accounting for about one-fifth of total trade volume for the past two decades. In 2008, U.S. exports of advanced technology products were $276 billion (nearly 21% of goods exports) and imports were $331 billion (16% of total goods imports) (figures 6-27 and 6-28 and appendix table 6-37). As with high-technology industries trade accounts, imports of advanced technology products grew faster than exports since the early 1990s, sending the U.S. trade balance in these products into deficit in 2002 (figure 6-28). By 2008, the deficit reached $56 billion, comprising 7% of the total U.S. goods trade deficit ($816 billion).

Changes in exchange rates may have been a contributing factor to these trends because the U.S. dollar's value against a basket of its major trading partners' currencies appreciated more than 60% between the early 1990s and 2002, coinciding with the shift from surplus to deficit (figure 6-28). However, the dollar depreciated about 20% through 2008, and the deficit continued to widen.

Figure 6-27
U.S. advanced technology product trade: 1992–2008

Current U.S. dollars (billions)



NOTE: U.S. advanced technology product trade classified by Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life sciences, optoelectronics, nuclear, and weapons.

SOURCE: Census Bureau, Foreign Trade Statistics, Country and Product Trade Data, Advanced Technology Products, http://www.census.gov/foreign-trade/statistics/product/index.html, accessed 15 September 2009.

Science and Engineering Indicators 2010

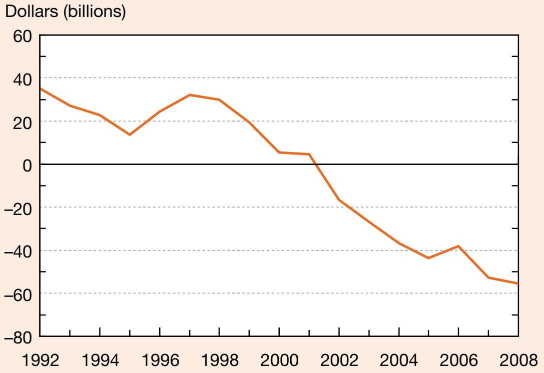
It is likely that the growing deficit was affected by changing world production and trade patterns, adoption of new business and production processes, establishment of productive capacity abroad, and the emergence of export-oriented high-technology industries in Asia and other regions and countries.

U.S. Advanced Technology Product Trade, by Technology

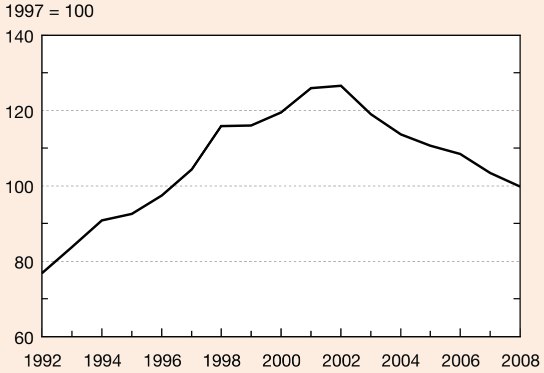
Five technology areas—information and communications, aerospace, electronics, the life sciences, and optoelectronics—accounted for a combined share of about 90% of U.S. advanced technology product trade in 2008 (figure 6-29; appendix tables 6-38 through 6-47). Information and communications had the largest single share (43%), followed by aerospace (21%), electronics (13%), the life sciences (11%), and optoelectronics (5%). Three of these technologies have generated substantial trade deficits: information and communications ($104 billion), optoelectronics ($21 billion), and the life sciences ($15 billion) (figure 6-30). The rapid rise in the overall deficit between 2002 and 2008 was driven by the deficit in ICT, widening from $48 billion to more than

Figure 6-28
U.S. advanced technology product trade balance and trade-weighted exchange rate: 1992–2008

Advanced technology product trade balance



Trade-weighted exchange rate



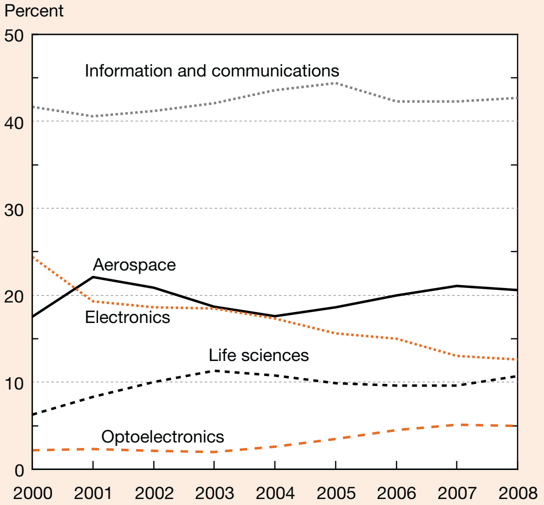
NOTES: Trade-weighted exchange rate is index of U.S. dollar's value against a basket of its major trading partners' currencies. U.S. advanced technology product trade classified by Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life sciences, optoelectronics, nuclear, and weapons.

SOURCES: Census Bureau, Foreign Trade Statistics, Country and Product Trade Data, Advanced Technology Products, http://www.census.gov/foreign-trade/statistics/product/index.html, accessed 15 September 2009; and Federal Reserve Bank of St. Louis, Economic Research, TWEXBMTH, Trade Weighted Exchange Index: Broad, http://research.stlouisfed.org/ fred2/series/TWEXBMTH?cid=105, accessed 7 November 2009.

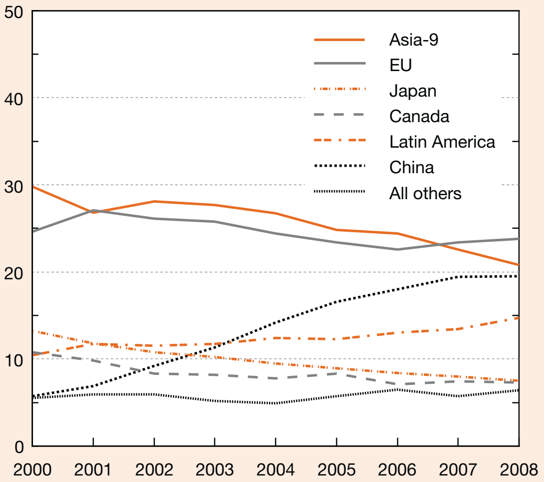
Science and Engineering Indicators 2010

Figure 6-29
U.S. advanced technology product trade, by selected technology and region/country/economy: 2000–08

Technology



Region/country/economy



EU = European Union

NOTE: U.S. advanced technology product trade classified by Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life sciences, optoelectronics, nuclear, and weapons. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. Latin America includes Angilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, French Guiana, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Venezuela, and Uruguay.

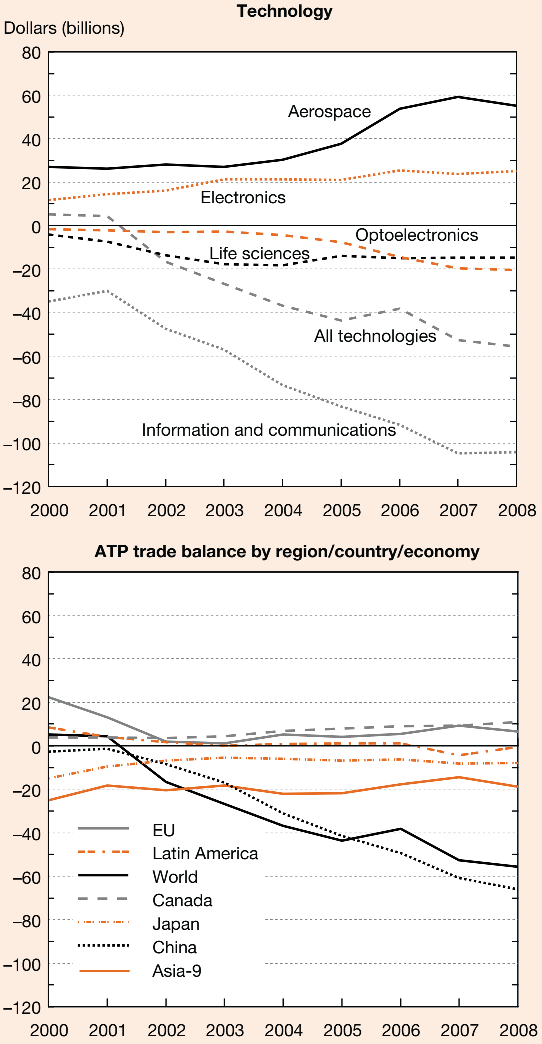
SOURCE: Census Bureau, Foreign Trade Statistics, Country and Product Trade Data, Advanced Technology Products, http://www.census.gov/foreign-trade/statistics/product/index.html, accessed 15 September 2009.

Science and Engineering Indicators 2010

$100 billion. The trend from surplus to deficit is similar to the trend in trade of ICT high-technology products.

Two technologies, aerospace and electronics, have generated significant trade surpluses (figure 6-30; appendix tables 6-38 and 6-39). The United States is the leading producer of aerospace products; it had a trade surplus of $55 billion in 2008 ($28 billion more than in 2000), as exports jumped from $53 billion to $90 billion and imports increased more moderately from $26 billion to $35 billion. The surplus in electronics was $25 billion in 2008 ($13 billion higher than at the beginning of the decade). In this technology, both

Figure 6-30
U.S. advanced technology product trade balance, by selected technology and region/country/economy: 2000–08


Technology

ATP trade balance by region/country/economy

ATP = advanced technology products; EU = European Union

NOTES: U.S. advanced technology product trade classified by Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life sciences, optoelectronics, nuclear, and weapons. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Latin America includes Angilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, French Guiana, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Venezuela, and Uruguay.

SOURCE: Census Bureau, Foreign Trade Statistics, Country and Product Trade Data, Advanced Technology Products, http://www.census.gov/foreign-trade/statistics/product/index.html, accessed 15 September 2009.

Science and Engineering Indicators 2010

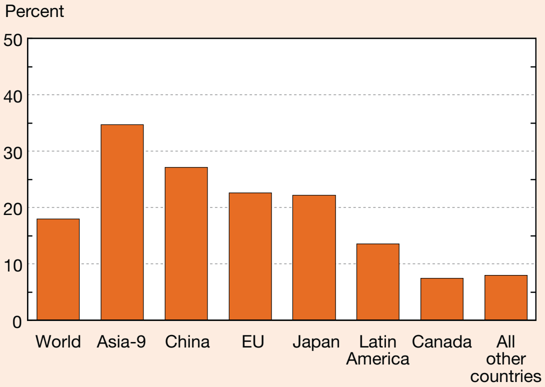
imports and exports fell during the period, but imports declined more steeply.

U.S. Advanced Technology Trade, by Region and Country

The majority of U.S. advanced technology trade occurs with six regions/countries: the EU (24%), the Asia-9 (21%), China (19%), Latin America (15%), Japan (7%), and Canada (7%) (figure 6-29 and appendix table 6-37). U.S. trade with Asia (Asia-9, China, and Japan) accounts for nearly half of total U.S. advanced technology trade. U.S. merchandise trade with Asia also contains a higher-than-average share of advanced technology goods. This share in 2008 was twice the U.S. average for exports to the Asia-9 (35%) and 27% for China. Japan's 22% share equaled that of the EU (figure 6-31).

China and Japan. China exported $92 billion of advanced technology products to the United States (about one-fourth of U.S. imports) and imported $26 billion in 2008. The United States has the largest deficit with China, which is its third largest trading partner among the six regions/countries

Figure 6-31
Advanced technology product share of U.S. merchandise trade, by region/country/economy: 2008



EU = European Union

NOTES: U.S. advanced technology product trade classified by Census Bureau and consists of advanced materials, aerospace, biotechnology, electronics, flexible manufacturing, information and communications, life sciences, optoelectronics, nuclear, and weapons. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. Latin America includes Angilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, French Guiana, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Venezuela, and Uruguay.

SOURCES: Census Bureau, Foreign Trade Statistics, Country and Product Trade Data, Advanced Technology Products, http://www.census.gov/foreign-trade/statistics/product/index.html; and U.S. International Trade in Goods, http://www. census.gov/foreign-trade/statistics/historical/index.html, accessed 15 September 2009.

Science and Engineering Indicators 2010

and the largest single country (figure 6-30; appendix table 6-37). ICT goods account for nearly 90% of U.S. imports of advanced technology products from China (appendix table 6-40). U.S. exports of advanced technology goods include aerospace, electronics, and information and communications (appendix tables 6-38 through 6-40).

The volume of U.S.-China advanced technology trade more than quadrupled over this decade, and in 2003 China surpassed Japan as the United States' single largest country partner in these goods (appendix table 6-37). U.S. imports from China have increased much faster than its exports to China, pushed by a rising trade volume in ICT technologies. The steep rise in imports and flat export growth widened the U.S. deficit with China in information and communications from $6 billion to $75 billion (figure 6-30; appendix table 6-40).

Japan was the largest trading country partner with the United States until it was overtaken by China in 2003 (appendix table 6-37). Information and communications technology constituted nearly half of all U.S. imports from Japan in 2008, similar to its prevalence in imports from China (appendix table 6-40). Among advanced technology exports to Japan, aerospace accounted for the largest share (42%); information and communications products ranked second (18%) (appendix table 6-38).

The Asia-9. The Asia-9's trade was one-fifth of total advanced technology trade volume in 2008 (figure 6-29), with exports of $73 billion to the United States and imports of $54 billion (figure 6-30; appendix table 6-37). Malaysia, Singapore, South Korea, and Taiwan are the Asia-9's major U.S. trading partners. The $19-billion U.S. deficit with the Asia-9 consists of a $12-billion deficit with Malaysia and smaller deficits with South Korea, Taiwan, and Thailand (and a small surplus with Singapore).

As with China, ICT products constituted the largest share of total U.S. advanced technology trade with the Asia-9. Important suppliers are Malaysia ($17 billion), South Korea ($13 billion), and Taiwan ($8 billion) (appendix table 6-40). U.S. imports of $52 billion and exports of $9 billion produced a deficit of more than $40 billion in ICT products in 2008.

The Asia-9 ICT deficit in information and communications was partly offset by a $24-billion combined surplus in aerospace, electronics, and flexible manufacturing products (appendix tables 6-38, 6-39, and 6-45). Combined U.S. exports of these technologies were $41 billion in 2008, 76% of total U.S. exports to the Asia-9. Important customers of these three technologies were South Korea, Singapore, and Taiwan (in all three categories), India (aerospace), and Malaysia and the Philippines (electronics).

The U.S. trade position in advanced technology goods with the Asia-9 has been relatively stable over this decade. This may reflect the migration of final assembly of many ICT goods from the Asia-9 to China, coinciding with a widening deficit of ICT trade with China.

The European Union. Trade with the EU accounts for nearly one-fourth of U.S. advanced technology product trade (figure 6-29; appendix table 6-37). The EU exported $69 billion and imported $76 billion, resulting in a $7-billion surplus in 2008 (figure 6-30). Five EU members—France, Germany, Ireland, the Netherlands, and the United Kingdom—accounted for nearly 80% of total U.S.-EU trade in these goods. Aerospace, the life sciences, and ICT had a combined 77% share of the volume of U.S.-EU advanced technology product trade in 2008 (appendix tables 6-38, 6-40, and 6-41).

The United States had substantial surpluses with the EU in aerospace ($13 billion) and ICT goods ($9 billion) (appendix tables 6-38 and 6-40). Important EU customers of aerospace and ICT are France, Germany, and the UK; the Netherlands purchases the most U.S. ICT goods of the EU countries.

The life sciences produced a $15-billion deficit (appendix table 6-41). Ireland was by far the largest EU supplier of life sciences products, accounting for more than half of the EU's $27 billion in exports to the United States in 2008. Other substantial suppliers were Belgium, France, Germany, and the UK.

The U.S. trade surplus with the EU narrowed from $22 billion in 2000 to $7 billion in 2008 (figure 6-30), reflecting the deficit in life sciences rising from $6 billion to $16 billion due to much more rapid growth of imports (appendix tables 6-37 and 6-41).

Latin America and Canada. U.S. advanced technology trade with Latin America amounted to 15% of total U.S. advanced trade in 2008 (figure 6-29; appendix table 6-37). Mexico is by far the largest trading partner in Latin America (10% share of U.S. advanced technology trade), followed by distant-second Brazil (2%). ICT products accounted for half of Latin America's total U.S. trade in these products (appendix table 6-40).

Strong growth in U.S. aerospace and ICT exports was more than offset by large import increases in optoelectronics and ICT (appendix tables 6-38, 6-40, and 6-42). Mexico was the main supplier of optoelectronic imports, which rose from $0.5 billion to $15 billion. The United States also had a substantial deficit with Mexico in ICT goods ($10 billion). The U.S.-Mexico trade deficit in these goods reflects, in part, Mexico's duty-free imports of U.S. components and their assembly and re-export to the United States.

U.S. advanced technology trade with Canada amounted to 7% of total trade in 2008 (figure 6-29; appendix table 6-37). Canada exported $17 billion and imported $28 billion, resulting in a surplus of $11 billion (figure 6-30; appendix table 6-37). ICT and aerospace constituted three-quarters of this bilateral trade (appendix tables 6-38 and 6-40). The United States had a $9-billion surplus with Canada in ICT goods and a $2-billion deficit in aerospace products.

Globalization of Knowledge-Intensive Service Industries

Services have historically been more local and insulated from global competition than manufactured goods because they were less easily traded and often had to be located near the consumer. However, rapid growth of new international markets, increased competition, and advances in communications and other enabling technologies have ushered in the globalization of services. Tradable knowledge-intensive services include three commercial services: business, financial, and communications. Education and health have also become globalized but to a much lesser extent than the commercial knowledge-intensive services. Overall, the current extent of globalization of knowledge-intensive services is less than that of high-technology manufacturing industries.

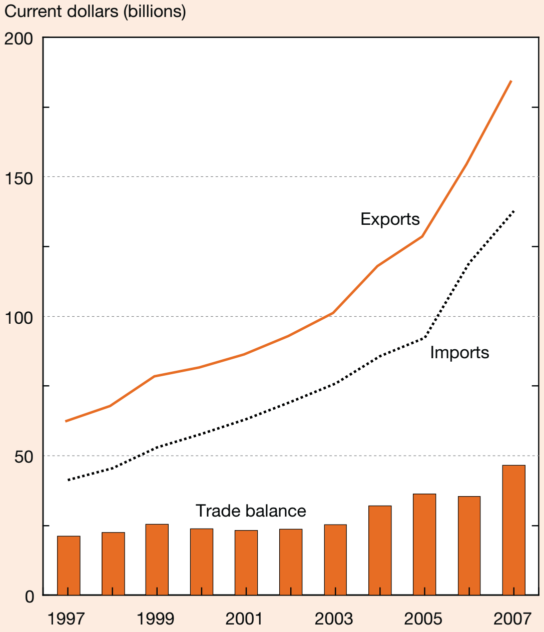
The volume of U.S. trade in commercial knowledge-intensive services is lower than trade in high-technology manufactured goods but is producing increased surpluses. Commercial knowledge-intensive service industries are a key component of the overall U.S. trade in private services, accounting for 40% of the total (appendix table 6-49). U.S. exports of (receipts for) commercial knowledge-intensive service industries were $185 billion in 2007 (nearly 40% of total private services exports), and imports (payments) were $138 billion (again, 40% of the total) (figure 6-32). The resulting surplus, $47 billion, accounted for one-third of the overall surplus in private services trade ($139 billion) in 2007.

Business, professional, and technical services, the category that includes R&D and computer services, is the largest component of trade in commercial knowledge-intensive service industries (55%) (table 6-4; appendix table 6-49) (See “Business to Business Linkages, Exports, and Imports of R&D Services” in chapter 4 for discussion of trends in U.S. trade in R&D services, a component of business services). Finance is the second-largest component (40%), with communications being much smaller (5%).

U.S. trade in commercial knowledge-intensive services has been in surplus for the past 10 years (figure 6-33), in contrast to deficits in U.S. trade of high-technology goods. Business services produced a $39-billion surplus in 2007, out of a total of $47 billion (table 6-4; appendix table 6-49). Financial services gained a small surplus, and telecommunications services trade is balanced.

The bulk of U.S. trade in commercial knowledge-intensive service industries was with the EU (42%), with business services as the largest component (table 6-4). The next-largest trade partner was Latin America (21%), with a relatively large share in financial services that may, in part, reflect offshore banking in the Caribbean. The Asia-9’s share of trade in commercial knowledge-intensive services was much smaller than in high-technology products.

Figure 6-32
U.S. trade in commercial knowledge-intensive services: 1997–2007



NOTES: Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health. Commercial knowledge-intensive services exclude education and health.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. International Services: Cross-Border Trade 1986– 2007, and Services Supplied Through Affiliates, 1986–2006, http://www.bea.gov/international/intlserv.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

U.S. Multinationals in Knowledge- and Technology-Intensive Industries

The Bureau of Economic Analysis (BEA) conducts an annual survey of U.S. multinationals that includes firms in KTI industries. The BEA data are not strictly comparable with the world industry data. However, the BEA data do provide useful information on the globalization of activity and the employment of U.S. multinationals in these industries.

Commercial Knowledge-Intensive Service Industries

U.S. multinationals in commercial knowledge-intensive service industries generated $720 billion in value added in 2006, of which more than 80% ($602 billion) occurred in the United States, according to BEA data (figure 6-34; appendix table 6-50). Financial services ranked first by value added ($270 billion), followed by business services ($239 billion) and communication services ($212 billion).[14] The proportion of value added from their U.S. operations was highest in communications (94%), followed by financial services (86%) and business services (71%). The distribution of

Table 6-4
U.S. exports and imports of commercial knowledge-intensive services, by region/country/economy: 2007
(Billions of dollars)

Service and region/country/economy	Exports	Imports	Balance
All commercial knowledge-intensive services			
All countries	184.5	137.8	46.7
Asia-9	12.7	12.2	0.5
Canada	14.6	10.8	3.8
China	7.8	4.1	3.7
EU	75.7	60.2	15.5
Japan	12.2	5.6	6.6
Latin America	34.1	34.1	0.0
All others	27.4	10.9	16.6
Financial services			
All countries	68.6	61.7	6.9
Asia-9	2.9	1.2	1.7
Canada	5.7	1.9	3.9
China	2.6	1.1	1.5
EU	27.6	26.8	0.8
Japan	4.1	1.6	2.5
Latin America	18.1	19.5	-1.4
All others	7.5	9.7	-2.1
Telecommunications			
All countries	8.3	7.3	0.9
Asia-9	0.6	0.8	-0.2
Canada	0.7	0.5	0.2
China	0.2	0.3	-0.1
EU	2.7	2.5	0.2
Japan	0.3	0.2	0.1
Latin America	2.8	2.1	0.7
All others	1.0	0.9	0.1
Business, professional, and technical services			
All countries	107.7	68.8	38.9
Asia-9	9.2	10.2	-1.0
Canada	8.1	8.4	-0.2
China	5.0	2.7	2.3
EU	45.4	30.9	14.5
Japan	7.9	3.9	4.0
Latin America	13.2	4.8	8.4
All others	18.9	8.0	10.9

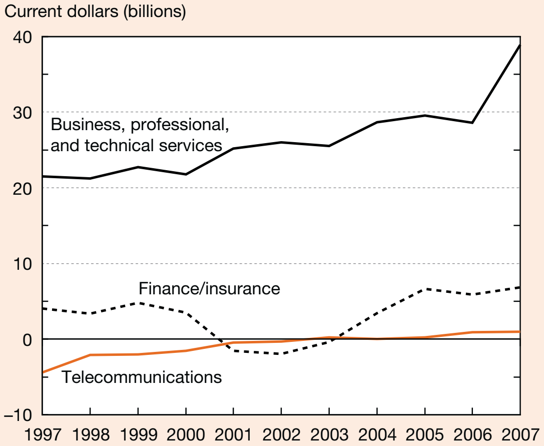
EU = European Union

NOTES: Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health. Commercial knowledge-intensive services exclude education and health. Business, professional and technical services classified as part of business services. China includes Hong Kong. Latin America includes Argentina, Bermuda, Brazil, Chile, Mexico, and Venezuela. Detail may not add to total because of rounding.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. International Services: Cross-Border Trade 1986–2007, and Services Supplied Through Affiliates, 1986–2006, http://www.bea.gov/international/intlserv.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

Figure 6-33
U.S. trade balance of selected commercial knowledge-intensive services, by selected industry: 1992–2007



NOTES: Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health. Commercial knowledge-intensive services exclude education and health. Business, professional, and technical services classified as part of business services.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. International Services: Cross-Border Trade 1986–2007, and Services Supplied Through Affiliates, 1986–2006, http://www.bea.gov/international/intlserv.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

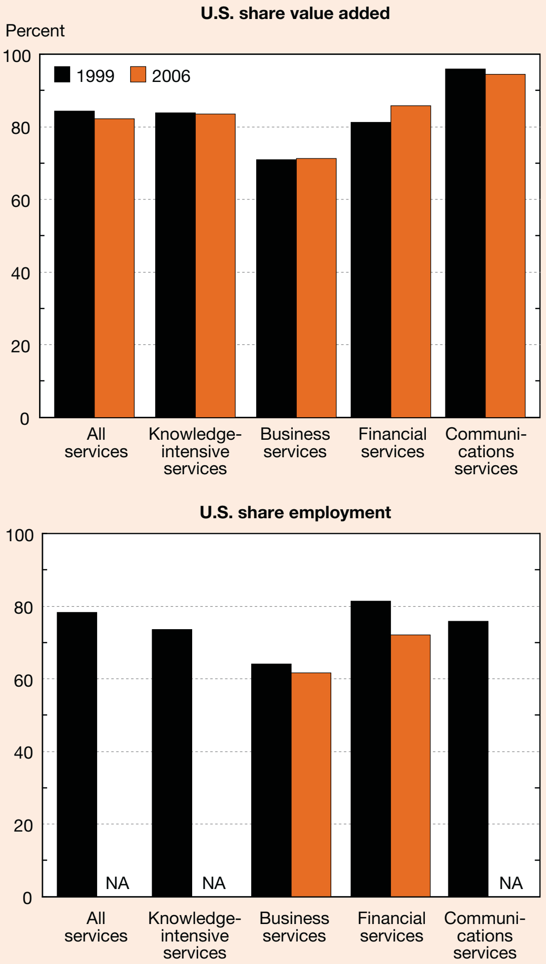
value added between U.S. and foreign affiliates showed little change between 1999 and 2006.

The U.S. multinationals in commercial knowledge-intensive service industries employed 3.7 million workers in the United States in 2006, of whom about 40% were employed in business services and about 30% each in communications and financial services (appendix table 6-50). Business and financial services firms employed 0.9 million and 0.5 million, respectively, at their foreign affiliates (data are not available for communications services). From 1999 to 2006, the foreign employment shares rose from 19% to 28% in financial services and from 36% to 38% in business services (figure 6-33).

High-Technology Manufacturing Industries

BEA data show that U.S. multinationals in four of these five industries generated more than $300 billion worldwide in value added in 2006, of which about two-thirds originated in the United States (appendix table 6-50). Production in the computer industry was the most globalized, as measured by the distribution between U.S. and foreign value added, with 48% of value added originating from the United States in 2006, down from 64% in the late 1990s (figure 6-35). The U.S. value added in the communications and semiconductors industry also showed a substantial shift to foreign

Figure 6-34
Globalization indicators of U.S. multinational corporations in commercial knowledge-intensive services: 1999 and 2006



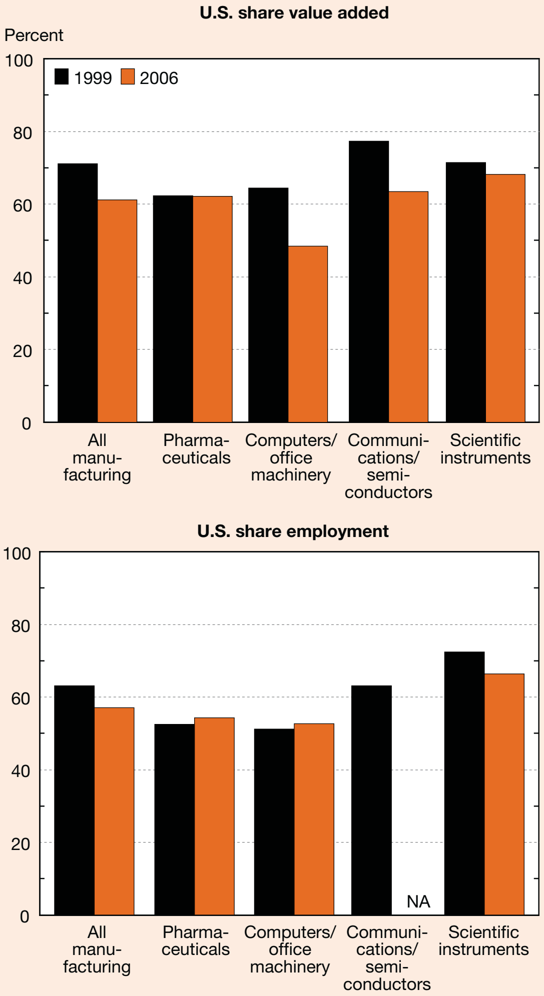
NA = not available

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. Knowledge-intensive services classified by Organisation for Economic Co-operation and Development and include business, financial, communications, education, and health. Commercial knowledge-intensive services exclude education and health.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies 1999–2006, http:// www.bea.gov/international/di1usdop.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

Figure 6-35
Globalization indicators of U.S. multinational corporations in selected high-technology manufacturing industries: 1999 and 2006



NA = not available

NOTES: Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs. High-technology manufacturing industries classified by Organisation for Economic Co-operation and Development and include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies 1999–2006, http://www.bea.gov/international/di1usdop.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

production, from 77% to 63%. The U.S. share was relatively stable in pharmaceuticals and scientific instruments.

U.S. multinationals in high-technology manufacturing employed 1.3 million workers in the United States in 2006 (appendix table 6-50). Employee data for foreign affiliates, available for three of the four industries, show that nearly half of the total workforce for pharmaceuticals and computers is employed abroad, along with one-third of the scientific instruments workforce. The distribution between U.S. and foreign employment showed little change in pharmaceuticals and computers from 1999 to 2006. However, the U.S.

employment share in scientific instruments fell from 72% to 66% over this period (figure 6-35).

Information and Communications Technology Services and Manufacturing

U.S. multinationals in the ICT industries generated more than $400 billion worldwide in value added in 2006, of which 70% was attributable to ICT services and 30% to ICT manufacturing (appendix table 6-50). U.S. ICT multinationals generated most (75%) of their production from their headquarters and other U.S. locations, and the remainder from their foreign affiliates (figure 6-36).

However, the distribution of value added between U.S. and foreign affiliates varies widely by industry. The U.S. share of value added in ICT services was highest in telecommunications (97%), about average in information and data processing services (77%), and considerably lower in computer systems design (58%) (figure 6-36; appendix table 6-50). In the two ICT manufacturing industries, the domestic value-added portion is below the overall ICT average: 64% in communications and semiconductors and 48% in computers and office machinery.

Globalization of ICT, as measured by the U.S. and foreign shares of value added, has increased in this decade. The U.S. share dropped from 81% of value added to 75% because of substantial declines in the two ICT manufacturing industries, whereas the U.S. share of value added remained stable in the ICT service industries (figure 6-36; appendix table 6-50). (Employment data for foreign affiliates for 2006 are not available for four of the five ICT industries.)

U.S. and Foreign Direct Investment in Knowledge- and Technology-Intensive Industries

Foreign direct investment (FDI) has the potential to generate employment, raise productivity, transfer skills and technology, enhance exports, and contribute to long-term economic development (Kumar 2009). Receipt of FDI may indicate a developing country's emerging capability and integration with countries that have more established industries. FDI in specific industries may suggest the potential for their evolution and the creation of new technologies.

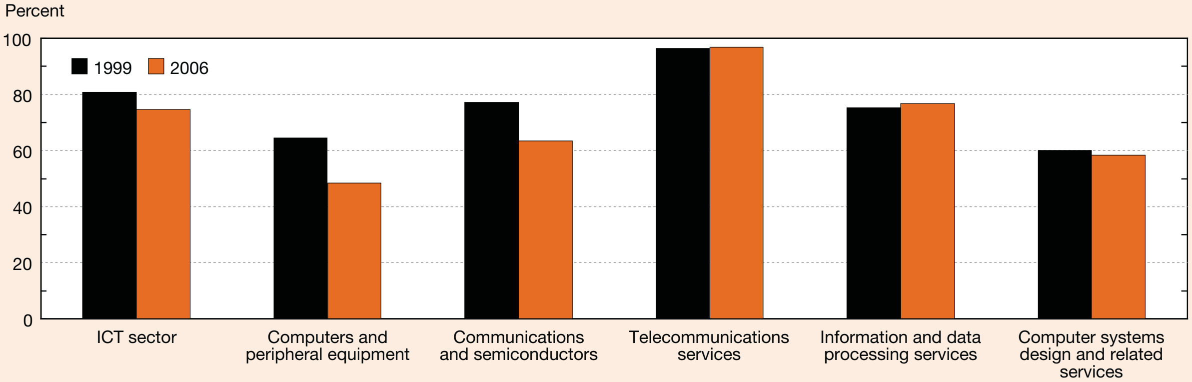
This section uses data from the BEA on U.S. direct investment abroad and foreign investment in the United States in KTI industries. The rising volume of trade by U.S.-based KTI firms has been accompanied by increases in U.S. direct investment abroad and FDI in the United States.

U.S. Direct Investment Abroad in Knowledge- and Technology-Intensive Industries

According to data from the BEA, the stock of U.S. direct investment abroad had reached $121 billion in high-technology manufactures and $834 billion in commercial knowledge-intensive service industries by 2008 (table 6-5; appendix table 6-51).[15] This represented one-quarter of the stock of all U.S. direct overseas investment in all manufacturing industries ($0.5 trillion) and about one-third of U.S. direct overseas investment in all services ($2.5 trillion).

The stock of U.S. foreign direct investment abroad in high-technology manufacturing industries increased from $87 billion in 2000 to $121 billion in 2008 (table 6-5; appendix table 6-51). Communications and semiconductors increased from $42 billion to $54 billion, pharmaceuticals

Figure 6-36
U.S. share of output of U.S. ICT multinational corporations, by industry: 1999 and 2006



ICT = information and communications technology

NOTES: ICT output on value-added basis. Value added is amount contributed by country, firm, or other entity to value of good or service and excludes purchases of domestic and imported materials and inputs.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Financial and Operating Data for U.S. Multinational Companies, 1999–2006, http://www.bea.gov/international/di1usdop.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

from $25 billion to $37 billion, aerospace from $3 billion to $11 billion, and scientific instruments from $3 billion to $10 billion. However, the investment stock of the computer industry dropped by 36%, from $14 billion to $9 billion, and its share of all high-technology manufacturing industries fell by half, from 16% to 7%.

The stock of U.S. direct investment abroad in commercial knowledge-intensive service industries was $834 billion in 2008, one-third of the stock of total U.S. direct investment abroad in all services (table 6-5; appendix table 6-51). Financial services dominated commercial knowledge-intensive services investments at $634 billion (76%), up from $217 billion in 2000. Business services grew from $61 billion in 2000 to $185 billion in 2008. However, the stock of U.S. FDI in communications fell from $27 billion to $15 billion.

Geographic data on U.S. FDI investments in high-technology industries is limited to computer and electronic products, which includes computers, communications and semiconductors, and scientific instruments. For these products, the EU was the largest recipient with $27 billion (35% share in 2008), followed by $23 billion in the Asia-9 (30%) (table 6-6). Investments in Canada, China, and Japan were 4%–13% of the total. There was little change in these shares from 2000 to 2008.

The largest foreign destinations for U.S. direct investment in financial services are the EU ($314 billion in 2008) and Latin America ($195 billion), for a combined 80% of the total (table 6-6). The Asia-9, Canada, China, and Japan have 5% or less of the total. The EU was the largest recipient at $78 billion (64% share) of investment in information services, which includes communications. Investments in Asia were smaller, with 2% in China and 5% each in the Asia-9 and Japan.

Data on professional, scientific, and technical services, a component of business services, show that the EU had $53 billion of the $81 billion in stock of worldwide U.S. FDI in this industry in 2008 (table 6-6). The Asia-9, Canada, and China were the next-largest recipients with shares of 5%–10%. The shares of these regions/countries shifted between 2000 and 2008. Canada's share increased from 6% to 10% and China's share increased from 2% to 5%. Japan's share fell sharply from 16% to 3%.

Foreign Direct Investment in U.S. Knowledge- and Technology-Intensive Industries

According to BEA data, the stock of FDI in U.S. high-technology manufacturing industries stood at $187 billion in 2008, up from $133 billion in 2000 and above the stock of $128 billion in U.S. investment abroad (table 6-5; appendix table 6-51). The FDI stock in the U.S. pharmaceuticals industry was about $125 billion in 2008, and the stock in communications and semiconductors was $25 billion, for a combined share of 80% of FDI stock in U.S. high-technology industries. The share of pharmaceuticals doubled, from 34% to 67%, and the share of communications and semiconductors fell from 47% to 13%.

FDI stock in U.S. commercial knowledge-intensive service industries was $390 billion in 2008, compared with

Table 6-5

Stock of U.S. direct investment abroad and foreign direct investment in United States, by selected industry/service: 2000 and 2008

(Billions of dollars)

	U.S. direct investment abroad		Foreign direct investment in U.S.	
Industry/service	2000	2008	2000	2008
All industries	1,316.2	3,162.0	1,256.9	2,278.9
Manufacturing	343.9	512.3	480.6	795.3
High-technology manufacturing	87.3	120.8	132.5	186.8
Aerospace	2.9	11.3	4.5	10.5
Communications and semiconductors	41.9	53.7	61.7	24.9
Computers and peripheral equipment	14.1	8.6	2.5	6.5
Pharmaceuticals	25.3	37.1	44.7	124.8
Scientific and measuring equipment	3.1	10.1	19.0	20.1
All services	874.6	2,486.1	735.9	1,285.0
Commercial KI services	305.0	834.1	NA	389.5
Business services	61.0	185.2	47.0	91.0
Communications	26.9	14.9	NA	49.7
Finance	217.1	634.0	167.0	248.9

NA = not available

NOTES: High-technology manufacturing industries and commercial knowledge-intensive services classified by Organisation for Economic Co-operation and Development. Detail may not add to total because of rounding.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad, Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1usdbal.htm, and Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1fdibal.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

Table 6-6

Stock of U.S. direct investment abroad and of foreign direct investment in United States, by selected industry and region/country/economy: 2000 and 2008

(Billions of dollars)

	U.S. direct investment abroad		Foreign direct investment in U.S.	
Industry/service and region/country/economy	2000	2008	2000	2008
Computers and electronic products				
All regions/countries/economies	59.9	76.5	92.8	63.3
Asia-9	20.0	22.9	NA	NA
Canada	4.9	4.6	27.1	-0.3
China	5.1	9.9	0.2	NA
EU	23.3	26.7	40.4	40.1
Japan	3.6	3.3	17.3	19.0
Latin America	0.7	1.4	2.8	1.5
All others	2.3	7.7	NA	NA
Financial services				
All regions/countries/economies	217.1	634.0	167.0	248.9
Asia-9	6.2	21.6	NA	NA
Canada	26.3	32.7	19.9	62.1
China	6.7	13.4	NA	0.0
EU	NA	314.1	94.8	146.0
Japan	22.9	28.0	14.1	21.7
Latin America	73.7	195.1	12.7	-19.8
All others	NA	29.1	NA	NA
Information services				
All regions/countries/economies	52.3	121.9	146.9	158.0
Asia-9	1.1	6.5	NA	NA
Canada	2.3	4.1	12.9	11.8
China	0.7	1.1	0.3	NA
EU	33.7	77.5	98.6	126.1
Japan	2.5	5.6	NA	1.8
Latin America	6.9	8.6	13.3	0.7
All others	5.2	18.5	NA	NA
Professional, scientific, and technical services				
All regions/countries/economies	32.9	81.2	30.5	62.1
Asia-9	1.5	5.2	NA	NA
Canada	1.9	8.2	1.2	2.2
China	0.8	3.7	NA	NA
EU	16.0	52.8	27.7	45.1
Japan	5.4	2.8	0.8	5.0
Latin America	3.5	2.1	0.5	1.8
All others	3.8	6.4	NA	NA

NA = not available

EU = European Union

NOTES: Regions/countries/economies are destination of U.S. direct investment abroad and source/origin of foreign direct investment in U.S. industries. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU data for 2000 exclude Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia. Latin America includes Argentina, Bermuda, Brazil, Chile, Mexico, and Venezuela. EU data for 2008 include all 27 member countries.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad, Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1usdbal.htm, and Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1fdibal.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

$729 billion in the stock of U.S. investment abroad in these industries (table 6-5; appendix table 6-51). The largest industry was financial services ($249 billion), followed by $91 billion in business services and $50 billion in communications. FDI stock in U.S. financial services increased by nearly 50% (from $167 to $249 billion) and nearly doubled in business services (from $47 billion to $91 billion). (Data for communications services are not available for 2000.)

Limited data on geographic origin show that the EU and Japan are the largest sources of foreign direct investment in U.S. computer and electronic products industries, which comprised more than 90% of the stock of worldwide investment in these U.S. industries ($63 billion) in 2008 (table 6-6). The EU's investment stayed constant at about $40 billion between 2000 and 2008. However, its share increased from 44% to 63% because of a $30-billion decline in the stock of total inward investment in this industry during this period. Japan's investment rose from $17 billion in 2000 to $19 billion in 2008. Canada's investment fell sharply from $27 billion (29% share) to a slight negative position ($0.3 billion).[16]

In commercial knowledge-intensive service industries, the two largest sources of FDI in U.S. financial services are the EU and Canada, which provided more than 80% of the $264 billion in stock of worldwide investment in this industry in 2008 (table 6-6). The EU had the largest share (80%) of the $146 billion in investment stock in the U.S. information services industry in 2008. Its share increased 13 percentage points between 2000 and 2008. Latin America's share fell from 9% to less than 1%. The EU was also the largest investor in professional, scientific, and technical services, with a share of 73% ($45 billion of inward investment in 2008). The EU's share, however, fell almost 20 percentage points between 2000 and 2008. Japan's share of investment in this industry more than doubled, from 3% to 8%.

Innovation-Related Indicators of U.S. and Other Major Economies

Innovation—the creation of new or significantly improved products or processes, along with novel marketing activities and organizational methods—is widely recognized as instrumental to the realization of commercial value in the marketplace and as a driver of economic growth.[17] ICT technologies, for example, have stimulated innovation of new products, services, and industries that have transformed the world economy over the past several decades. However, direct measures of innovation for the United States and many other regional/national economies remain limited. (See the section on intangible assets in this chapter and sidebar, "Developments in Innovation-Related Metrics," in chapter 4.)

U.S. Trade in Intangible Assets

Intangible assets are those that embody knowledge content, for example, patents, trademarks, and licensing of computer software (Idris 2003). These can be traded (licensed for use). The United States has a longstanding surplus in trade of intangible assets with the rest of the world (figure 6-37).

U.S. receipts for exports of intangible assets were $83 billion in 2007, 14% higher than in 2006 (figure 6-37; appendix table 6-52).[18] U.S. imports (payments) were $25 billion (up by 5%), producing a $58-billion surplus. U.S. exports and imports of intangible assets have grown every year but one between 1992 and 2007, and the surplus has widened over the period.

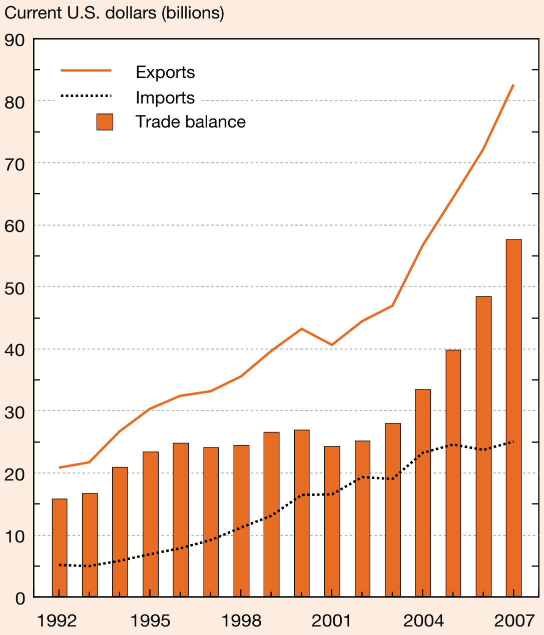
About three-quarters of the intangible assets trade involved exchanges between multinationals and their affiliates, either with U.S. parents and their foreign affiliates or with foreign parents and their U.S. affiliates (appendix table 6-52).[19] Firms with marketable industrial processes may prefer affiliated over unaffiliated transactions to exercise greater control over the distribution and use of this property, especially when the intellectual property is instrumental to the firm's competitive position in the marketplace (Branstetter, Fishman, and Foley 2006). Differential tax policies may also affect a firm's choice of transaction mechanisms.

Despite the greater value of transactions among affiliated companies, both affiliated and unaffiliated transactions have grown at the same pace over the past two decades. These trends suggest a greater internationalization of U.S. business activity and a growing reliance on intellectual property and other intangible assets developed overseas.[20]

U.S. Trade in Industrial Processes

A major component of U.S. intangible assets trade is industrial processes—the use of patents, trade secrets, and other proprietary rights. These data are used as approximate

Figure 6-37
U.S. trade in intangible assets: 1992–2007



NOTE: Intangible assets include industrial processes, books, records, tapes, broadcasting and recording, franchise fees, trademarks, and use of computer software. Industrial processes include royalties, license fees, and other fees associated with use of patents, trade secrets, and other proprietary rights used in connection with production of goods.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. International Services: Cross-Border Trade 1986–2007, and Services Supplied Through Affiliates, 1986–2006, http://www.bea.gov/international/intlserv.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

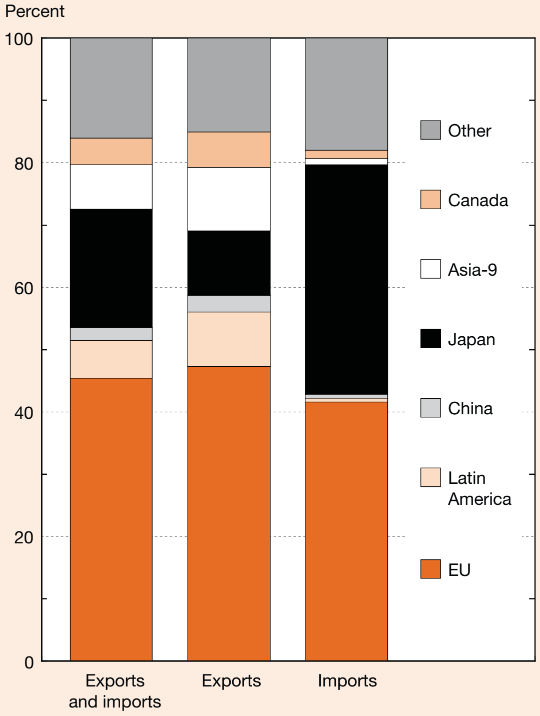
indicators of relative comparative advantage in the creation of industrial technology and its subsequent diffusion.

Comparable data on trade in industrial processes are available only for 2006 and 2007. These data include the combined transactions among affiliated firms (i.e., among firms that are tied to one another by ownership rights) and unaffiliated ones.

U.S. exports of industrial processes were $37 billion in 2007, 45% of total intellectual property exports; U.S. imports were $18 billion, 72% of total intangible assets imports (figure 6-38). The resulting surplus, $19 billion, accounted for one-third of the overall surplus in U.S. trade in intangible assets.

The EU had the largest share of any economy (45%) in U.S. trade in industrial processes, followed by Japan (19%). Latin America, the Asia-9, and China had shares below 10% (figure 6-38). More than half of the U.S. surplus in 2007 was with the EU ($10.2 billion). The United States ran a surplus of $3–$4 billion with the Asia-9 and Latin America, and nearly a $1-billion surplus with China. These surpluses were partially offset by a $2.8-billion deficit with Japan.

Figure 6-38
U.S. trade in industrial processes, by region/country/economy: 2007



NOTES: Industrial processes include royalties, license fees, and other fees associated with use of patents, trade secrets, and other proprietary rights used in connection with production of goods. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU includes all 27 member states. "Other" includes Australia, Israel, New Zealand, Norway, South Africa, Saudi Arabia, and others (data source lists unspecified countries as "other").

SOURCE: U.S. Bureau of Economic Analysis, International Economic Accounts, U.S. International Services: Cross-Border Trade 1986– 2007, and Services Supplied Through Affiliates, 1986–2006, http://www.bea.gov/international/intlserv.htm, accessed 15 September 2009.

Science and Engineering Indicators 2010

Global Trends in Patenting

To foster inventiveness, nations assign property rights to inventors in the form of patents. These rights allow the inventor to exclude others from making, using, or selling the invention for a limited period in exchange for publicly disclosing details and licensing the use of the invention.[21] Inventors obtain patents from government-authorized agencies for inventions judged to be "new…useful…and…nonobvious."[22]

Patenting is an intermediate step toward innovation, and patent data provide indirect and partial indicators of innovation. Not all inventions are patented, and the propensity to patent differs by industry and technology area. Not all patents are of equal value; patents may be obtained to block rivals, negotiate with competitors, or help in infringement lawsuits (Cohen, Nelson, and Walsh 2000).

Indeed, the vast majority of patents are never commercialized. However, the smaller number of patents that are commercialized result in new or improved products or processes or even entirely new industries. In addition, their licensing may provide an important source of revenue, and patents may provide important information for subsequent inventions and technological advances.

This discussion focuses largely on patent activity at the U.S. Patent and Trademark Office (USPTO). It is one of the largest patent offices in the world and has a significant share of applications and grants from foreign inventors because of the size and openness of the U.S. market.[23] These market attributes make U.S. patenting data useful for identifying trends in global inventiveness.

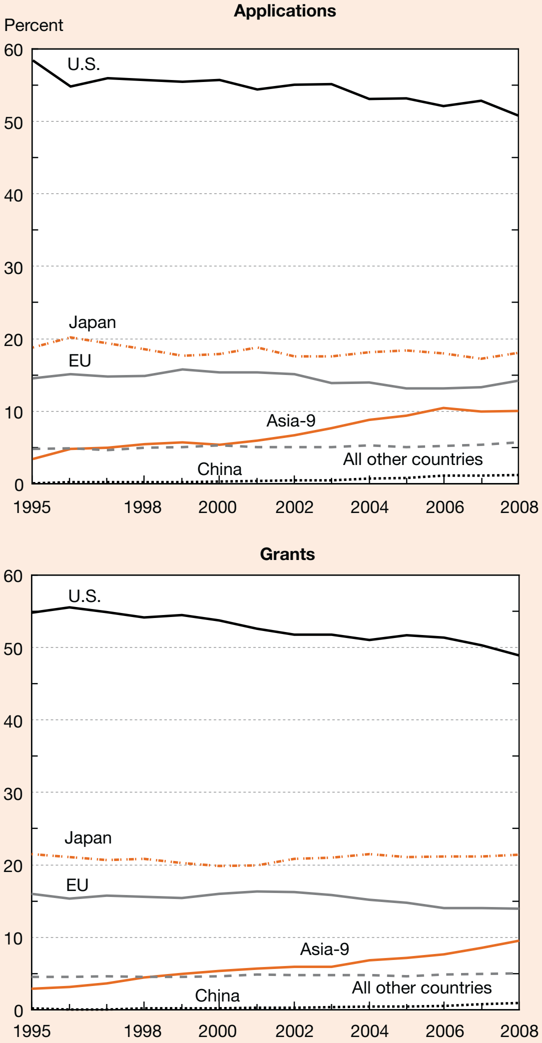
This section also deals with a subset of patents that their owners presume to be of sufficient economic value to warrant the high costs associated with patent filing and maintenance in three of the world's largest markets: the United States, the EU, and Japan.[24]

Trends in Applications for USPTO Patents

Data on patent filings provide a more current look at inventiveness trends than do data on patents granted because of the long lead times.[25] As it turns out, trends in patent applications are a reasonable proxy for later trends in patents granted.

Inventors filed 456,000 patent applications with USPTO in 2008, unchanged from 2007, but nearly double the number a decade ago (figure 6-39; appendix tables 6-53 and 6-54). The strong growth of U.S. patent applications between the mid-1990s and 2007 coincided with a strengthening of the patent system and the extension of patent protection into new technology areas through policy changes and judicial decisions during the 1980s and 1990s (NRC 2004). The

Figure 6-39
Region/country/economy share of USPTO patent applications and grants: 1995–2008



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Patent applications allocated among regions/countries/economies on basis of residence of first-named inventor. Patent grants fractionally allocated among regions/countries/economies on basis of proportion of residences of all named inventors. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU includes all 27 member states.

SOURCE: USPTO, Number of Utility Patent Applications Filed in the United States, by Country of Origin, Calendar Years 1965 to Present, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm, accessed 2 October 2009; and Historic Data, All Technologies (Utility Patents) Report, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_at.htm#PartA1_1a, accessed 15 September 2009.

Science and Engineering Indicators 2010

flattening of growth in 2008 may reflect the onset of the global financial crisis and economic downturn in 2008.

Inventors residing in the United States filed 232,000 of these applications in 2008, about 9,000 less than in 2007 and the first yearly decline since 1996 (figure 6-39; appendix tables 6-53 and 6-54).[26] The U.S. resident share continued to fall, dropping from 53% in 2007 to 51% in 2008, and down from 55% in 1996, which may be indicative of increased globalization and increased recognition by developing countries of the potential value of intellectual property. Most USPTO patents credited to the United States are owned by corporations (see sidebar, "U.S. Patents Granted, by Type of Ownership").[27]

Japan, the EU, and the Asia-9 are the main sources of inventors outside of the United States who file U.S. patent applications (figure 6-39; appendix table 6-54). Japan-based inventors filed 82,000 applications (18%) in 2008, followed by 65,000 by EU inventors (14%) and 46,000 (10%) by Asia-9 inventors, mostly from South Korea and Taiwan. China is ranked a distant fifth with a 1% share. The majority of applications from other regions originate from advanced countries, including Australia, Canada, and Switzerland.

The number of patent applications from Japan and the EU grew more slowly from 1995 to 2008 than those originating elsewhere (appendix tables 6-53 and 6-54). The Asia-9's number of applications rose at more than twice the average rate, driven by increases in South Korea and Taiwan, and increased the Asia-9 share from 5% to 10% (figure 6-39). Growth in the number of applications from India and China accelerated during this period but from very low levels. The location of China-based inventors shifted from Hong Kong (64% of China's patent applications in 1997) to mainland China (81% of China's patent applications in 2008).

USPTO patents granted among these five major world regions/countries reveal trends very similar to those observed for patent applications through 2008 (figure 6-39; appendix tables 6-56 and 6-57). However, the U.S. share edged down from 50% in 2007 to 49% in 2008, the first time the U.S. share has been less than half for the past four decades (USPTO 2008). The Asia-9's share rose from 9% to 10% and the shares of the EU, Japan, and China remained steady.

USPTO Patents Granted, by Technology Area

This section discusses trends in several technology areas. The biggest—information and communications technologies—accounts for nearly 40% of all USPTO patents (figure 6-40 and appendix table 6-60). Two smaller technology areas, aerospace and pharmaceuticals, are closely associated with their respective high-technology industries. Measurement and control equipment is linked with scientific instruments industries. Biotechnology, medical equipment, and medical electronics are important technologies for health care.

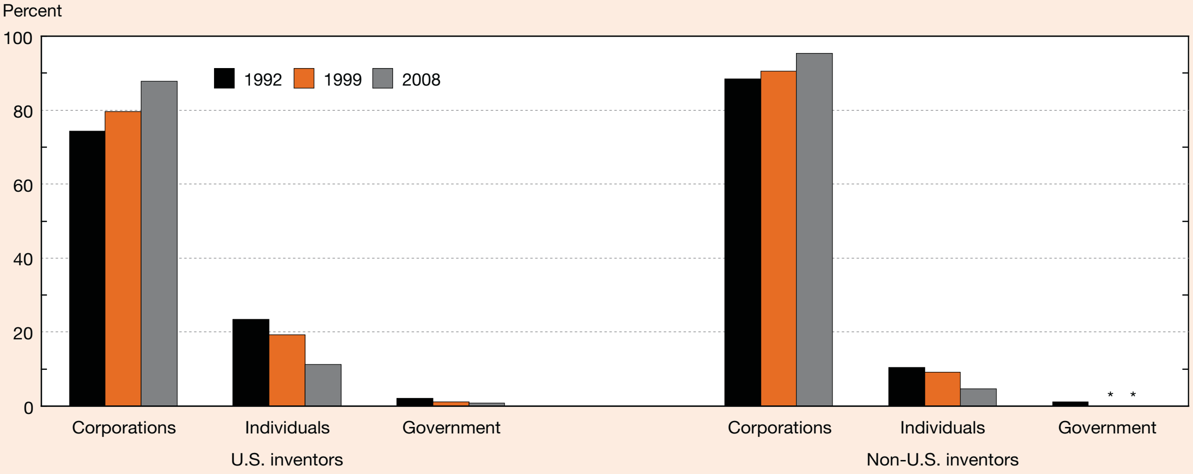
ICT Patenting. Patents in the largest single patent group, ICT—computers, semiconductors, and telecommunications—have risen rapidly and accounted for 65,000

U.S. Patents Granted, by Type of Ownership

Corporations own the majority of patents granted to U.S. entities, and their share has been steadily increasing since the early 1990s (figure 6-C). In 2008, U.S. corporations owned 88% of patents issued to U.S. inventors, with individuals owning 11%; in 1992, the respective shares were 74% and 24%. The U.S. Patent and Trademark Office defines the corporate sector as including U.S. corporations, small businesses, and educational institutions. U.S. universities and colleges owned about 4% of U.S. utility patents granted to corporations in 2005. (For a further discussion of academic patenting, see "Academic Patents, Licenses, Royalties, and Startups" in chapter 5.)

Corporations also own the majority of U.S. patents issued to the rest of the world; that share has also been increasing over the past decade. The individual ownership share of patents issued to the rest of the world (which is about half the level in the United States) has fallen since the early 1990s.

Figure 6-C
USPTO patents granted, by ownership type: 1992, 1999, and 2008



* = <0.5

USPTO = U.S. Patent and Trademark Office

NOTES: Corporations refer to private, nonprofit, and educational institutions. Bulk of corporate patents originate from private companies.

SOURCE: USPTO, All Technologies (Utility Patents) Report, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/all_tech.htm, accessed 2 October 2009.

Science and Engineering Indicators 2010

(41% share) of the 158,000 patents granted in 2008, up from 22,000 (21%) in 1995 (figure 6-40 and appendix tables 6-58 and 6-60). The U.S. share of ICT patents (48%) was identical to its total share of patents; it was higher in computers (55%) and substantially lower in semiconductors (37%) (figures 6-39 and 6-41).

Japan ranked second in ICT patents (23% in 2008) (figure 6-41; appendix table 6-59). This area of strength, relative to its average share of 21%, reflects a higher-than-average share in semiconductors (29%) (figure 6-39; appendix table 6-62). Nevertheless, Japan's overall ICT share declined steeply during the decade, from 36% in 1995 to 23% in 2008, reflecting declining shares in all three ICT technologies (appendix tables 6-61 through 6-63).

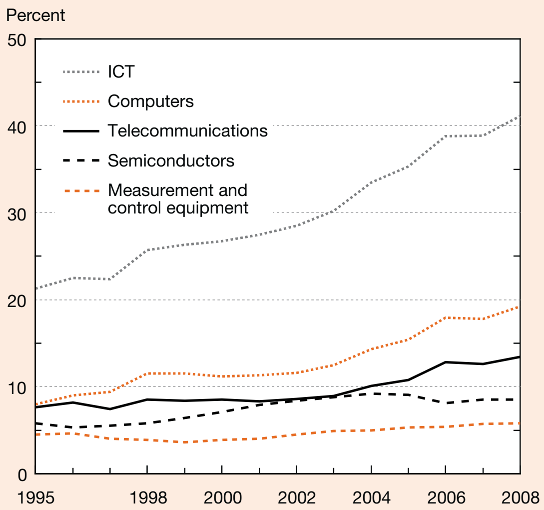
The EU, fourth-ranked in ICT, was relatively weaker in these technologies compared with its overall share (figures 6-39 and 6-41; appendix tables 6-59 and 6-61 through 6-63). Its share has been roughly flat in all three ICT technology areas.

The Asia-9's share of ICT patents more than doubled, from 5% in 1995 to 13% in 2008, because of strong growth in all three technology areas (figure 6-41; appendix tables 6-59, 6-61, 6-62, 6-63). The Asia-9 surpassed the EU in 2007 and ranked third in ICT patents. The majority of patents fueling this growth originated from South Korea and Taiwan. China's share of USPTO ICT patents was small (1%), but strong growth from a low base in computer and semiconductor patents was evident over the decade.

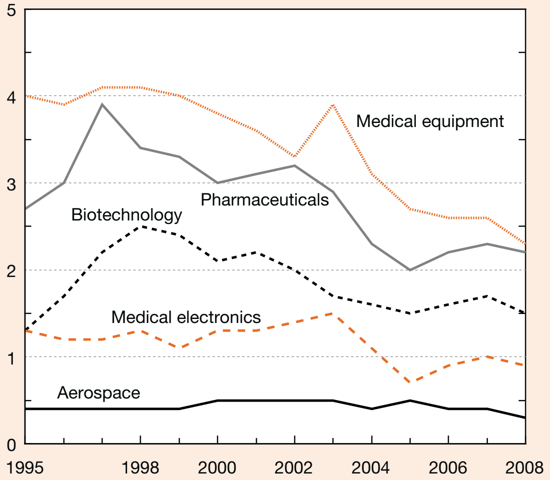
Patents in Other Technology Areas. The United States has a comparatively higher-than-average share of patents in aerospace and four technology areas connected with health: pharmaceuticals, biotechnology, medical equipment, and medical electronics (figures 6-39 and 6-42; appendix tables 6-64 through 6-68). Its share of aerospace patents fluctuated

Figure 6-40
USPTO patent grants, by selected technology area: 1995–2008

ICT technologies and measurement and control equipment



Aerospace and medical-related technologies



ICT = information and communications technology; USPTO = U.S. Patent and Trademark Office

NOTE: Technologies classified by The Patent Board™.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2009).

Science and Engineering Indicators 2010

broadly above 60%. In the health-related areas, the U.S. share stayed above 60% in medical equipment and medical electronics, and was just below 60% in pharmaceutical and biotechnology patents.

The EU's patents position is relatively strong in aerospace, pharmaceuticals, biotechnology, measurement and control equipment, and medical electronics (figure 6-42; appendix tables 6-64, 6-66, 6-68, and 6-69). Its share of patents in these technologies is about 20% compared with its 14% overall share (figure 6-39). Its share in medical equipment patents is close to its overall share.

As a group, the Asia-9 is relatively weaker in these technologies, as indicated by its patent shares in each technology area, which are half or less of the overall Asia-9 share; the exception is measurement and control equipment, which is near the average (7%) (figures 6-39 and 6-42; appendix tables 6-64 through 6-69). The Asia-9 share has risen over the past decade in measurement and control equipment, pharmaceuticals, and biotechnology. Its share has remained roughly stable in the other technologies.

China's share in pharmaceuticals, biotechnology, and measurement and control equipment is the same as its overall share (figures 6-39 and 6-42; appendix tables 6-65, 6-66, and 6-69). Its shares in aerospace, medical equipment, and medical electronics are 0.5%, significantly below its overall share (1%) (appendix tables 6-64, 6-67, and 6-68).

Patenting of Valuable Inventions: Triadic Patents

Using patent counts as an indicator of national inventive activity does not differentiate between inventions of minor and substantial economic potential. Inventions for which patent protection is sought in three of the world's largest markets—the United States, the EU, and Japan—are likely to be viewed by their owners as justifying the high costs of filing and maintaining these patents in three markets. That is, they are deemed to be substantially economically valuable.

The number of such "triadic" patents was estimated at about 51,600 in 2006 (the last year for which these data are available), up from 41,500 in 1997, and showing little growth after 2004. The United States, the EU, and Japan held basically equal shares (figure 6-43; appendix table 6-70),[28] and their nearly identical positions in triadic patents contrast with a far greater gap between them in USPTO patent applications and grants.

The United States, the EU, and Japan together accounted for more than 93% of triadic patents in 1997, but that share dropped to 87% by 2006 (figure 6-43; appendix table 6-70). The Asia-9's corresponding share increase from 1% in 1997 to 6% in 2006 was almost entirely driven by increasing South Korean high-value filings. Taiwan had much lower activity in triadic patent filings than in total USPTO applications and grants, and high-value patent filings by China and India, though increasing, remain minuscule.

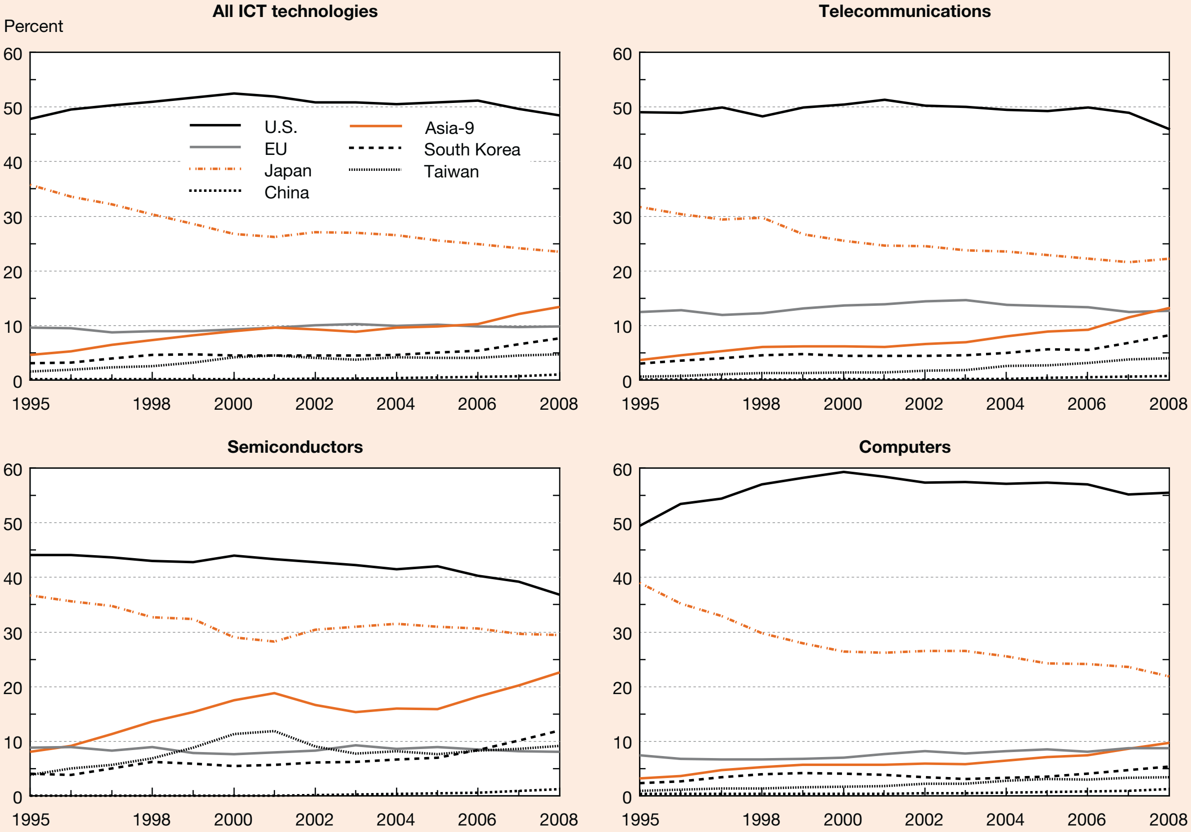
U.S. High-Technology Small Businesses

Many of the new technologies and industries seen as critical to U.S. economic growth are also closely identified with small businesses, that is, those employing fewer than 500 people. Biotechnology, the Internet, and computer software are examples of industries built around new technologies in whose initial commercialization small businesses played an essential role.

This section covers patterns and trends that characterize small businesses operating in high-technology industries. It is based on data from the Census Bureau. Two sources of financing for high-technology small businesses are examined, using

Figure 6-41

USPTO patents granted in information and communications technology, by selected region/country/economy: 1995–2008



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries/economies on the basis of proportion of residences of all named inventors from different regions/countries/economies. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU includes all 27 member states.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2009).

Science and Engineering Indicators 2010

data from the National Venture Capital Association and the University of New Hampshire's Center for Venture Research.

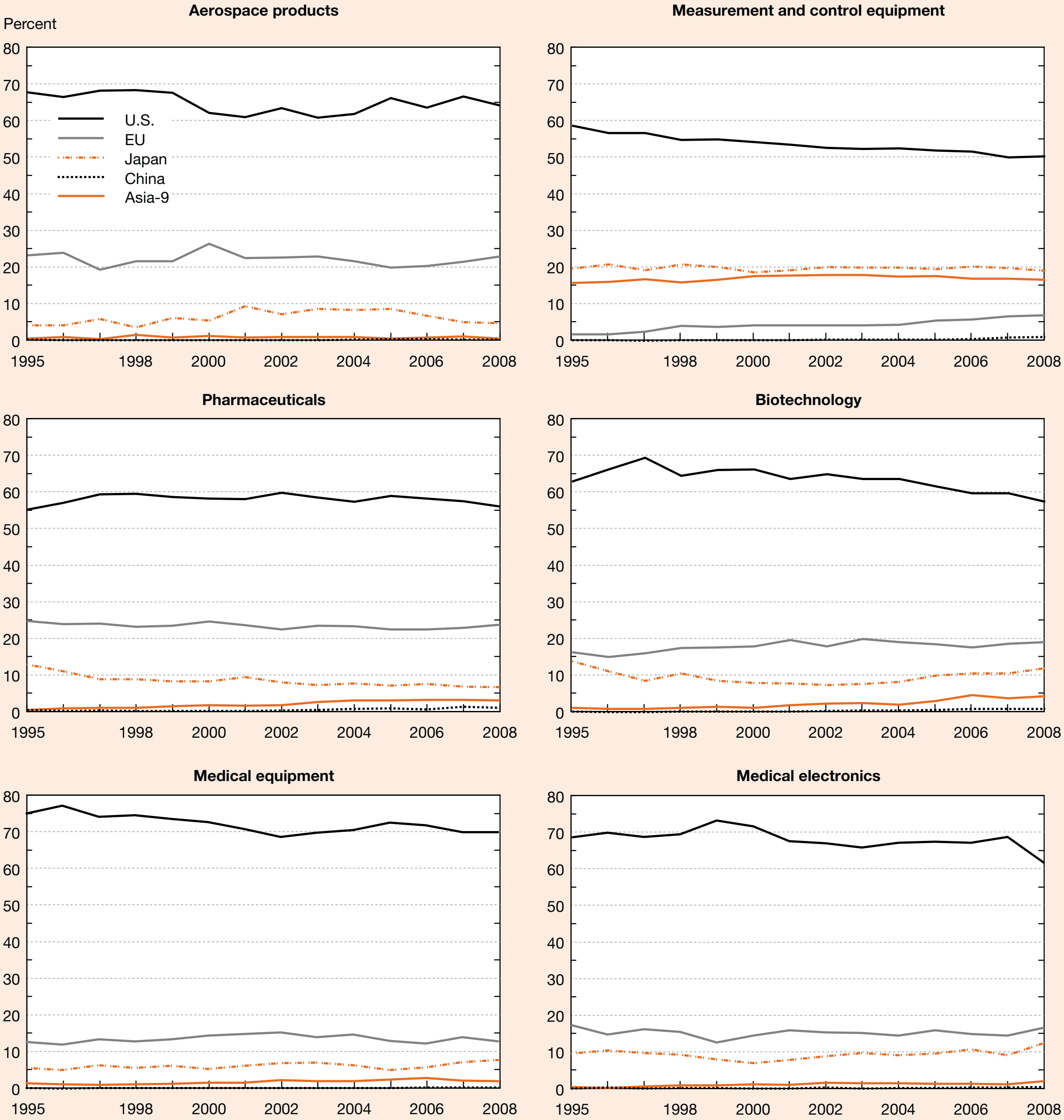
Employment in High-Technology Small Businesses

Small firms (those with fewer than 500 employees) employed about one-third of all workers in industries classified by the Bureau of Labor Statistics (BLS) as high technology. In contrast, small firms accounted for slightly more than half of total employment in all industries[29] in 2006 (table 6-7). About one-half million small businesses operating in high-technology industries employed 5 million workers in 2006 (appendix table 6-71).[30]

In 2006, most workers in these high-technology small businesses (68%) were in the service sector (table 6-8; appendix table 6-71), concentrated in six BLS high-technology categories: architecture, computer systems design, consulting, management, commercial equipment and services, and R&D. These service industries collectively employed more than 85% of workers employed by all small businesses in high-technology service industries in 2006. The manufacturing sector employs most of the remaining workers in high-technology small businesses (30% in 2006).

Small business employment in high-technology manufacturing is similarly concentrated within a relatively small number of industries: motor vehicle parts, metal working, semiconductors, other machinery, fabricated metals, and navigational and measurement tools (table 6-8; appendix table 6-71). These six industries collectively employed more than half of all workers in all manufacturing high-technology small businesses and 15% of the entire high-technology small business labor force in 2006.

Figure 6-42
USPTO patents granted in selected technologies, by selected region/country/economy: 1995–2008



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Technologies classified by The Patent Board™. Patent grants fractionally allocated among regions/countries/economies on basis of proportion of residences of all named inventors. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU includes all 27 member states.

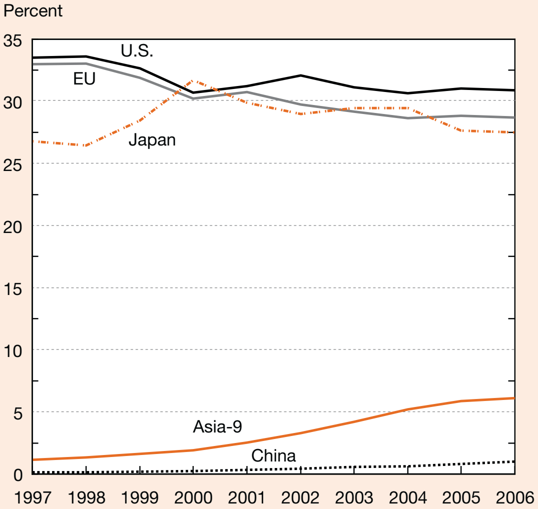
SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2009).

Science and Engineering Indicators 2010

Financing of High-Technology Small Businesses

Entrepreneurs seeking to start or expand a small firm with new or unproven technology may not have access to public or credit-oriented institutional funding. Two types of financing, called *angel investment* and *venture capital investment,* are often critical to financing nascent and growing high-technology and entrepreneurial businesses. (In this section, *business* denotes anything from an entrepreneur with an idea to a legally established operating company.)

Figure 6-43
Global triadic patent families, by selected region/country/economy: 1997–2006



EU = European Union

NOTES: Triadic patent families include patents applied for in U.S. Patent and Trademark Office, European Patent Office, and Japan Patent Office. Patent families fractionally allocated among regions/countries/economies based on proportion of residences of all named inventors. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. China includes Hong Kong. EU includes all 27 member states.

SOURCE: Organisation for Economic Co-operation and Development, Patents Statistics http://stats.oecd.org/WBOS/index.aspx, Patents by Region database, accessed 2 October 2009.

Science and Engineering Indicators 2010

Angel investors tend to be wealthy individuals who invest their own funds in entrepreneurial businesses, either individually or through informal networks, usually in exchange for ownership equity. Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always get to participate in managerial decisions.

Venture capital firms have categorized their investments into four broad financing stages, which are also relevant for discussion of angel investment:

- **Seed and startup** supports proof-of-concept development (seed) and initial product development and marketing (startup).
- **Early funds** support the initiation of commercial manufacturing and sales.
- **Expansion financing** provides working capital for company expansion, funds for major growth (including plant expansion, marketing, or development of an improved product), and financing to prepare for an initial public offering (IPO).
- **Later-stage funds** include acquisition financing and management and leveraged buyouts. Acquisition financing provides resources for the purchase of another company, and a management and leveraged buyout provides funds to enable operating management to acquire a product line or business from either a public or a private company.

Angel investor funds are concentrated in the seed-startup and early stages. During the 2007–08 period, they provided 80% of investment for these stages, compared with 20% in

Table 6-7
Firms and employment in U.S. small businesses versus all businesses: 2006

	All technologies		High technology	
Business	Firms (thousands)	Employment (millions)	Firms (thousands)	Employment (millions)
All businesses	6,022	120.0	519	15.4
Small businesses (number)	6,004	60.2	504	5.3
Small businesses (%)	99.7	50.2	97.1	34.4

NOTES: Small businesses are firms with <500 employees. Firms include those reporting no employees on their payroll. Firm is an entity that is either a single location with no subsidiary or branches or topmost parent of a group of subsidiaries or branches. High-technology industries defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations. High-technology small business employment is lower bound estimate because employment not available for a few industries due to data suppression.

SOURCES: Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/csd/susb/susb06.htm, accessed 1 June 2009; and Hecker DE. 2006. High-technology employment: A NAICS-based update. Monthly Labor Review 128(7):57–72, http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 1 June 2009.

Science and Engineering Indicators 2010

Table 6-8
Leading types of employers among high-technology small businesses, by industry: 2006

Industry	Employment (thousands)	Percent distribution
All industries	5,275	100.0
Service industries	3,599	68.2
Top six combined	3,085	58.5
Architectural, engineering, and related services	923	17.5
Computer systems design and related services	667	12.6
Management, scientific, and technical consulting services	637	12.1
Management of companies and enterprises	352	6.7
Professional and commercial equipment and supplies merchant wholesalers	311	5.9
Scientific research and development services	194	3.7
All others	514	9.7
Manufacturing	1,554	29.5
Top six combined	800	15.2
Motor vehicle parts manufacturing	163	3.1
Metalworking machinery manufacturing	139	2.6
Semiconductor and other electronic component manufacturing	136	2.6
Other general purpose machinery manufacturing	135	2.6
Other fabricated metal product manufacturing	127	2.4
Navigational, measuring, electromedical, and control instruments manufacturing	100	1.9
All others	754	14.3
Other	122	2.3

NOTES: Small businesses are firms with <500 employees. Firms include those reporting no employees on their payroll. Firm is an entity that is either a single location with no subsidiary or branches or is topmost parent of a group of subsidiaries or branches. High-technology industries defined by Bureau of Labor Statistics on basis of employment intensity of technology-oriented occupations. High-technology small business employment is lower bound estimate because employment not available for a few industries due to data supression. Other includes agriculture, mining, and utilities.

SOURCES: Census Bureau, Statistics of U.S. Businesses, http://www.census.gov/csd/susb/susb06.htm, accessed 1 June 2009; and Hecker DE. 2006. High-technology employment: A NAICS-based update. Monthly Labor Review 128(7):57–72, http://www.bls.gov/opub/mlr/2005/07/art6full.pdf, accessed 1 June 2009.

Science and Engineering Indicators 2010

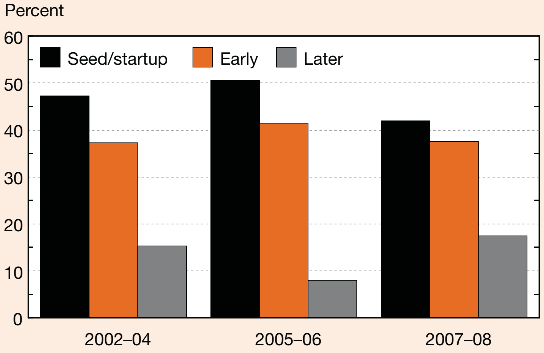
later stages (figure 6-44). Venture capital, however, is provided primarily for expansion and later-stage funding (figure 6-45; appendix table 6-72).

This section examines angel and venture capital investment patterns in the United States, focusing on the period from 2001 to 2008. The section examines (1) changes in the overall level of investment, (2) investment by stage of financing, and (3) the technology areas that U.S. angel and venture capitalists find attractive.

U.S. Angel Investment. According to data from the Center for Venture Research, angel investors provided $19 billion in financing in 2008, a sharp drop from $26 billion in 2007 following 5 consecutive years of increases (figure 6-46; appendix table 6-73).[31] An estimated 55,000 businesses received financing from angel investors in 2008, 1,600 fewer than in 2007 but 4,500 more than in 2006 (table 6-9). The average investment per business fell from about $455,000 in 2007 to $346,000 in 2008.

Although angel investors continue to concentrate on the riskiest stage of business development, they have become more conservative in their investment patterns. The share of angel funding going to seed-startup was 42% in the 2007–08 period compared with 47% in the 2002–04 period (figure 6-44).

Figure 6-44
Distribution of U.S. angel capital investment, by financing stage: 2002–08



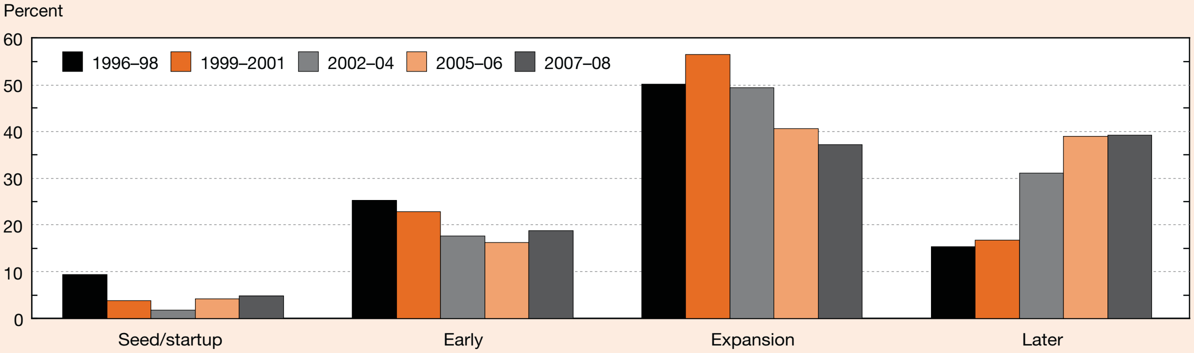
NOTES: Seed/startup includes proof of concept, research, and product development. Early includes financing for activities, such as initial expansion, commercial manufacturing, and marketing. Later includes major expansion of activities, preparation for an initial public offering, acquisition financing, and management and leveraged buyout.

SOURCE: Jeffrey Sohl, Analysis Reports, Center for Venture Research, University of New Hampshire, http://wsbe.unh.edu/analysis-reports-0, accessed 7 November 2009.

Science and Engineering Indicators 2010

Figure 6-45

U.S. venture capital investment, by share of investment stage: 1996–2008



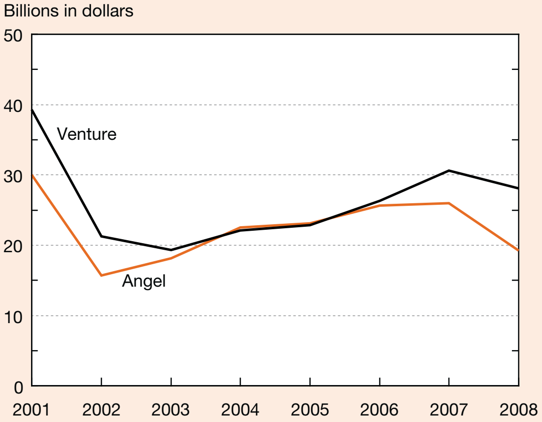
NOTES: Seed/startup includes proof of concept, research, and product development. Early includes financing for activities, such as initial expansion, commercial manufacturing, and marketing. Expansion includes major expansion of activities or preparation for initial public offering. Later includes acquisition financing and management and leveraged buyout.

SOURCE: PriceWaterhouseCoopers/National Venture Capital Association MoneyTree™ Report based on data from Thomson Reuters, https://www.pwcmoneytree.com/MTPublic/ns/index.jsp, accessed 7 November 2009.

Science and Engineering Indicators 2010

Figure 6-46

U.S. angel and venture capital investment: 2001–08



SOURCES: PriceWaterhouseCoopers/National Venture Capital Association MoneyTree™ Report based on data from Thomson Reuters, https://www.pwcmoneytree.com/ MTPublic/ns/index.jsp, accessed 7 November 2009; and Jeffrey Sohl, Analysis Reports, Center for Venture Research, University of New Hampshire, http://wsbe.unh.edu/analysis-reports-0, accessed 7 November 2009.

Science and Engineering Indicators 2010

Changes in the technology areas that attract angel investment may indicate changes in the parts of the economy that offer future growth opportunities. Healthcare services received the largest share of angel investment in 2008 (16%), 5 percentage points lower than its 2006 share (figure 6-47). Software received 13% of total angel investment in 2008, 5 percentage points lower than its 2006 share. Biotechnology received 11% of total investment in 2008, 7 percentage points lower than its 2006 share. The share of industrial/energy increased from 6% in 2006 to 8% in 2008, possibly reflecting opportunities that angel investors see in green and clean energy technologies.

Businesses receiving angel investment in 2007 employed about 200,000 workers (table 6-10). This figure is about the same as employment in the 2005–06 period. Each business employed an average of 3.5 workers in 2007, slightly lower than the average in 2005–06.

U.S. Venture Capital Investment. U.S. venture capitalists invested $28.1 billion in 2008, an 8% decline compared with the level in 2007 and the first decline since 2003 (figure 6-46; appendix table 6-72). The amounts of angel and venture capital investment have been very similar for the past 5 years. Since declining sharply in 2001 following the end of the dot.com boom, angel and venture capital investments have generally been strengthening, but in 2008 they remained well below their previous peaks.

Venture capitalists financed 3,300 firms in 2007, far fewer than the number of businesses financed by angel investors in the same year (57,000) (table 6-9; appendix table 6-72). Average venture capital investment has been about $8.5 million per firm for the past several years, much larger than the corresponding figure for angel investment.

The number of businesses funded by venture capital and the average amount of investment have been increasing during the past several years. The number of businesses was about 3,300 in 2007–08, one-quarter higher than the average for the 2002–05 period (table 6-9; appendix table 6-72). The average investment per business in 2008 ($8.6 million) was about $675,000 lower (not inflation adjusted) than that in 2007 but approximately $650,000 higher than the average for the 2002–03 period.

Table 6-9
Average investment of angel and venture capital per business: 2002–08

	Angel capital			Venture capital		
Year	Businesses (*n*)	Total investment ($billions)	Average investment/ business ($thousands)	Businesses (*n*)	Total investment ($billions)	Average investment/ business ($thousands)
2002	36,000	15.7	436	2,634	21.3	8,087
2003	42,000	18.1	431	2,461	19.3	7,842
2004	48,000	22.5	469	2,625	22.1	8,419
2005	49,500	23.1	467	2,708	22.9	8,456
2006	51,000	25.6	502	3,089	26.3	8,514
2007	57,120	26.0	455	3,301	30.6	9,270
2008	55,480	19.2	346	3,262	28.1	8,614

NOTE: Business includes anything from an entrepreneur with an idea to a legally established operating company.

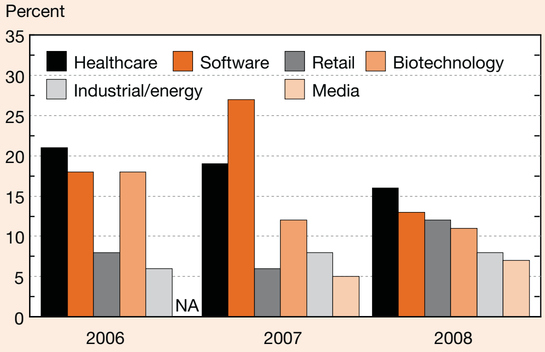
SOURCES: Jeffrey Sohl, Analysis Reports, Center for Venture Research, University of New Hampshire, http://wsbe.unh.edu/analysis-reports-0; and National Venture Capital Association and Price Waterhouse Coopers, Money Tree Report, https://www.pwcmoneytree.com/MTPublic/ns/index.jsp, accessed 15 March 2009.

Science and Engineering Indicators 2010

Venture capital investment has become generally more conservative than angel investment, and venture capital investments have more often been made in the later stages of business development. Capital provided for expansion and later-stage financing accounted for a combined share of 75% or more from 2002 to 2008 (figure 6-44; appendix table 6-72). Expansion financing accounted for half or more of all venture capital investment from 1996 through 2004, after which its share declined to 37% in 2007–08 as later-stage investments rose to 39%.

Venture capitalists have largely abandoned the seed-startup stage, which was 9% in the 1996–98 period, declined to 2% in the 2002–04 period, and recently recovered to a modest 5% (figure 6-44; appendix table 6-72). The factors behind the downturn are thought to be the desire for lowered investment risk, a shorter time horizon for realizing gains, and an increase in venture capital companies' base level for investment, which has come to exceed the amounts typically required for the earliest stages. The recent increase is thought to reflect the emergence of promising new investment opportunities after the closeout of holdings in mature companies (NVCA 2007a).

Figure 6-47
U.S. angel capital investment, by selected technology area: 2006–08



NOTES: Technology areas classified by Center for Venture Research, University of New Hampshire.

SOURCE: Jeffrey Sohl, Analysis Reports, Center for Venture Research, University of New Hampshire, http://wsbe.unh.edu/analysis-reports-0, accessed 7 November 2009.

Science and Engineering Indicators 2010

Venture Capital Financing, by Industry. Computer software had the largest share of venture capital funding of any industry in 2007–08 (18%) but registered a 5-percentage-point decline from 1999–2001 levels (figure 6-48; appendix table 6-72). Likewise, the share of telecommunications declined to 7% in 2007–08, about half of its 1999–2001 level.

Biotechnology received the second highest share of venture capital funding in 2007–08 (16%), slightly below the 2002–06 level but more than triple its share during the 1999–2001 period (figure 6-48; appendix table 6-72). The trend in medical devices and equipment was similar. Its share quadrupled from 3% during the 1999–2001 period to 13% in 2007–08.

Industrial/energy's share more than doubled from 6% in 2005–06 to 13% in 2007–08, similar to the trend in angel investment and thought to reflect investor interest in renewable and clean energy (figure 6-48; appendix table 6-72). Likewise, investments in clean technologies—a cross-cutting category of green and renewable energy—increased from a 9% share of venture investment in 2007 to a 15% share in 2008.

Table 6-10
Investors and employees of firms receiving angel capital investment: 2001–07

Year	Businesses receiving investment	Angel investors	Total employees	Average employees per business receiving investment
2001	NA	NA	NA	NA
2002	36,000	200,000	NA	NA
2003	42,000	220,000	NA	NA
2004	48,000	225,000	141,200	2.9
2005	49,500	227,000	198,000	4.0
2006	51,000	234,000	201,400	3.9
2007	57,120	258,200	200,000	3.5

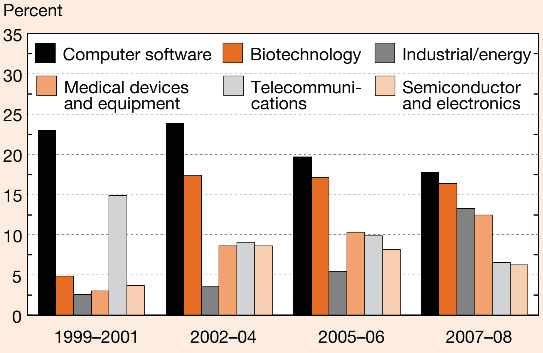
NA = not available

NOTE: Business includes anything from an entrepreneur with an idea to a legally established operating company.

SOURCE: Jeffrey Sohl, Analysis Reports, Center for Venture Research, University of New Hampshire, http://wsbe.unh.edu/analysis-reports-0.

Science and Engineering Indicators 2010

Figure 6-48
U.S. venture capital investment, by share of selected technology area: 1999–2008



SOURCE: PriceWaterhouseCoopers/National Venture Capital Association MoneyTree™ Report based on data from Thomson Reuters, https://www.pwcmoneytree.com/MTPublic/ns/index.jsp, accessed 7 November 2009.

Science and Engineering Indicators 2010

Innovation and Knowledge-Based Economic Growth

The World Bank developed its Knowledge Economy Index (KEI) to show the potential of countries to adopt, generate, diffuse, and harness knowledge in economic development. Knowledge is regarded as an important factor of innovation, given the shift of economic activity toward KTI industries and the growing importance of intangible assets.

The KEI is a simple average of four indicator scores that measure countries' relative standing in ICT, innovation, education, and economic incentive and institutional regime. In turn, the four component indicators are composed of several variables each. Countries are ranked in order of their scores on each variable, and scores are normalized on a scale of 0 to 10 compared with all countries: The top 10% of performers get a normalized score between 9 and 10, the next decile receives normalized scores between 8 and 9, and so on.

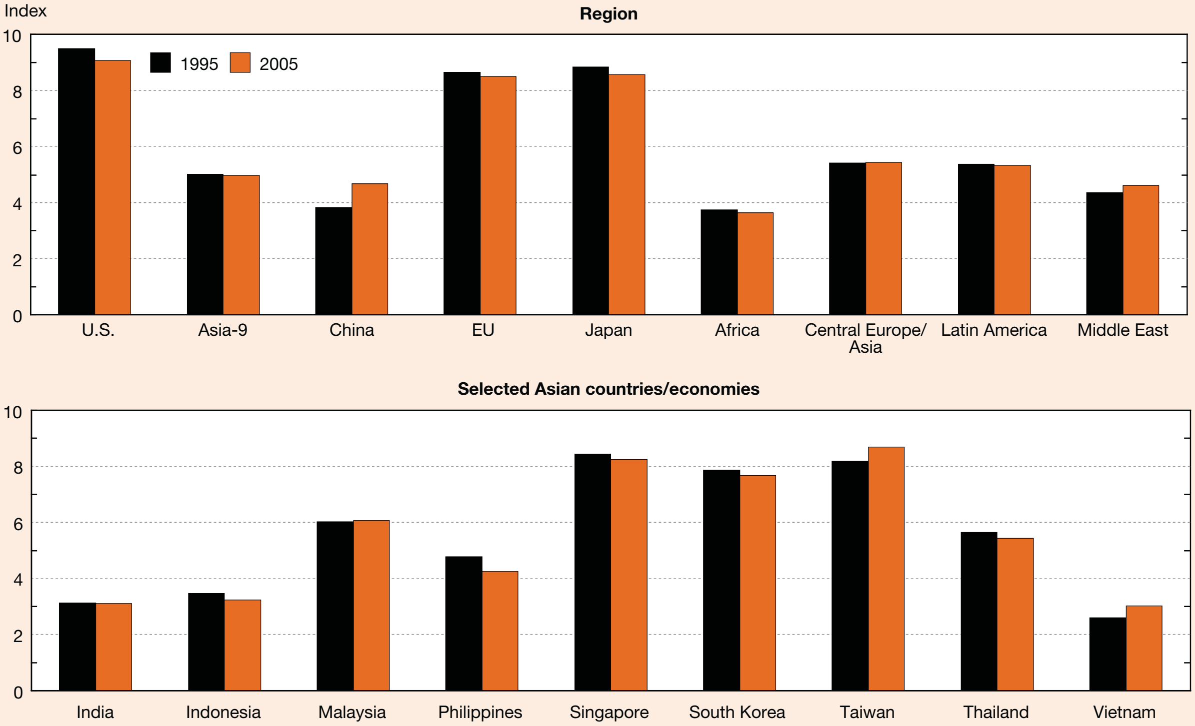
The 2005 KEI scores of the United States, Japan, and the EU were the highest among the major regions/countries/economies, followed by those of Taiwan, Singapore, and South Korea (figure 6-49; appendix table 6-74). Over a decade (1995–2005), the KEI scores of the United States, the EU, and Japan declined somewhat (figure 6-49; appendix table 6-74). The U.S. score fell largely because of a decline in the ICT sector, whose index value dropped from 9.8 to 8.9, and also because of weakness in the education sector. Japan's lowered KEI score reflected a decline in Japan's economic incentive regime; the EU's score was reduced because of a lowered education sector score.

Among the developing countries/economies, China, Taiwan, and Vietnam showed considerable improvement over the decade, albeit from very different levels (figure 6-49; appendix table 6-74). China improved its scores in all four component indicators, with the largest gains in the ICT and innovation scores. Although China's gap with the developed economies narrowed, its KEI score remains well below those of the developed economies.

Among the Asia-9, Taiwan and Vietnam showed solid increases (figure 6-49; appendix table 6-74). India's KEI index remained unchanged, thus widening the gap with China. India's modest score gains in innovation and economic incentive regime values were offset by weaknesses in ICT and education indicators, which remained in the 20% percentile range.

Among other developing countries, Brazil, Croatia, and Sri Lanka showed solid gains (appendix table 6-74). The improvement in Brazil's score reflected a large increase in its education score and a rise in its ICT score.

Figure 6-49
World Bank Knowledge Economic Index, by selected region/country/economy: 1995 and 2005



NOTES: Knowledge Economy Index is simple average of four indicator scores, each composed of several variables, measuring regions/countries/economies' relative standing in information and communications technology, innovation, education, economic incentive, and institutional regime. Regions/countries/economies ranked in order of scores on each variable, and scores normalized on 0–10 scale against all regions/countries/economies. Top 10% of performers receive normalized score between 9 and 10, decile receives normalized scores between 8 and 9, and so on. Scores for regions weighted by country's/economy's share of region's economic activity according to World Bank's gross domestic product on 2005 purchasing power parity basis. Africa includes Angola, Burkina Faso, Cameroon, Egypt, Ghana, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Tunisia, Uganda, and Zimbabwe. Asia-9 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Central Europe/Asia includes Albania, Armenia, Azerbaijan, Belarus, Croatia, Georgia, Kazakhstan, Kyrgyz Republic, Macedonia, Moldova, Russia, Tajikistan, Turkey, and Ukraine. China includes Hong Kong. EU excludes Malta. Latin America includes Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay, and Venezuela. Middle East includes Bahrain, Iran, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, and Yemen.

SOURCE: World Bank, Knowledge Assessment Methodology, http://web.worldbank.org/WBSITE/EXTERNAL/WBI/WBIPROGRAMS/KFDLP/EXTUNIKAM/0,,menuPK:1414738~pagePK:64168427~piPK:64168435~theSitePK:1414721,00.html, accessed 2 October 2009.

Science and Engineering Indicators 2010

Conclusion

The U.S. economy continues to be a leading global economy and competitor in technology-based industries as measured by its overall performance, market position in KTI industries, and position in patenting and other measures of technological capability. The U.S. economy has grown relatively rapidly and become more productive while sustaining a high and rising per capita income.

The strong competitive position of the U.S. economy is tied to continued U.S. global leadership in many KTI industries. The United States continues to hold the dominant market position in commercial knowledge-intensive service industries, which account for nearly one-fifth of global economic activity. The U.S. trading position in technology-oriented services remains strong, as evidenced by the continued U.S. surplus in commercial knowledge-intensive services and licensing of patents and trade secrets.

Although the United States remains a leader in many KTI industries, its market position in most of these industries has either flattened or slipped. The historically strong U.S. trade position in advanced technology products has shifted to deficit because of the faster growth of imports. This shift is due in part to U.S. companies moving assembly and other routine activities to China and other East Asian countries. However, the U.S. deficit also reflects the development of indigenous capability of East Asian countries in high-technology manufacturing industries.

China and other emerging Asian economies are showing rapid progress in their overall economic progress and technological capabilities. Their market positions in KTI industries—particularly high-technology manufacturing industries—have strengthened, and their shares of U.S. and economically valuable patents have risen, led by South Korea and Taiwan. World Bank indicators of innovative capacity also show that these emerging Asian economies are converging with the United States or are making rapid progress.

China has become a leading global producer and exporter of high-technology manufacturing goods by becoming the world's major assembly center, supplied by components and inputs from East Asian economies. However, China's rapid progress in other indicators of technological capability and the nascent rise of globally competitive Chinese companies suggest that China is moving to more technologically challenging and higher end manufacturing activities.

The EU's position is similar to that of the United States—relatively strong economic performance with flat or slight declines in its market position of KTI industries. Japan's economy has shown less dynamism compared with the United States and the EU, and its market position has declined steeply in many KTI industries. Japan's loss of market position in high-technology manufacturing industries is due, in part, to Japanese companies shifting production to China and other Asian economies.

The severe downturn of the global economy, starting in 2008, has interrupted these trends observed over the past decade. The United States, the EU, and other developed economies have experienced sharp declines in their commercial knowledge-intensive service industries. The steep drop in exports of high-technology manufacturing goods has adversely affected many Asian economies and slowed China's growth. Whether the global downturn will lead to fundamental changes in the market positions of the United States and other major economies in the production and trade of KTI industries remains uncertain.

Notes

1. The Asia-9 includes India, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

2. See OECD (2001) for a discussion of classifying economic activities according to degree of "knowledge intensity." A different, product-based classification of the Census Bureau is used in part of the discussion on trade.

3. In designating these high-technology manufacturing industries, OECD took into account both the R&D done directly by firms and R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct intensities were calculated as the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several non-manufacturing industries have equal or greater R&D intensities. For additional perspectives on OECD's methodology, see Godin (2004).

4. The combined estimated R&D expenditures of these regions/countries were $969 billion (2007 purchasing power parity) of an estimated $1.1 trillion in global R&D expenditures in 2007.

5. Purchasing power parity is the exchange rate required to purchase an equivalent market basket of goods.

6. This is an imprecise measure for comparing productivity growth, especially between developed and developing economies. One reason is that productivity is more difficult to measure in the service sector, and services typically have a far larger part of GDP in developed compared with developing economies.

7. See Atkinson and McKay (2007:16–17), for a discussion and references to the impact of IT on economic growth and productivity.

8. See Bresnahan and Trajtenberg (1995) and DeLong and Summers (2001) for a discussion of ICT and general-purpose technologies.

9. This index is composed of three measures: telephones per 1,000 people, computers per 1,000 people, and Internet users per 10,000 people. Country scores on measures are normalized on a scale of 1–10, with 10 being equivalent to the highest score received by a country.

10. See Mann (2006:90–92), for a discussion of the economic benefits of importing versus exporting ICT.

11. The U.S. dollar strengthened about 30% in value between 1995 and 2001 against a trade-weighted basket of European currencies (1995–98) and the euro (1999–2001) and subsequently lost more than 50% in value against the euro between 2001 and 2007. This exchange-rate movement lowered European industry output measured in U.S. current dollars between 1995 and 2001 and raised it between 2001 and 2007.

12. IHS Global Insight data as of July 2009.

13. The U.S. trade balance is affected by many other factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies between the United States and its trading partners.

14. U.S. multinational financial services data for 1999 and 2006 do not include banks and depository institutions, which are included in the global industry data on financial services.

15. U.S. direct investment abroad by industry and country is a lower-bound estimate because an increasing share of U.S. direct investment (36% in 2008) is through holding companies that invest in other industries that may be in

a different country. For more information, see Ibarra and Koncz (2008).

16. In these data, BEA values foreign direct investment (FDI) at historical cost. According to BEA, a negative FDI position in the United States occurs when total claims of U.S. subsidiaries on their foreign multinational parent companies (MNCs) exceed the foreign MNCs' investment in the United States, which typically results when U.S. affiliates are net lenders to their foreign parents.

17. There are widely different definitions of innovation, but common to these definitions is the commercialization of something that did not previously exist.

18. Earlier data are not comparable because of a change in the data collected.

19. An *affiliate* is a business enterprise located in one country that is directly or indirectly owned or controlled by an entity in another country. The controlling interest for an incorporated business is 10% or more of its voting stock; for an unincorporated business, it is an interest equal to 10% of voting stock.

20. In addition, data on the destination of multinational corporate sales to foreign affiliates also suggest that market access is an important factor in the firms' decisions to locate production abroad. See Borga and Mann (2004).

21. Rather than granting property rights to the inventor, as is the practice in the United States and many other countries, some countries grant property rights to the applicant, which may be a corporation or other organization.

22. U.S. patent law states that any person who "invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent." The law defines nonobvious as "sufficiently different from what has been used or described before [so] that it may be said to be *nonobvious* to a person having ordinary skill in the area of technology related to the invention." These terms are part of the criteria in U.S. patent law. For more information, see USPTO, "What Is a Patent?," at http://www.uspto.gov/web/offices/pac/doc/general/index.html#patent. Accessed 19 June 2009.

23. The Japan Patent Office (JPO) is also a major patent office but has a much smaller share of foreign patents compared with the USPTO and the European Patent Office (EPO).

24. Although the USPTO grants several types of patents, this discussion is limited to utility patents, commonly known as patents for inventions. They include any new, useful, or improved-on method, process, machine, device, manufactured item, or chemical compound.

25. USPTO reports that average time to process an application (pendancy) was 31.1 months for utility, plant, and reissue patent applications in FY 2006, compared with 18.3 months in FY 2003. Applications for utility patents account for the overwhelming majority of these requests. EPO reports that the average pendancy was 45.3 months in 2005.

26. Unless otherwise noted, USPTO patents are assigned to countries on the basis of the residence of the first-named inventor.

27. U.S. patenting data by type of ownership and by state are available only for U.S. patents granted.

28. Triadic patent families with co-inventors residing in different countries are assigned to their respective countries/economies on a fractional count basis (i.e., each country/economy receives fractional credit on the basis of the proportion of its inventors listed on the patent). Patents are listed by priority year, which is the year of the first patent filing. Data for 1998–2003 are estimated by the OECD.

29. The high-technology definition used here is from the Bureau of Labor Statistics and differs from that used in earlier sections.

30. See Hecker (2005) for a definition and methodology for determining high-technology industries. Several industries identified by BLS as high technology before 2003 are not covered in the Census Bureau's data.

31. Comparable data on angel capital investment before 2001 are not available.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Angel investment: Financing from affluent individuals for business startups, usually in exchange for ownership equity. Angel investors typically invest their own funds or organize themselves into networks or groups to share research and pool investment capital.

Asia-9: India, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

Commercial knowledge-intensive services: Knowledge-intensive services that are generally privately owned and compete in the marketplace without public support. These services are business, communications, and financial services.

Company or firm: A business entity that is either a single location with no subsidiary or branches or the topmost parent of a group of subsidiaries or branches.

EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the UK.

EU (EU-27): Current member countries of the European Union are Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the UK.

Foreign direct investment: Financial investment by which a person or an entity acquires a lasting interest in and a degree of influence over the management of a business enterprise in a foreign country.

Gross domestic product (GDP): The market value of all final goods and services produced within a country within a given period of time.

Harmonized code, harmonized system (HS): Developed by the Customs Cooperation Council, the Harmonized System, or Harmonized Commodity Description and Coding System, is used to classify goods in international trade.

High-technology manufacturing industries: Those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

Information and communications technology industries: A subset of knowledge- and technology-intensive industries, consisting of two high-technology manufacturing industries, computers and office machinery and communications equipment and semiconductors and two knowledge intensive service industries, communications and computer services, which is a subset of business services.

Intellectual property: Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

Intra-EU exports: Exports from EU countries to other EU countries.

Knowledge-intensive industries: Those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, communications, education, financial, and health services.

Knowledge- and technology-intensive industries: Those that have a particularly strong link to science and technology. These industries are five service industries, financial, business, communications, education, and health and five manufacturing industries, aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

Normalizing: To adjust to a norm or standard.

Not obvious: One criterion (along with "new" and "useful") by which an invention is judged to determine its patentability.

Productivity: The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by GDP or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

Purchasing power parity (PPP): The exchange rate required to purchase an equivalent market basket of goods.

R&D intensity: The proportion of R&D expenditures to the number of technical people employed (e.g., scientists, engineers, and technicians) or the value of revenues.

Small business: A company or firm with less than 500 employees.

Triadic patent: A patent for which patent protection has been applied within the three major world markets: the United States, Europe, and Japan.

Utility patent: A type of patent issued by the U.S. Patent and Trademark office for inventions, including new and useful processes, machines, manufactured goods, or composition of matter.

Value added: A measure of industry production that is the amount contributed by the country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Value chain: A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

Venture capitalist: Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always participate in managerial decisions.

References

Atkinson RD, McKay AS. 2007. *Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution.* Special Report. Washington, DC: The Information Technology & Innovation Foundation. http://www.itif.org/index.php?id=34. Accessed 24 September 2009.

Athukorala P-C, Yamashita N. 2006. Production fragmentation and trade integration: East Asia in a global context. *North American Journal of Economics and Finance* 17:233–56.

Borga M, Mann M. 2004. U.S. international services: Cross-border trade in 2003 and sales through affiliates in 2002. Survey of Current Business, October:25–31.

Branstetter LG, Fisman R, Foley CF. 2006. Do stronger intellectual property rights increase international technology transfer? Empirical evidence from U.S. firm-level panel data. *Quarterly Journal of Economics* 121:321–49.

Bresnahan T, Trajtenberg M. 1995. General purpose technologies: "Engines of growth"? *Journal of Econometrics* 65:83–108.

Cohen W, Nelson R, Walsh J. 2000. Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not). National Bureau of Economic Research (NBER) Working Paper No. 7552. http://www.nber.org/papers/w7552. Accessed 15 June 2009.

Dedrick J, Kraemer KL, Linden G. 2008. Who profits from innovation in global value chains? A study of the iPod and Notebook PCs. University of California, Irvine. http://pcic.merage.uci.edu/papers/2008/WhoProfits.pdf. Accessed 15 June 2009.

DeLong JB, Summers LH. 2001. How important will the information economy be? Some simple analytics. University of California, Berkeley, and National Bureau of Economic Research. http://econ161.berkeley.edu/Econ_Articles/summers_jh_2001/jh_analytics.pdf. Accessed 19 October 2009.

Godin B. 2004. The new economy: What the concept owes to the OECD. *Research Policy* 33:679–90.

Hecker D. 2005. High-technology employment: A NAICS-based update. *Monthly Labor Review* July:57–72. http://www.bls.gov/opub/mlr/2005/07/art6full.pdf. Accessed 15 June 2009.

Ibarra M, Koncz J. 2008. Direct investment positions for 2008: Country and industry detail. *Survey of Current Business* 89(7):20–34. http://www.bea.gov/scb/pdf/2009/07%20July/0709_dip.pdf. Accessed 27 August 2009.

Idris K. 2003. *Intellectual Property—A Power Tool for Economic Growth.* Geneva: World Intellectual Property Organization. http://www.wipo.int/about-wipo/en/dgo/wipo_pub_888/index_wipo_pub_888.html. Accessed 15 June 2009.

International Monetary Fund (IMF). 2009. World economic outlook databases. http://www.imf.org/external/ns/cs.aspx?id=28. Accessed 7 August 2009.

Kaminski B, Ng F. 2001. *Trade and Production Fragmentation: Central European Economies in European Union Networks of Production and Marketing, Volume 1.* World Bank Policy Research Working Paper No. 2611. http://go.worldbank.org/74S201OXJ0. Accessed 24 September 2009.

Koopman R, Wang Z, Wei S-J. 2008. How Much of Chinese Exports Is Really Made in China? Assessing Domestic Value Added When Processing Trade is Pervasive. National Bureau of Economic Research (NBER) Working Paper No. 14109. http://www.nber.org/papers/w14109. Accessed 15 June 2009.

Kumar A. 2007. Does foreign direct investment help emerging economies? *Economic Letter* 2(1), January. Federal Reserve Bank of Dallas. http://dallasfed.org/research/eclett/2007/el0701.html. Accessed 20 October 2009.

Mann C, Kirkegaard JF. 2006. *Accelerating the Globalization of America: The Role for Information Technology.* Washington, DC: Institute for International Economics.

National Research Council (NRC). 2004. *A Patent System for the 21st Century.* Merrill SA, Levin RC, Myers MB, editors. Committee on Intellectual Property Rights in the Knowledge-Based Economy. Washington, DC: National Academies Press.

National Venture Capital Association (NVCA). 2007. *National Venture Capital Association Yearbook 2007.* Thomson Financial.

Ng F, Yeats A. 2003. Major Trade Trends in East Asia: What Are Their Implications for Regional Cooperation and Growth? Policy Research Working Paper No. 3084. The World Bank. http://econ.worldbank.org/external/default/main?pagePK=64165259&piPK=64165421&theSitePK=469372&menuPK=64216926&entityID=000094946_03071704242197. Accessed 4 August 2009.

Organisation for Economic Co-operation and Development (OECD). 2001. *Knowledge-Based Industries.* Paris: Directorate for Science, Technology, and Industry/ Economic Analysis Statistics.

Organisation for Economic Co-operation and Development (OECD). 2007. *Science, Technology and Industry Scoreboard 2007, Annex 1.* Paris: Directorate for Science, Technology, and Industry. http://masetto.sourceoecd.org/pdf/sti2007/922007081e1-annex1.pdf. Accessed 26 June 2009.

Rosen DH, Wing HP. 2005. China and the changing economic geography of Asia? Seminar Series 5. Washington, DC: National Defense University, Institute for National Strategic Studies, and American Enterprise Institute for Public Policy Research. http://www.aei.org/event/1109. Accessed 15 June 2009.

United States Patent and Trademark Office (USPTO). 2008. Extended year set—Historic patents by country, state, and year; Utility patents (December 2008). http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utlh.htm. Accessed 28 August 2009.

Chapter 7
Science and Technology: Public Attitudes and Understanding

List of Sidebars

List of Tables

List of Figures

Highlights

Information Sources, Interest, and Involvement

Television and the Internet are the primary sources Americans use for science and technology (S&T) information. The Internet is the main source of information for learning about specific scientific issues such as global climate change or biotechnology.

- More Americans select television as their primary source of S&T information than any other medium.
- The Internet ranks second among sources of S&T information, and its margin over other sources is large and has been growing.
- Internet users do not always assume that online S&T information is accurate. About four out of five have checked on the reliability of information at least once.

Continuing a long-standing pattern, Americans consistently express high levels of interest in S&T in surveys. However, other indicators, such as the types of news they follow closely, suggest a lower level of interest.

- High levels of interest in S&T are part of a long-standing trend, with more than 80% of Americans reporting they were "very" or "moderately" interested in new scientific discoveries. But relative to other news topics, interest in S&T is not particularly high.
- As with many news topics, the percentage of Americans who say they follow "science and technology" news "closely" has declined over the last 10 years.
- Recent surveys in other countries, including South Korea, China, and much of Europe, indicate that the overall level of public interest in "new scientific discoveries" and "use of new inventions and technologies" tends to be higher in the United States.
- Interest in "environmental pollution" or "the environment" is similarly high in the U.S., Europe, South Korea, and Brazil. About 9 in 10 respondents in each country expressed interest in this topic.

In 2008, a majority of Americans said they had visited an informal science institution such as a zoo or a natural history museum within the past year. This proportion is generally consistent with results from surveys conducted since 1979, but slightly lower than the proportion recorded in 2001.

- Americans with more formal education are much more likely to engage in informal science activities.
- Compared with the United States, visits to informal science institutions tend to be less common in Europe, Japan, China, Russia, and Brazil.

Public Knowledge About S&T

Many Americans do not give correct answers to questions about basic factual knowledge of science or the scientific inquiry process.

- Americans' factual knowledge about science is positively related to their formal education level, income level, the number of science and math courses they have taken, and their verbal ability.
- People who score well on long-standing knowledge measures that test for information typically learned in school also appear to know more about new science related topics such as nanotechnology.

Levels of factual knowledge of science in the United States are comparable to those in Europe and appear to be higher than in Japan, China, or Russia.

- In the United States, levels of factual knowledge of science have been stable; Europe shows evidence of recent improvement in factual knowledge of science.
- In European countries, China, and Korea demographic variations in factual knowledge are similar to those in the United States.

Compared to the mid-1990s, Americans show a modest improvement in understanding the process of scientific inquiry in recent years.

- Americans' understanding of scientific inquiry is strongly associated with their factual knowledge of science and level of education.
- Americans' scores on questions measuring their understanding of the logic of experimentation and controlling variables do not differ by sex. In contrast, men tend to score higher than women on factual knowledge questions in the physical sciences.

Public Attitudes About S&T in General

Americans in all demographic groups consistently endorse the past achievements and future promise of S&T.

- In 2008, 68% of Americans said that the benefits of scientific research have strongly outweighed the harmful results, and only 10% said harmful results slightly or strongly outweighed the benefits.
- Nearly 9 in 10 Americans agree with the statement "because of science and technology, there will be more opportunities for the next generation."
- Americans also express some reservations about science. Nearly half of Americans agree that "science makes our way of life change too fast."

- Americans tend to have more favorable attitudes about the promise of S&T than Europeans, Russians, and the Japanese. Attitudes about the promise of S&T in China and South Korea are as positive as those in the United States and in some instances even more favorable. However, residents of China and Korea are more likely than Americans to think that "science makes our way of life change too fast."

Support for government funding of scientific research is strong.

- In 2008, 84% of Americans expressed support for government funding of basic research.
- More than one-third of Americans (38%) said in 2008 that the government spends too little on scientific research and 11% said the government spends too much. Other kinds of federal spending such as health care and education generate stronger public support.

The public expresses confidence in science leaders.

- In 2008, more Americans expressed a "great deal" of confidence in scientific leaders than in the leaders of any other institution except the military.
- Despite a general decline in confidence in institutional leaders that has spanned more than three decades, confidence in science leaders has remained relatively stable. The proportion of Americans indicating "a great deal of confidence" in the scientific community oscillated between 35% and 45% in surveys conducted since 1973. In every survey, the scientific community has ranked either second or third among institutional leaders.
- On science-related public policy issues (including global climate change, stem cell research, and genetically modified foods), Americans believe that science leaders, compared with leaders in other sectors, are relatively knowledgeable and impartial and should be relatively influential. However, they also perceive a considerable lack of consensus among scientists on these issues.

Over half of Americans (56%) accord scientists "very great prestige." Ratings for engineers are lower (40% indicate "very great prestige"), but nonetheless better than those of most other occupations.

- In 2008, scientists ranked higher in prestige than 23 other occupations surveyed, a ranking similar to that of firefighters.
- Between 2007 and 2008, engineers' rating of "very high prestige" increased from 30% of survey respondents to 40%.

Public Attitudes About Specific S&T Issues

Americans have recently become more concerned about environmental quality. However, concern about the environment is outranked by concern about the economy, unemployment, and the war in Iraq.

- Between 2004 and 2008, the proportion of Americans expressing "a great deal" or "a fair amount" of worry about the quality of the environment increased from 62% to 74%. Nonetheless, when asked to name the country's top problem in early 2009, only about 2% mentioned environmental issues.
- In 2008, 67% of Americans believed that the government was spending too little to reduce pollution and 7% thought it was spending too much.
- The trend in support for environmental protection is less evident when Americans are asked about trade-offs between environmental protection and economic growth. In March 2009, 51% of all Americans indicated that economic growth should take precedence over the environment.

Americans support the development of alternative sources of energy.

- A majority of Americans favor government spending to develop alternate sources of fuel for cars (86%), to develop solar and wind power (79%), and to enforce environmentally friendly regulations such as setting higher emissions and pollution standards for business and industry (84%).
- Since the mid-1990s, American public opinion on nuclear energy has been evenly divided, but the proportion of Americans favoring the use of nuclear power as one of the ways to provide electricity for the U.S. increased from 53% in 2007 to 59% in 2009.
- Europeans are divided on nuclear energy, but support is on the rise. The proportion of Europeans who said they favored energy production by nuclear power stations increased from 37% in 2005 to 44% in 2008, while the proportion opposing it decreased from 54% in 2005 to 45% in 2008. Support for nuclear energy varies a great deal among countries in this region. Citizens in countries that have operational nuclear power plants are more likely to support nuclear energy than those in other countries.

Despite the increased funding of nanotechnology and growing numbers of nanotechnology products in the market, Americans remain largely unfamiliar with this technology.

- Even among respondents who had heard of nanotechnology, knowledge levels were not high.
- When nanotechnology is defined in surveys, Americans express favorable attitudes overall.

A majority of Americans favor medical research that uses stem cells from human embryos. However, Americans are overwhelmingly opposed to reproductive cloning and wary of innovations using "cloning technology."

- Support for embryonic stem cell research is similar to previous years. In 2008, 57% of Americans favored embryonic stem cell research while 36% opposed it. A higher proportion (70%) favors stem cell research when it does not involve human embryos.
- More than three-quarters of Americans oppose human cloning.

Introduction

Chapter Overview

Science and technology (S&T) affect all aspects of American life. As workers, Americans use technology to improve productivity in ways that could not even be imagined a generation ago, applying recently invented tools and applications. As consumers, they entertain themselves with high technology electronic products; make friends, communicate, and keep informed about the world through the Internet; and benefit from advances in medical technologies. As citizens, they may engage in discussions on climate change, stem cell research, and deficit spending—issues about which atmospheric scientists, microbiologists, and macroeconomists have formal training and expertise.

It is increasingly difficult for Americans to be competent as workers, consumers, and citizens without some degree of competence in S&T. Because competence begins with understanding, this chapter presents indicators about news, information, and knowledge of S&T. How the American citizenry collectively deals with public issues that involve S&T may, in turn, affect what kinds of S&T development America will support. Thus the chapter includes indicators of people's attitudes about S&T-related issues. To put U.S. data in context, this chapter examines trend indicators for past years and comparative indicators for other countries.

Chapter Organization

The chapter is divided into four major sections. The first section includes indicators of the public's sources of information about, level of interest in, and active involvement with S&T. The second section reports indicators of public knowledge, including measures of factual knowledge of science and engineering and people's understanding of the scientific process. When possible, it compares American adults' understanding of science to that of American students. The third and fourth sections of the chapter describe public attitudes toward S&T. The third section contains data on attitudes about S&T in general, including support for government funding of basic research, confidence in the leadership of the scientific community, perceptions of the prestige of S&E occupations, and opinions about how much influence science and scientists should have in public affairs. The fourth section addresses public attitudes on issues in which S&T plays an important role, such as the environment, the quality of science and math education, and the use of animals in scientific research. It also includes indicators of public opinion about several emerging lines of research and new technologies, including nuclear power, biotechnology, genetically modified (GM) food, nanotechnology, stem cell research, and cloning.

A Note About the Data and the Terminology

This chapter emphasizes trends over time, patterns of variation within the U.S. population, and international patterns. It gives less weight to the specific percentages of survey respondents who gave particular answers to the questions posed to them. Although, inevitably, the chapter reports these percentages, they are subject to numerous sources of error and should be treated with caution. Caution is especially warranted for data from surveys that omit significant portions of the target population, have low response rates, or have topics that are particularly sensitive to subtle differences in question wording. In contrast to specific percentages, consistent and substantial trends and patterns warrant greater confidence (see sidebar, "Survey Data Sources").

Most of the international comparisons involve identical questions asked in different countries. However, language and cultural differences can affect how respondents interpret questions and can introduce numerous complexities, so international comparisons require careful consideration.

Throughout the chapter, the terminology used in the text reflects the wording in the corresponding survey question. In general, survey questions asking respondents about their primary sources of information, interest in issues in the news, and general attitudes use the phrase "science and technology." Thus the term "S&T" is used in the parts of the chapter discussing these data. Survey questions asking about confidence in institutional leaders, prestige of occupations, and views of different disciplines use terms such as "scientific community," "scientists," "researchers," or "engineers," so "S&E" is used in sections examining issues related to occupations, careers, and fields of research. Although science and engineering are distinct fields, national data that make this distinction are scarce.

Information Sources, Interest, and Involvement

Because S&T are relevant to so many aspects of daily life, information about S&T can help Americans make informed decisions and more easily navigate the world around them. Interest in and involvement with S&T can lead Americans to acquire more information and achieve greater understanding.

S&T Information Sources

U.S. Patterns and Trends

More Americans get most of their information about current news events from television than from any other source. When asked "Where do you get most of your information about current news events?," 47% say television, with substantial percentages also reporting the Internet (22%) and newspapers (20%) as their main source (figure 7-1; appendix table 7-1). Since the 1990s, the proportion of Americans getting information about current news events from the

Survey Data Sources

National scope	Sponsoring organization	Title	Years used	Information used	Data collection method	Number of respondents/ margin of error of general population estimates
United States	National Science Foundation (NSF)	Public Attitudes Toward and Understanding of Science and Technology (1979–2001); includes University of Michigan Survey of Consumer Attitudes 2004	1979–2001, 2004	Information sources, interest, informal science institution visits, government spending, general attitudes, science/ math education and animal research attitudes	Random direct dialing (RDD) computer-assisted telephone survey	n = ~1,600–2,000 ± 2.47% – ± 3.03%
	National Opinion Research Center (NORC) at the University of Chicago	General Social Survey (GSS)	1973–2008	Government spending, confidence in institutional leaders	Face-to-face interviews	Government spending: n = 1,574–2,992 ± 2.1% – ± 3.5% Confidence in institutional leaders: n = 876–1,989 ± 2.6% – ± 3.8%
	NORC at the University of Chicago	GSS S&T module	2006, 2008	Information sources, interest, informal science institution visits, government spending, general attitudes, science/ math education and animal research attitudes, nanotechnology awareness and attitudes	Face-to-face interviews	n = 1,864 (2006) ± 2.68% n = 1,505 (2008) ± 2.98%
	Gallup Organization	Various ongoing surveys	1984, 1990–1992, 1995, 1997–2009	Environment, stem cell research, nuclear power attitudes	RDD	n = ~1,000 ±3.0%
	Virginia Commonwealth University (VCU) Center for Public Policy	VCU Life Sciences Survey	2001–08	S&T interest, general attitudes, stem cell research and animal research attitudes	RDD	n = ~1,000 ± 3.0% (2006 and 2007) ± 3.8% (2008)
	Department of Education, National Center for Education Statistics (NCES)	National Assessment of Education Progress (NAEP)	2000 (8th graders); 2005 (4th and 8th graders)	Science knowledge	Paper questionnaires	2000 (independent national sample): n = 15,955 8th graders ± 2.2% (one question used) 2005 (combined national/state sample): n = 147,700 4th graders ± 1.0% (one question used) n = 143,400 8th graders ± 0.8% – 1.2% (three questions used)
	American Association for the Advancement of Science (AAAS)	AAAS Project 2061 (unpublished results, 2008)	2007 (middle school students)	Science knowledge	Paper questionnaires	n = 2,047 middle school students n = 1,597 (follow-up question)
	Pew Research Center for the People & the Press	Biennial News Consumption Survey	1996–2008	Information sources, interest	RDD	n = 3,615 (2008) ± 2.0%
	Pew Research Center for the People & the Press	News Interest Index	2007–2008	Information sources, interest	RDD	n = ~1,000 ± 3.5%
	Pew Internet & American Life Project	Pew Internet & American Life Project Survey	2006	Information sources, interest, involvement	RDD	n = 2,000 ± 3.0%
	Harris Interactive	The Harris Poll	1977–2008	Occupational prestige attitudes, internet use	RDD	Occupational prestige: n = ~1,000 (~500 asked about each occupation) Internet use n = ~2,020
	CBS News/ New York Times	CBS News/New York Times Poll	2008	Genetically modified food awareness and attitudes	RDD	n = 1,065 ± 3.0%
	Woodrow Wilson International Center for Scholars	Project on Emerging Nanotechnologies (2008)	2008	Nanotechnology awareness and attitudes	Telephone interviews	n = 1,003 ± 3.1%

Survey Data Sources

National scope	Sponsoring organization	Title	Years used	Information used	Data collection method	Number of respondents/ margin of error of general population estimates
International	European Commission	Special Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology* (2005); Special Eurobarometer 282/Wave 67.2: *Scientific Research in the Media* (2007); Special Eurobarometer 297/ Wave 69.1: *Attitudes Towards Radioactive Waste* (2008); Special Eurobarometer 300/ Wave 69.2: *Europeans' Attitudes Towards Climate Change* (2008)	1992, 2005, 2007, 2008	Knowledge, trust in scientists and public support for basic research attitudes, among others	Face-to-face interviews	n = 32,897 total:~1,000 for 27 countries, ~500 for 4 countries (2005) n = 26,717 total: :~1,000 for 24 countries, ~500 for 3 countries (2007) n = 26,746 total:~1,000 for 24 countries, ~500 for 3 countries (2008) n=30,170 total:~1,000 for 27 countries, ~500 for 4 countries (2008) ± 1.9% – ± 3.1%
	Canadian Biotechnology Secretariat	Canada-U.S. Survey on Biotechnology	2005	Biotechnology, nanotechnology, and other technology attitudes (includes U.S. data on specific issues)	RDD	Canada: n = 2,000 ± 2.19% U.S.: n = 1,200 ± 2.81%
	British Council, Russia	Russian Public Opinion of the Knowledge Economy (2004)	1996, 2003	Various knowledge and attitude items	Paper questionnaires	n = 2,107 (2003)
	Chinese Ministry of Science and Technology	*China Science and Technology Indicator 2002* (2002)	2001	Various knowledge and attitude items	Information not available	n = 8,350
	China Research Institute for Science Popularization (CRISP)	Chinese Public Understanding of Science and Attitudes towards Science and Technology, 2007 (2008)	2007	Various knowledge and attitude items	Face-to-face interviews	n = 10,059 (2007) ±3.0%
	Japan National Institute of Science and Technology Policy	The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan	2001	Various knowledge and attitude items	Face-to-face interviews	n=2,146
	Korea Foundation for the Advancement of Science and Creativity (KOFAC, formerly Korea Science Foundation)	Survey of Public Attitudes Toward and Understanding of Science and Tech-nology 2004, 2008	2004, 2006, 2008	Interest, informal science institution visits, various knowledge and attitude items	Face-to-face interviews	n = 1,000 ±3.1%
	Malaysian Science and Technology Information Centre	*Public Awareness of Science and Technology Malaysia 2004* (2005)	2004	Various knowledge and attitude items	Face-to-face interviews	n = 6,896 ± 2.0%
	India National Council of Applied Economic Research	India Science Survey 2004	2004	Various knowledge and attitude items	Face-to-face interviews	n = 30,255
	Department of Education, NCES	Trends in International Mathematics and Science Study (TIMSS)	2003 (8th grade)	Science knowledge	Paper questionnaires	U.S.: n = 8,912 ± 1.4% (for all TIMSS questions) Other 44 countries: n = 2,943–8,952± 1.0% – 2.4% (for all TIMSS questions)
	BBVA Foundation	BBVA Foundation International Study on Attitudes Towards Stem Cell Research and Hybrid Embryos (2008)	2007/2008 combined	Knowledge, awareness, and attitudes on stem cell research	Face-to-face interviews	n = 1,500 in each of 15 countries ± 2.6%
	Ministry of Science and Technology of Brazil	*Public Perceptions of Science and Technology* (2007)	2006	Interest, informal science institution visits	Face-to-face interviews	n = 2,004 ± 2.2%
	Samuel Neaman Institute for Advanced Studies in Science and Technology	*Science and Technology in the Israeli Consciousness* (2006)	2006	Prestige of science careers	Telephone interviews	n = 490

NOTES: All surveys are national in scope. Statistics on number of respondents and margin of error are as reported by the sponsoring organization. When a margin of error was not cited, none was given by the sponsor.

Internet has increased considerably and the proportion using newspapers for current events has declined (figure 7-2).[1] However, audiences are getting news from both traditional sources (television, print) and the Internet and blending these sources together, rather than choosing between one or another (Pew Research Center for the People and the Press 2008).

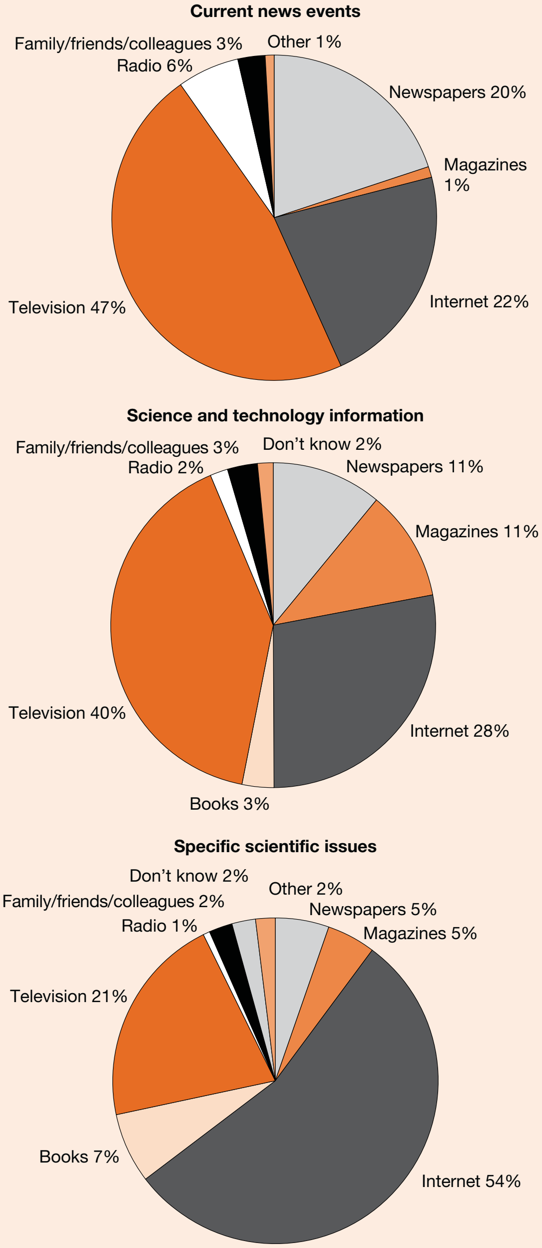
Americans report a somewhat different pattern of primary sources for S&T information than for information about current news events (figure 7-3; appendix tables 7-1 and 7-2). For both kinds of information, more Americans select television as their primary source than any other medium, followed by the Internet. The Internet, magazines, and books or other printed material are more widely used as primary information sources for S&T than for current news; the opposite is true for television, newspapers, and radio (figure 7-3). The proportion of Americans who said the Internet was their primary source for S&T news grew from 22% in 2006 to 28% in 2008. Since 2001, this proportion has more than tripled (figure 7-2).

When asked, "If you wanted to learn about scientific issues such as global warming or biotechnology, where would you get information?," 54% of Americans choose the Internet even though almost one out of five Americans cannot access the Internet at home, work, schools, libraries, and other locations (Harris Interactive 2008a). Television (21%) ranked as a distant second (figure 7-1; appendix table 7-3). Reliance on the Internet, which grew substantially over the past decade, is still growing but shows signs of leveling off (figure 7-2).

In general, use of the Internet for news and information, including S&T information, is higher among younger audiences and increases with education and income. (Access to high-speed Internet connections is also associated with more time online and more extensive reliance on the Internet for news and information [Cole 2007; Horrigan 2006].) Conversely, the use of television decreases with education and income and increases with age (appendix tables 7-1 and 7-2). Analyses that examine age differences in patterns of media use through repeated cross-sectional surveys hide considerable generational effects, because they only show a snapshot of a single point in time (Losh 2009). Younger generations that grow up relying more exclusively on the Internet are not likely to shift to traditional media as they age.

National data that address the processes through which Americans acquire and sort through S&T information are scarce. A Pew Internet and American Life Project survey (Horrigan 2006) examined how Americans use the Internet to acquire information about science. It found that a clear majority of Internet users had engaged in some information search activities, including "look[ing] up the meaning of a particular scientific term or concept" (70%), "look[ing] for an answer to a question you have about a scientific concept or theory" (68%), and "learn[ing] more about a science story or scientific discovery you first heard or read about offline" (65%). In addition, just over half had used the Internet to "complete a science assignment for school, either for

Figure 7-1
Primary source of information, by use: 2008

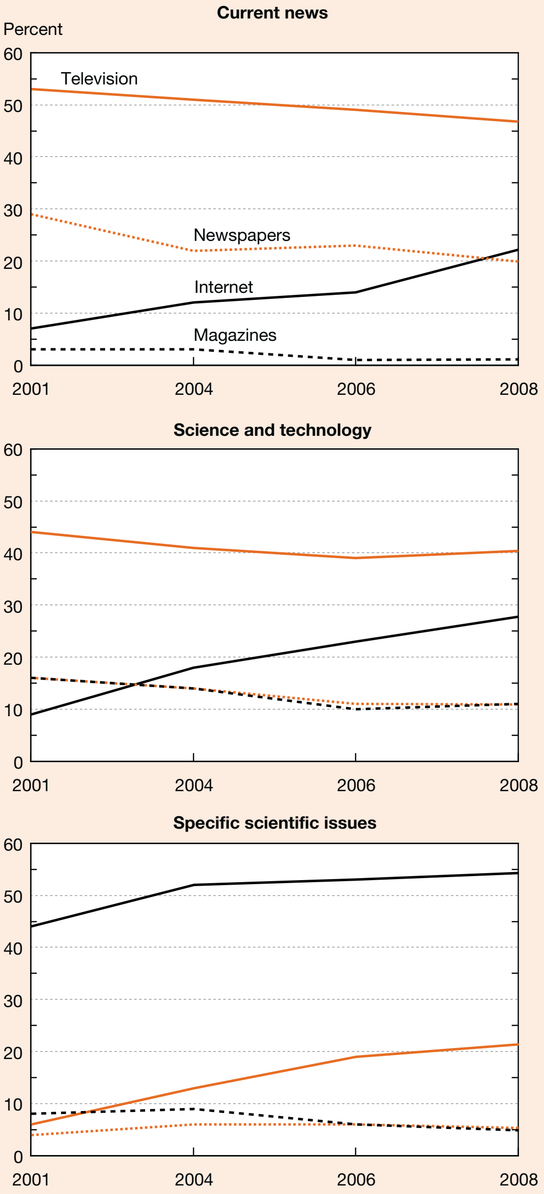


NOTES: Government agencies included in "other" category because <1.0% response. For current news events, books also included in "other" category and "don't know" not shown because <1.0% response. For science and technology information, "other" category not shown because <1.0% and no government agency responses. Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix tables 7-1, 7-2, and 7-3.

Science and Engineering Indicators 2010

Figure 7-2
Primary source of information about current events, science and technology, and specific scientific issues: 2001–08



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); University of Michigan, Survey of Consumer Attitudes (2004); and University of Chicago, National Opinion Research Center, General Social Survey (2006, 2008). See appendix tables 7-1, 7-2, and 7-3.

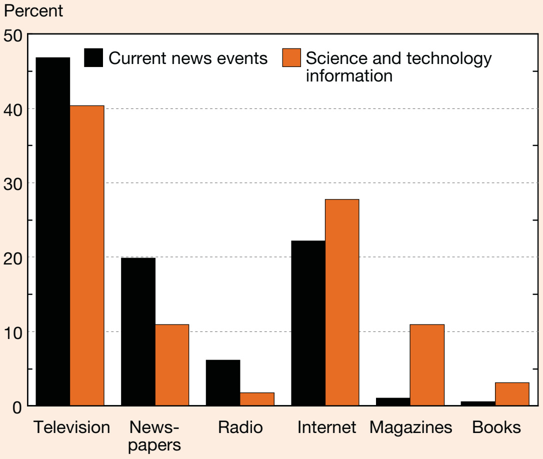
Science and Engineering Indicators 2010

yourself or for a child" (55%) or to "check the accuracy of a scientific fact or statistic" (52%). Fewer had used the Internet to "download scientific data, graphs, or charts" (43%) or "compare different or opposing scientific theories" (37%). How skillfully or how often Americans engage in the search for scientific information, whether on the Internet or elsewhere, remains unknown.

Using information effectively involves more than finding it. In an information-saturated society, people often need to assess the quality of the information they encounter and determine its credibility. Survey data provide some indication of how Americans assess the credibility of public information. For the past ten years, Americans have become more skeptical of the information they encounter in major broadcast and print media, but recently this trend has leveled off. Americans' judgments of media credibility are shaped by factors other than critical thinking skills and the quality of the information provided. For example, judgments of the credibility of particular mass media information sources are associated with political party affiliations (Pew Research Center for the People and the Press 2008).

Evidence about how Americans judge the credibility of S&T information in the media is scant. Pew's study of how Americans acquire science information indicates that Internet users who seek science information online do not always assume that the information they find there is accurate. The vast majority (80%) reported they have checked information at least once in different ways, either by comparing it to other information they found online, comparing it to offline sources (science journals, encyclopedia), or looking up the original source of the information (Horrigan 2006; for additional details see NSB 2008).

Figure 7-3
Primary source of current news events and science and technology information: 2008



SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix tables 7-1 and 7-2.

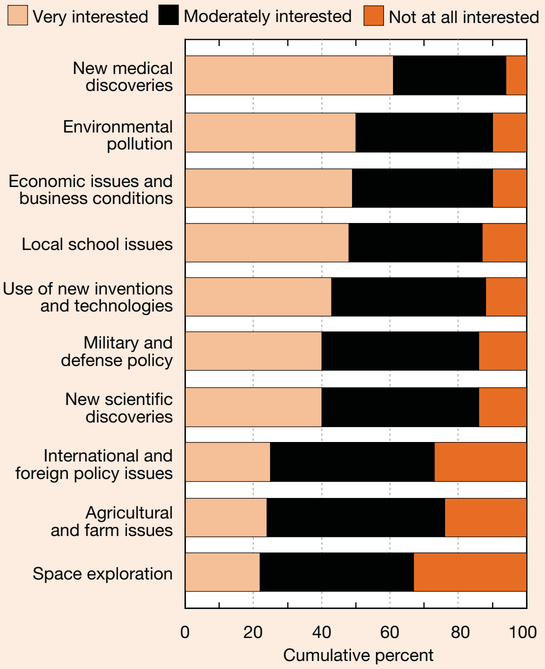
Science and Engineering Indicators 2010

International Comparisons

As in the United States, data collected between 2001 and 2008 in other countries, including the European Union (EU) states, Japan, Russia, and China, uniformly identify television as the leading source of S&T news and information. In a 2008 South Korean survey, more respondents named the Internet (28%) as their primary source of S&T information than named newspapers (16%) (KOFAC 2009). In most other countries, however, newspapers generally ranked second and relatively few survey respondents cited the Internet as an important source of S&T information. This may be due to differences in the availability of Internet access across countries (Internet World Statistics 2009). National differences in how questions were asked make precise comparisons among different countries impossible.

More recent data on S&T for the other countries do not exist; further details on these older data are presented in the 2006 edition of *Science and Engineering Indicators* (NSB 2006). Television is also the dominant source of S&T information in India, where about two-thirds of survey respondents in 2004 said it was their main information source (Shukla 2005). Radio (13%) and friends/relatives (12%) ranked ahead of print sources such as newspapers, books, and magazines, which together accounted for 9% of responses. India's relatively low literacy rate (144th of 176 countries in a 2005 ranking) may contribute to this reliance on nonprinted sources.

Figure 7-4
Public interest in selected issues: 2008



SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix table 7-4.

Science and Engineering Indicators 2010

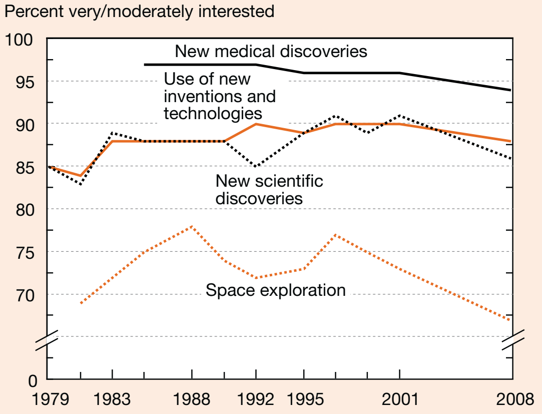
Public Interest in S&T

U.S. Patterns and Trends

High levels of self-reported interest in S&T are part of a long-standing pattern, as shown in the results of 12 surveys funded by the National Science Foundation (NSF). More than 80% of Americans report they are interested in new scientific discoveries (figure 7-4). When asked in the General Social Survey (GSS) in 2008 about their interest in new scientific discoveries, 86% reported that they are either "very" or "moderately" interested (appendix table 7-4). The proportion of respondents expressing interest in new scientific discoveries decreased slightly between 2001 and 2008 (figure 7-5), but this decline might have resulted from a difference in the surveys' data collection over that period.[2] Comparable data from the Virginia Commonwealth University (VCU) show a stable trend in public interest in new scientific discoveries between 2001 and 2006—during this period the proportion of Americans who said they had "a lot" or "some" interest in new scientific discoveries fluctuated between 83% and 87% (VCU Center for Public Policy 2006; see NSB 2008). Interest in new scientific discoveries increases with education and the number of mathematics and science courses people have taken (appendix table 7-5).

Relative to interest in other topics, however, interest in S&T in the GSS was not particularly high (figure 7-4). Interest in "new scientific discoveries" and "use of new inventions and technologies" ranked in the middle among the 10 areas

Figure 7-5
Public interest in selected science-related issues: 1979–2008



NOTES: Table includes all years for which data collected; other years extrapolated.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1985–2001); and University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix table 7-4.

Science and Engineering Indicators 2010

most frequently listed in the surveys: above space exploration, agriculture and farming, and international and foreign policy; below new medical discoveries, environmental pollution, economic issues and business conditions, and about the same as military and defense policy and local schools. Of course, a more inclusive concept of S&T might treat several of the topics in this list, such as space exploration and new medical discoveries, as part of the S&T category; furthermore, other topics often include substantial S&T content.[3]

Survey responses about the types of news Americans follow raise questions about how interested Americans really are in S&T. For more than 10 years, Pew (Pew Research Center for the People and the Press 2008) has collected data on categories of news that Americans follow "very closely." In 2008, 13% of the public followed S&T news closely. S&T news ranked 13th among 18 topics, tied with consumer news and ahead of entertainment, culture and the arts, celebrity news, and travel (table 7-1). As is the case for many other news topics, the percentage of Americans who say they follow S&T closely has declined between 1996 and 2008. S&T's relative standing in the list of topics has also slipped; it ranked ahead of seven topics in 1996, but ahead of only two of the same topics in 2008.

Since 1986, the Pew Research Center for the People and the Press has maintained a news interest index that tracks individual stories that make headlines. The index is based on frequent surveys that record the proportion of Americans who, when asked about a news story, say they are following it "very closely." Stories that attract considerable public interest are often included in several surveys, and the same story may appear several times in the news interest index. In 2007, stories that dominated the list of the public's top news stories included the rising price of gasoline, the war in Iraq, and human and natural disasters (such as the Virginia Tech University shootings, the Minneapolis bridge collapse, and the California wildfires) (PEJ 2008). In 2008, stories about the condition of the U.S. economy, rising gas prices, the debate over a Wall Street bailout, the 2008 presidential election, major drops in the U.S. stock market, and the impact of Hurricane Ike appeared near the top of the list (PEJ 2009). Interest in S&T does not appear to have been the central factor motivating the public's interest in these stories rather than others.

A different kind of news indicator is the amount of coverage news organizations devote to S&T. This indicator can involve either sheer quantity (e.g., broadcast time) or prominence (e.g., lead stories). For 20 years, the Tyndall Report has tracked the time that the three major broadcast networks devoted to 18 categories of news on their nightly newscasts (Tyndall Report 2009). Two categories with large science, engineering, and technology components are "science, space, and technology," and "biotechnology and basic

Table 7-1

News followed "very closely" by American public: 1996–2008

(Percent)

Type of news	1996	1998	2000	2002	2004	2006	2008
Weather	NA	NA	NA	NA	53	50	48
Crime	41	36	30	30	32	29	28
Education	NA	NA	NA	NA	NA	NA	23
Community	35	34	26	31	28	26	22
Environment	NA	NA	NA	NA	NA	NA	21
Politics/Washington news	16	19	17	21	24	17	21
Local government	24	23	20	22	22	20	20
Health news	34	34	29	26	26	24	20
Sports	26	27	27	25	25	23	20
Religion	17	18	21	19	20	16	17
International affairs	16	16	14	21	24	17	16
Business and finance	13	17	14	15	14	14	16
Consumer news	14	15	12	12	13	12	13
Science and technology	20	22	18	17	16	15	13
Culture and arts	9	12	10	9	10	9	11
Entertainment	15	16	15	14	15	12	10
Celebrity news	NA	NA	NA	NA	NA	NA	7
Travel	NA	NA	NA	NA	NA	NA	6

NA = not available, question not asked

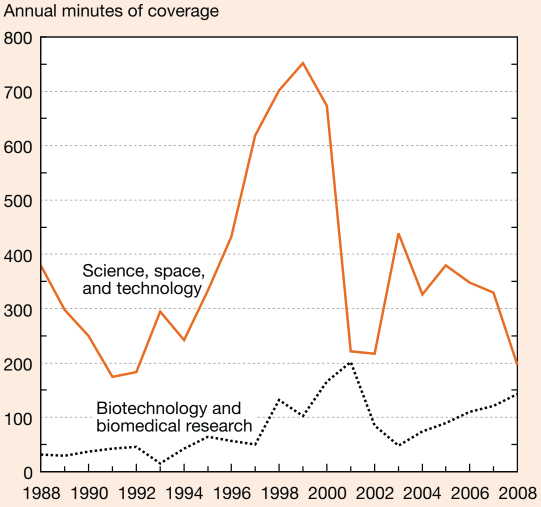
NOTES: Data reflect respondents who said they followed type of news "very closely." Table includes all years for which data collected.

SOURCES: Pew Research Center for the People and the Press, Online papers modestly boost newspaper readership: Maturing Internet news audience broader than deep (30 July 2006), Biennial News Consumption Survey (27 April–22 May 2006), http://people-press.org/reports/display.php3?ReportID=282, accessed 26 April 2007 (1996–2006); Pew Research Center for the People and the Press, Audience segments in a changing news environment: Key news audiences now blend online and traditional sources (17 August 2008), p. 39, Biennial News Consumption Survey (30 April–01 June 2008), http://people-press.org/reports/pdf/444.pdf, accessed 21 September 2009.

Science and Engineering Indicators 2010

Figure 7-6

Network nightly news coverage of science and technology: 1988–2008



NOTES: Data reflect annual minutes of story coverage on topics by major networks ABC, CBS, and NBC, out of approximately 15,000 total annual minutes on weekday nightly newscasts. Excluded from science, space, and technology are forensic science and media content. Excluded from biotechnology and basic medical research are stories on clinical research and medical technology.

SOURCE: Tyndall Report, special tabulations (2009), http://www.tyndallreport.com, accessed 23 September 2009.

Science and Engineering Indicators 2010

medical research. "Science, space and technology" includes stories on manned and unmanned space flight, astronomy, scientific research, computers, the Internet, and telecommunications media technology. It excludes forensic science, and telecommunications media content. "Biotechnology and basic medical research" includes stem cell research, genetic research, cloning, and agribusiness bioengineering and excludes clinical research and medical technology. Stories often do not fall neatly into a single category or theme.

Neither category has ever occupied a large percentage of the approximately 15,000 minutes of annual nightly weekday newscast coverage on the networks. "Science, space, and technology," the larger of the two categories, garnered 752 minutes in its peak year (1999) (figure 7-6).[4] The time devoted to "science, space, and technology" coverage in the network nightly news has been on a downward trend since 2003, while the time devoted to "biotechnology and basic medical research," though considerably lower, has been on the rise in the same period.

Trends in the "science, space, and technology" category, along with recent annual lists of leading individual stories in that category, suggest that developments in the nation's space program and new ways to use cellular phones and the Internet received the largest amount of news coverage (table 7-2). In the "biotechnology and basic medical research" category, the war on cancer, the use of genetic testing to predict disease, and stem cell research received the largest amount of news coverage. Time devoted to cancer research coverage is greater than for any other story. The importance of

Table 7-2

Leading nightly news story lines on science and technology, by topic area: 2007 and 2008

(Annual minutes of coverage)

Topic area/leading story line	2007	Topic area/leading story line	2008
Science, space, and technology		Science, space, and technology	
NASA Space Shuttle program	39	Mars astronomy: NASA rovers search for water	19
International space station construction	31	Spy satellite falls out of orbit, shot down	18
NASA astronaut love triangle	21	Mathematics education in schools	11
NASA astronauts suspected of drunken space flights	18	High-technology multitasking is distracting	11
Cellular telephone computer combo invented: iPhone	14	Cellular telephone extras: ringtones, wallpaper	7
Videostreams shared online in viral networks: YouTube[a]	12	Internet search engine Yahoo! takeover bid	7
Internet used by teens for social networking: Facebook	12	International space station construction	6
High school science fair competitions held for students	10	Physicists build supercollider in Switzerland	5
Mathematics education in schools	8	Inventions and innovations in technology surveyed	5
Inventions and innovations in technology surveyed	7	China censors Internet access and e-mail traffic	5
Biotechnology/basic medical research		Biotechnology/basic medical research	
War on cancer/research efforts	70	War on cancer/research efforts	69
Human embryo stem cell biotechnology research	27	Genetic DNA biotech analysis predicts diseases	29
		Organs may be grown in laboratory for implant	12
		Surgery improved by minimally invasive techniques	11
		Animal cloning in agriculture safety research	6

[a]Refers to the rise of YouTube as a video file-sharing technology.

NOTES: Data reflect annual minutes of story coverage on these topics by major networks ABC, CBS, and NBC, out of approximately 15,000 total annual minutes on weekday nightly newscasts. Shown are the story lines receiving at least 5 minutes of coverage in 2007 and 2008. Excluded from science, space, and technology are stories on forensic science and media content. Excluded from biotechnology and basic medical research are stories on clinical research and medical technology.

SOURCE: Tyndall Report, special tabulations (January 2009), http://www.tyndallreport.com, accessed 23 September 2009.

Science and Engineering Indicators 2010

competing stories, such as the economic crisis, plays a role in deciding what news is covered.

International Comparisons

Using identical questions, recent surveys conducted in other countries indicate that the overall level of self-reported public interest in S&T is lower than in the United States. Between 75% and 80% of survey respondents in South Korea, China, and Europe said they were "very" or "moderately" interested in "new scientific discoveries" and "use of new inventions and technologies" compared to 86% and 88% respectively of Americans in the 2008 GSS, respectively (appendix table 7-4) (KOFAC 2009; CRISP 2008; EC 2005). Using slightly different questions, about three-quarters of Brazilians said they were "very interested" or "a little interested" in "science and technology" (MCT of Brazil 2006). In Malaysia, 58% of the respondents said they were "interested" or "very interested" in the "latest inventions in new technology" and 51% in the "latest inventions in science" (MASTIC 2004).

In the 2005 European survey (called the 2005 "Eurobarometer"), there was considerable variation among different countries in self-reported interest in S&T-related issues, and the overall level of interest was down from the most recent survey in 1992. In both the United States and in Europe, men showed more interest in S&T than women. For more recent European data on interest in scientific research in general, see sidebar "Scientific Research in the Media in Europe."[5]

Interest in environmental issues is similarly high in the United States, Europe, South Korea, and Brazil—about 9 in 10 respondents in each country or region expressed interest in this topic, although slight variations in survey terminology should be taken into account.[6] In Malaysia, interest in "environmental pollution" was lower (61% said they were "interested" or "very interested" in this issue).

Like Americans, Europeans and Brazilians are more interested in medicine than in S&T in general. In the United States, nearly everyone was interested in new medical discoveries (94%); in Brazil, most people (91%) were interested in "medicine and health" issues. In Europe, South Korea, and China, interest in new medical discoveries seemed to be lower—between 77% and 83% said they were "very" or "moderately" interested in this issue. In Malaysia, 59% indicated they were "interested" or "very interested" in the "latest inventions in the field of medicine."[7]

Involvement

Involvement with S&T outside the classroom in informal, voluntary, and self-directed settings—such as museums, science centers, zoos, and aquariums—is an indicator of interest in S&T.[8] By offering visitors the flexibility to pursue individual curiosity, such institutions provide a kind of exposure to S&T that is well suited to helping people develop further interest.

In the 2008 GSS, 59% of Americans indicated that they had visited an informal science venue during the previous

Scientific Research in the Media in Europe

In 2007, the European Commission conducted a survey to learn how to motivate European citizens to become more involved in science, research, and innovation. Face-to-face interviews were conducted in people's homes, in their national language, in the European Union's (EU) 27 member states (EC 2007).

The survey shows that the majority of Europeans (57%) are "very" and "fairly" interested in scientific research. Interest is much higher in the EU-15 (62%) than in the 12 countries that recently joined (38%). The countries most interested in scientific research were Sweden, Denmark, France, Luxembourg, the Netherlands, Belgium, and Finland. Men and more highly educated individuals expressed more interest in this subject. Medicine attracted the highest degree of public interest (62%), followed by the environment (43%).

Television is the most popular medium for information and also the medium with the widest reach. The majority of EU citizens (61%) watch television programs about scientific research regularly or occasionally, nearly half read scientific articles in general newspapers and magazines, and 28% look at information on scientific issues on the Internet. Television is also the most trusted medium for obtaining science information, ranking first in trustworthiness in 25 out of the 27 EU member states.

Overall, EU-27 citizens are satisfied with media coverage of scientific research, in particular those who are interested in this subject. The majority believe the coverage devoted to scientific research in the media is sufficient, but about one-third believes that it is not given enough importance. Most European citizens view science media coverage as reliable, objective, useful, varied, and sufficiently visual. However, they also express that science media coverage is difficult to understand, removed from their actual concerns, and not entertaining. More highly educated respondents are more likely to view media coverage of scientific information as more useful, understandable, entertaining, and not too far removed from citizen concerns.

Europeans tend to prefer to receive short news reports about scientific research on a regular basis (43%) rather than occasional in-depth information (34%). In addition, they prefer to restrict public scientific debates to scientists and experts rather than to actively participate themselves, and they would prefer that scientists rather than journalists present scientific information.

year[9] (appendix table 7-6). Half said they had visited a zoo or aquarium and over one-quarter had visited a "natural history museum" (27%) or a "science and technology museum" (26%). One in three Americans had visited an art museum and 64% had visited a public library. These data are generally consistent with data collected by the Pew Internet and American Life Project and the Institute for Museum and Library Services (for more detail on these surveys, see NSB 2008). Among those who visited each of these institutions, the number of annual visits was highest for public libraries, which averaged about 15 visits per year.

The proportion of respondents who reported attending the three institutions (zoo/aquarium, S&T museum, and public library) is down slightly from the last time these questions were asked in 2001. However, these differences may be due to changes in the data collection methods over this period discussed earlier in the chapter, rather than to actual changes in attendance.

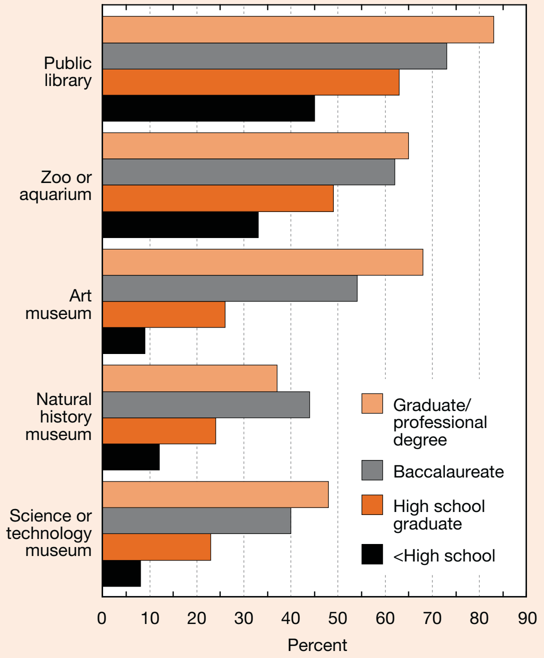
Respondents in households with children 18 or younger were more likely to visit a zoo or aquarium, a public library, and also a natural history museum. Minors in the household did not make a difference in the proportion of adults who visited an art museum or an S&T museum (appendix table 7-7).

Americans with more years of formal education are more likely than others to engage in these informal science activities (figure 7-7; appendix table 7-7). Those in higher income brackets are more likely to have attended a zoo or an aquarium, a natural history or an S&T museum, or an art museum, but just as likely as those in the lowest income bracket to have visited a public library. In general, visits to informal science institutions are lower among Americans who are 65 or older.

In addition, respondents who get most of their information about S&T from the Internet or use this medium to learn about scientific issues are more likely to have visited any informal science institution, even after controlling for expressed interest in scientific issues. This suggests that use of these different sources of exposure to science information complement, rather than replace, one another.

Fewer Europeans report visits to informal science institutions (EC 2005). In the EU-25, about 27% of adults said they had visited a zoo or aquarium, 16% said they had visited a "science museum or technology museum or science centre," and 8% said they had attended a "science exhibition or science 'week.'" As in the United States, older and less-educated Europeans reported less involvement in these activities. In addition, European adults in households with more inhabitants more often reported informal science activities. Insofar as household size indicates the presence of minor children, this probably indicates another parallel with the United States. One demographic pattern is notably different between Europe and the United States: where European men (19%) are much more likely than women (13%) to visit informal science or technology museums and centers, these gender differences do not exist in the United States (appendix table 7-7). (For additional details on the comparison with European data, see NSB 2008.)

Figure 7-7
Attendance at informal science and other cultural institutions, by institution type and education level: 2008



NOTE: Percent indicates respondents who had attended the noted institution at least once.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix table 7-7.

Science and Engineering Indicators 2010

Compared with the United States, visits to natural history and science and technology museums are less common in Japan, South Korea, China, Brazil, and Russia (table 7-3). The proportion of respondents who indicated they had visited a zoo/aquarium is similar in the U.S., China, and Japan. Unmeasured differences in the prevalence and accessibility of informal science learning opportunities across countries make it difficult to attribute different visit patterns to differences in interest.

Public Knowledge About S&T

Scientific literacy can be relevant to the public policy and personal choices that people make. In developing measures for scientific literacy across nations, the Organisation for Economic Co-operation and Development (OECD) (2003) noted that literacy had several components:

> Current thinking about the desired outcomes of science education for all citizens emphasizes the development of a general understanding of important concepts and

Table 7-3
Visits to informal science and other cultural institutions, by country/region: Most recent year
(Percent)

Institution	United States, 2008	South Korea, 2008	China, 2007	Brazil, 2006	EU, 2005	Russia, 2003	Japan, 2001
Zoo/aquarium[a]	50	36	52	28	27	9	43
Natural history museum	27	NA	14	NA	NA	NA	20
Science/technology museum[b]	26	11	17	4	16	1	13
Public library	64	34	41	25	34	16	47
Art museum	32	34	18	12	23	7	35

NA = not available, question not asked

EU = European Union

[a] "Zoo, botanic garden, or environmental park" for Brazil, "Zoo, aquarium, or botanic garden" for China, "Zoo" for Russia.
[b] "Science museums or technology museums or science centers" for EU.

NOTES: Responses to (United States, Japan, Korea) *I am going to read you a short list of places and ask you to tell me how many times you visited each type of place during the last year, that is, the last 12 months* (Percentage includes those who visited each institution one or more times); (EU, Russia, China, Brazil) *Which of the following have you visited in the last twelve months* (Multiple answers possible).

SOURCES: (United States) University of Chicago, National Opinion Research Center, General Social Survey (2008); Korea Foundation for the Advancement of Science and Creativity (formerly Korea Science Foundation), Survey of Public Attitudes Toward and Understanding of Science and Technology (2008); Chinese Ministry of Science and Technology, *Chinese Public Understanding of Science and Attitudes towards Science and Technology,* 2007 (2008); (Brazil) Ministry of Science and Technology, *Public Perceptions of Science and Technology* (2007); (EU) Eurobarometer 224/Wave 63.1: Europeans, Science and Technology (2005); (Russia) British Council, *Russian Public Opinion of the Knowledge Economy* (2004); Japan National Institute of Science and Technology Policy, The 2001 Survey of Public Attitudes Toward and Understanding of Science & Technology in Japan (2001). See appendix table 7-6 for U.S. trends.

Science and Engineering Indicators 2010

> explanatory frameworks of science, of the methods by which science derives evidence to support claims for its knowledge, and of the strengths and limitations of science in the real world. It values the ability to apply this understanding to real situations involving science in which claims need to be assessed and decisions made…
>
> Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (pp. 132–33)

As the reference to changes made through human activity makes clear, the OECD definition implies an understanding of technology. The OECD takes the view that literacy is a matter of degree and that people cannot simply be classified as either literate or not literate.

A good understanding of basic scientific terms, concepts, and facts; an ability to comprehend how science generates and assesses evidence; and a capacity to distinguish science from pseudoscience are widely used indicators of scientific literacy. (For a different perspective on scientific literacy, see sidebar, "Asset-Based Models of Knowledge.")

U.S. survey data indicate that many Americans cannot provide correct answers to basic questions about scientific facts and do not apply appropriate reasoning strategies to questions about selected scientific issues. Residents of other countries, including highly developed ones, perform no better, on balance, when asked similar questions. However, compared to middle-school students, American adults perform relatively well. In light of the limitations of using a small number of questions largely keyed to knowledge taught in school, generalizations about American's knowledge of science should be made cautiously.

Understanding Scientific Terms and Concepts

U.S. Patterns and Trends

U.S. data show that the public's level of factual knowledge about science has not changed much over time. Figure 7-8 shows average numbers of correct answers to a series of mostly true-false science questions in different years for which fully comparable data were collected (appendix table 7-8).[10] Although performance on individual questions varies somewhat over time (appendix table 7-9), overall scores are relatively similar.

Factual knowledge of science is positively related to people's level of formal schooling, income level, and the number of science and math courses they have taken. Factual knowledge is also positively related to scores on a 10-item vocabulary test included in the GSS, which scholars in many disciplines have often used to assess verbal skills (Malhotra, Krosnick, and Haertel 2007).[11] In the factual questions included in NSF surveys since 1979, which allow for the observation of trends over time (referred to as "trend factual questions" below), men score higher on the questions in the physical sciences and women score higher on those in the biological sciences (table 7-4).[12]

Respondents 65 and older are less likely than others to answer the questions correctly (appendix tables 7-8 and 7-10). An analysis of surveys conducted between 1979 and 2006 concluded that generational experiences are more important than cognitive declines associated with aging in explaining these differences (Losh 2009, 2010).

The factual knowledge questions that have been repeatedly asked in U.S. surveys involve information that was being taught in grades K–12 when most respondents were young. Because science continually generates new knowledge that reshapes how people understand the world, scientific literacy requires lifelong learning so that citizens become familiar with terms, concepts, and facts that emerged after they completed their schooling.

In 2008, the GSS asked Americans questions that tested their knowledge of a topic that has not been central to the standardized content of American science education: nanotechnology. Survey respondents who scored relatively well overall on the questions that were asked repeatedly over the years also exhibited greater knowledge of this topic (figure 7-9).[13] Likewise, the educational and demographic characteristics associated with higher scores on the trend factual knowledge questions are also associated with higher scores for this new topic (appendix table 7-11). These data suggest that the knowledge items used to measure trends, although focused on the kind of factual knowledge learned in school, are a reasonable indicator of factual science knowledge in general, including knowledge that is acquired later in life.

Similarly, national standards for what students should know reflect new science concepts beyond those covered by the long-standing questions that measure trends in public knowledge of science. In 2008, the GSS included questions on science and mathematics knowledge that were more closely aligned with national standards for what students should know. The questions were selected from three national exams administered to students and Project 2061, an initiative by the American Association for the Advancement of Science (AAAS) that develops assessment materials aligned

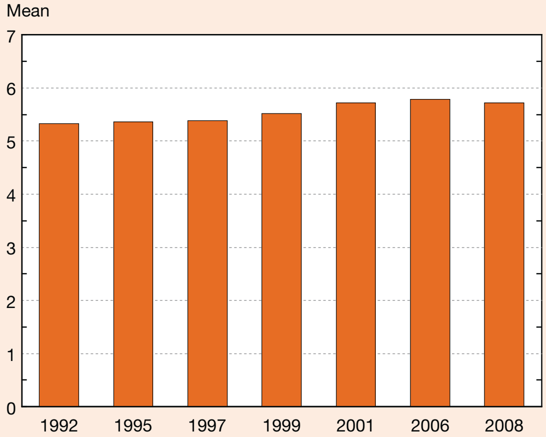
Asset-Based Models of Knowledge

Many researchers and educators interested in the public's understanding of science advocate studying the skills people bring to bear on scientific issues that they deal with in their daily lives (e.g., gardening, bird-watching). Because individuals encounter S&T in different ways, they acquire different S&T knowledge "assets," which they then can use to make sense of unfamiliar issues (National Research Council 2009). For researchers and educators who favor an asset-based model of scientific literacy, public understanding of science is less a "generalized body of knowledge and skills that every citizen should have by a certain age" than "a series of specific sets of only moderately overlapping knowledge and abilities that individuals construct over their lifetimes" (Falk, Storksdieck, and Dierking 2007). In education, asset-based perspectives on knowledge have been useful in helping teachers build on children's existing strengths to improve their performance.

Generalized assessments of S&T knowledge may underestimate the assets available to individuals when they deal with S&T matters of greater interest and consequence to them, because these types of assessments ask questions on topics of little interest to many respondents. In contrast, a knowledge assessment that is tailored to an S&T domain with which an individual is familiar might yield very different results. In addition, because people often use their knowledge assets in group interactions, such as a nature outing, some researchers question the value of individual assessments in a test or survey (Roth and Lee 2002).

Researchers have developed measures of adult science understanding to assess how people make sense of specific experiences or scientific materials (Friedman 2008). National indicators that evaluate domain-specific knowledge or group problem-solving are not practical, but a perspective on scientific literacy that stresses domain-specific or group assets is useful, because it points to a significant limitation of generalized indicators of individual scientific literacy.

Figure 7-8
Correct answers to factual knowledge of science questions: 1992–2008



NOTES: Mean number of correct responses to 9 questions included in "factual knowledge of science, scale 1"; see appendix table 7-8 for explanation and list of questions. See appendix tables 7-9 and 7-10 for responses to individual questions. Includes all years for which data collected.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1992–2001); and University of Chicago, National Opinion Research Center, General Social Survey (2006, 2008).

Science and Engineering Indicators 2010

Table 7-4

Correct answers to scientific literacy questions, by sex: 2001, 2004, 2006, and 2008

(Percent)

Question	2001	2004	2006	2008
Physical science				
The center of the Earth is very hot. (True)				
Male	85	86	85	88
Female	76	72	75	80
All radioactivity is man-made. (False)				
Male	81	82	77	74
Female	71	66	64	67
Lasers work by focusing sound waves. (False)				
Male	61	59	62	64
Female	30	28	32	34
Electrons are smaller than atoms. (True)				
Male	52	52	61	59
Female	43	39	48	47
The continents have been moving their location for millions of years and will continue to move. (True)				
Male	83	85	85	82
Female	74	71	75	73
Does the Earth go around the Sun, or does the Sun go around the Earth? (Earth around Sun)				
How long does it take for the Earth to go around the Sun? (One year)				
Male[a]	66	NA	66	58
Female[a]	42	NA	46	44
Biological science				
It is the father's gene that decides whether the baby is a boy or a girl. (True)				
Male	58	51	55	53
Female	72	70	72	71
Antibiotics kill viruses as well as bacteria. (False)				
Male	46	49	50	47
Female	55	58	61	60
A doctor tells a couple that their genetic makeup means that they've got one in four chances of having a child with an inherited illness. (1) Does this mean that if their first child has the illness, the next three will not? (No); *(2) Does this mean that each of the couple's children will have the same risk of suffering from the illness?* (Yes)				
Male	68	67	72	66
Female	67	62	67	63
Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many of them experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug? Why is it better to test the drug this way? (The second way because a control group is used for comparison)				
Male[b]	39	49	42	37
Female[b]	38	43	41	39

NA = not available

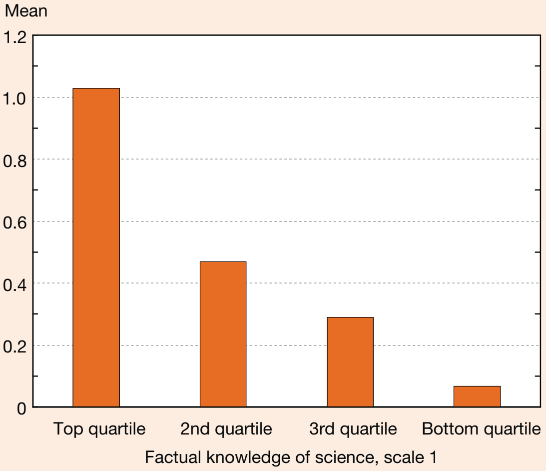
[a] Data represent composite of correct responses to both questions. Second question only asked if first question answered correctly. No composite percentage computed for 2004 because second question not asked.

[b] Data represent a composite of correct responses to both questions.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); University of Michigan, Survey of Consumer Attitudes (2004); and University of Chicago, National Opinion Research Center, General Social Survey (2006, 2008). See appendix tables 7-9 and 7-10 for factual knowledge questions. See appendix tables 7-13 and 7-14 for scientific process questions (probability and experiment).

Science and Engineering Indicators 2010

Figure 7-9
Correct answers to nanotechnology questions, by factual knowledge of science: 2008



NOTES: Mean number of correct responses to two factual questions on nanotechnology. Respondents saying they had heard "nothing at all" about nanotechnology not asked questions; these respondents count as zero (0) correct. See appendix table 7-11 for responses to nanotechnology questions. See notes to appendix table 7-8 for trend factual knowledge of science questions included in NSF surveys (scale 1).

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008).

Science and Engineering Indicators 2010

with current curricular standards.[14] This battery of questions included nine factual questions, two questions measuring chart reading and understanding of the statistical concept of "mean," and five questions that tested reasoning and understanding of the scientific process. Two out of the 16 questions were open-ended and the rest were multiple-choice (see sidebar, "New Science Knowledge Questions").[15]

The results show that survey respondents who answered the additional factual knowledge questions correctly also tended to provide correct answers to the trend factual knowledge questions (figure 7-10; appendix tables 7-10 and 7-12). This suggests again that the trend factual questions are a reasonable indicator of the type of knowledge students are tested on in national assessments.

Out of seven factual science knowledge questions where comparison scores with fourth and eighth grade students were possible, adult Americans received a higher or similar score in five of them (table 7-5). Comparisons should be made cautiously because of the differences in circumstances in which students and adults responded to these science knowledge questions. Students' tests were on paper and self-administered, whereas the majority of respondents in the GSS answered orally to an interviewer. Elementary and middle school students had an advantage over adults in that classroom preparation preceded their tests.

New Science Knowledge Questions

These questions were included in the 2008 General Social Survey to assess different aspects of science and technology knowledge. Answers are bold. The factual knowledge questions (questions 1, 3–5, and 7–11) are combined into scale 2 in some figures and appendix tables. Other questions test a person's knowledge of charts and statistics (questions 12 and 13), reasoning/life sciences (questions 2 and 14), and experiment/controlling variables (questions 6 and 14–16). Note that the correct answer for question 14 can be reached by using reasoning skills, knowledge in the life sciences, or understanding of the experiment/controlling variables concept.

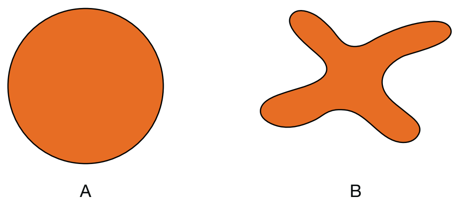
Opening script: Now, we are going to do some more detailed questions on science and technology. Scientists and educators are interested in how familiar adults are with the things being taught in today's schools. Many of these questions are likely to concern things that weren't taught or emphasized when you were in school. Some of the questions involve pictures or graphs.

1. What property of water is most important for living organisms?

A) It is odorless.
B) It does not conduct electricity.
C) It is tasteless.
D) It is liquid at most temperatures on Earth.

2. Please look at Card 1. The two objects shown there have the same mass, but object B loses heat more quickly than object A.

Card 1
Body Structures and Heat Loss



Which combination of bodily features would be BEST suited to a small animal that lives in a cold climate and needs to minimize heat loss?

A) Long ears and a long body.
B) Small ears and a short tail.
C) A long nose and a long tail.
D) A short nose and large ears.
E) A long tail and a short nose.

New Science Knowledge Questions *continued*

3. Which of the following is a key factor that enables an airplane to lift?

- **A) Air pressure beneath the wing is greater than that above the wing.**
- B) Pressure within the airplane is greater that that of the outside.
- C) Engine power is greater than that of friction.
- D) The plane's wing is lighter than air.

4. Lightning and thunder happen at the same time, but you see the lightning before you hear the thunder. Explain why this is so.

A correct response indicates that light travels faster than sound so the light gets to your eye before the sound reaches your ear.

5. A solution of hydrochloric acid (HCl) in water will turn blue litmus paper red. A solution of the base sodium hydroxide (NaOH) in water will turn red litmus paper blue. If the acid and base solutions are mixed in the right proportion, the resulting solution will cause neither red nor blue litmus paper to change color.

A correct response refers to a neutralization or a chemical reaction that results in products that do not react with litmus paper.

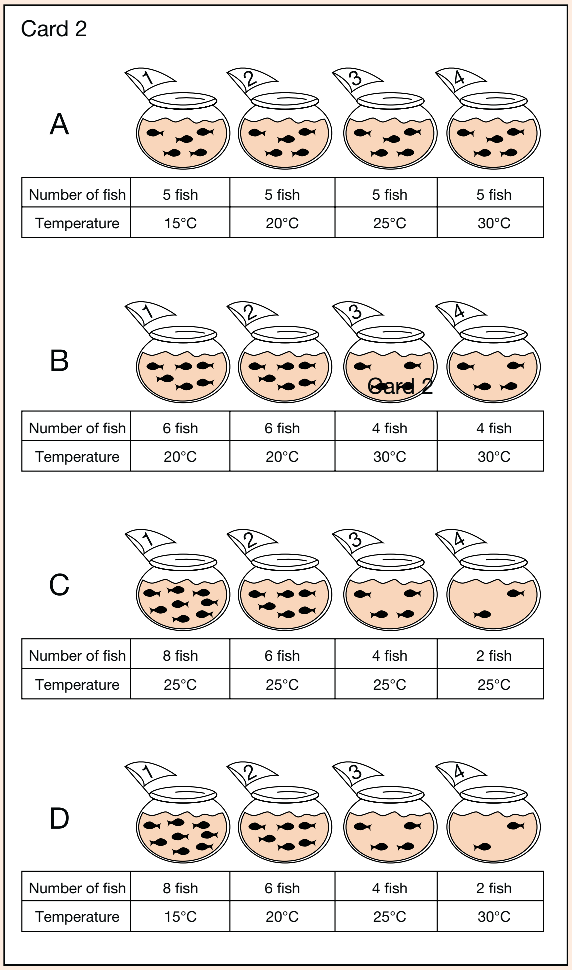
6. Please look at Card 2. A student wants to find out if temperature affects the behavior of goldfish. He has 4 fish bowls and 20 goldfish. Which of the experiments on Card 2 should he do? **Correct answer: A.**

7. A farmer thinks that the vegetables on her farm are not getting enough water. Her son suggests that they use water from the nearby ocean to water the vegetables. Is this a good idea?

- A) Yes, because there is plenty of ocean water.
- B) Yes, because ocean water has many natural fertilizers.
- **C) No, because ocean water is too salty for plants grown on land.**
- D) No, because ocean water is much more polluted than rainwater.

8. Which one of the following is NOT an example of erosion?

- A) The wind in the desert blows sand against a rock.
- B) A glacier picks up boulders as it moves.
- C) A flood washes over a riverbank, and the water carries small soil particles downstream.
- **D) An icy winter causes the pavement in a road to crack.**



A

Number of fish	5 fish	5 fish	5 fish	5 fish
Temperature	15°C	20°C	25°C	30°C

B

Number of fish	6 fish	6 fish	4 fish	4 fish
Temperature	20°C	20°C	30°C	30°C

C

Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	25°C	25°C	25°C	25°C

D

Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	15°C	20°C	25°C	30°C

9. Traits are transferred from generation to generation through the…

- A) sperm only.
- B) egg only.
- **C) sperm and egg.**
- D) testes.

10. How do most fish get the oxygen they need to survive?

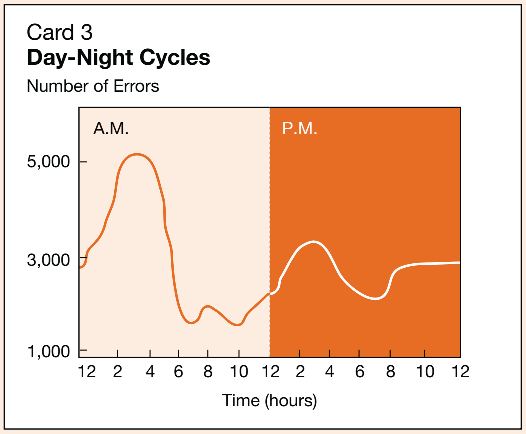
- A) They take in water and break it down into hydrogen and oxygen.
- **B) Using their gills, they take in oxygen that is dissolved in water.**
- C) They get their oxygen from the food they eat.
- D) They come to the surface every few minutes to breathe air into their lungs.

New Science Knowledge Questions *continued*

11. For which reason may people experience shortness of breath more quickly at the top of a mountain than along a seashore?

A) A slower pulse rate.
B) A greater gravitational force on the body.
C) A lower percent of oxygen in the blood.
D) A faster heartbeat.
E) A slower circulation of blood.

12. Please look at Card 3. Day-night rhythms dramatically affect our bodies. Probably no body system is more influenced than the nervous system. The figure on Card 3 illustrates the number of errors made by shift workers in different portions of the 24-hour cycle.



Based on the data illustrated in the figure, during which of these time periods did the most errors occur?

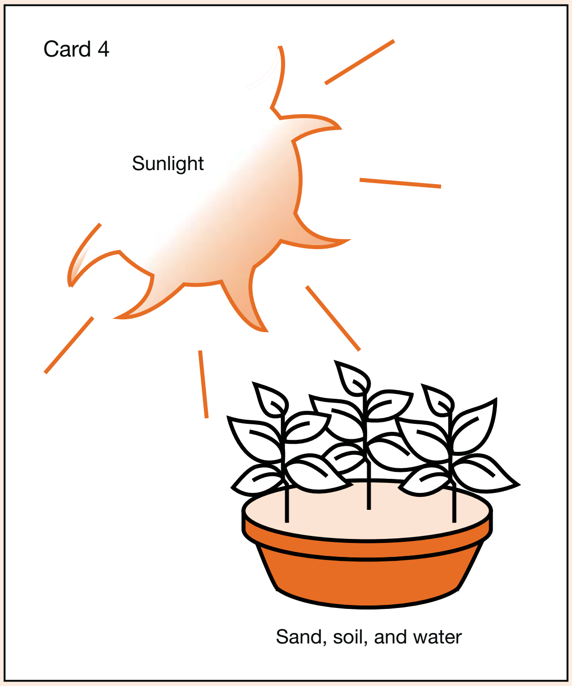
A) 2 A.M. to 4 A.M.
B) 8 A.M. to 10 A.M.
C) 12 P.M. to 2 P.M.
D) 2 P.M. to 4 P.M.
E) 8 P.M. to 10 P.M.

13. As part of a laboratory experiment, five students measured the weight of the same leaf four times. They recorded 20 slightly different weights. All of the work was done carefully and correctly. Their goal was to be as accurate as possible and reduce error in the experiment to a minimum.

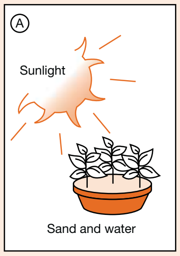
Which of the following is the BEST method to report the weight of the leaf?

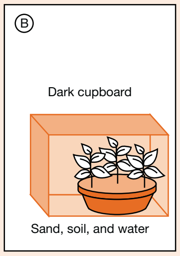
A) Ask the teacher to weigh the leaf.
B) Report the first measurement.
C) Average all of the weights that were recorded.
D) Average the highest and lowest weights recorded.
E) Discard the lowest five weights.

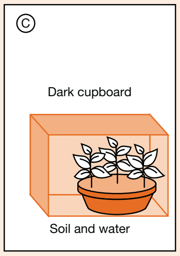
14. Please look at Card 4. A gardener has an idea that a plant needs sand in the soil for healthy growth. In order to test her idea she uses two pots of plants. She sets up one pot of plants as shown on the top part of the card. Which one of the pictures on the bottom part of the card shows what she should use for the second pot? **Correct answer is E.**

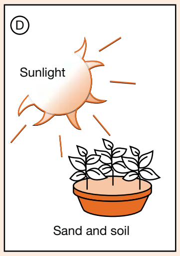


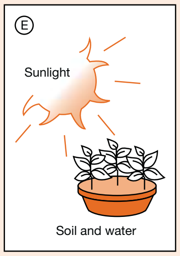
Which ONE of the following should she use for the second pot of plants?





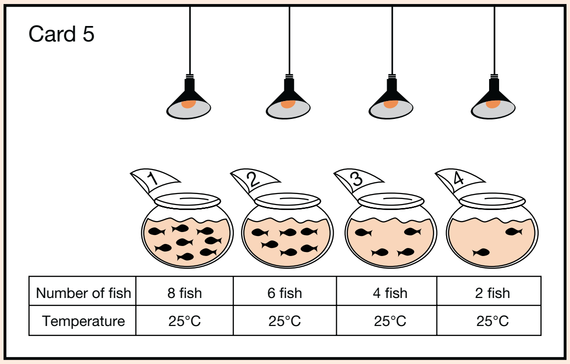






New Science Knowledge Questions
continued

15. Please look at Card 5. What is the scientist trying to find out from this experiment?



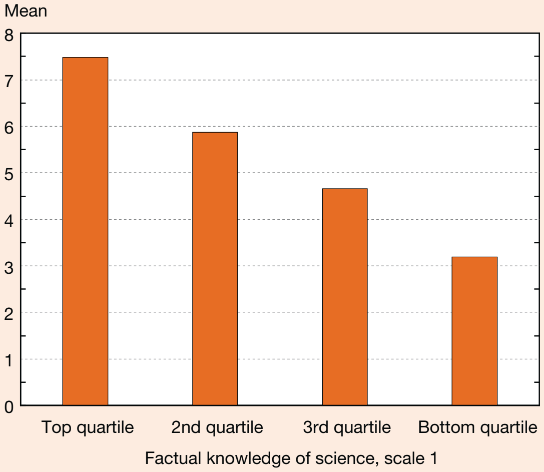
Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	25°C	25°C	25°C	25°C

- **A) If the number of fish in the fish bowl affects the behavior of the fish.**
- B) If the temperature of the fish bowl affects the behavior of the fish.
- C) If the temperature and the amount of light affect the behavior of the fish.
- D) If the number of fish, the temperature, and the amount of light affect the behavior of the fish.

16. Why did you choose that answer?

- A) Because I already know what affects the behavior of fish.
- **B) Because that is what is allowed to change in this experiment.**
- C) Because that is what stays the same in this experiment.
- D) Because that is what the scientist decided to include in this experiment.

Figure 7-10
Correct answers to new factual knowledge questions, by trend factual knowledge questions: 2008



NOTES: Mean number of correct responses to nine new factual questions included in scale 2; see appendix table 7-12 for questions. See notes to appendix table 7-8 for questions included in scale 1.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008).

Science and Engineering Indicators 2010

The variation patterns on these items were similar to the trend factual questions. However, men scored higher than women in all but one of the additional factual knowledge questions included in the 2008 GSS (appendix tables 7-10 and 7-12).

International Comparisons

Adults in different countries and regions have been asked identical or substantially similar questions to test their factual knowledge of science. (For an examination of how question wording is related to international differences in knowledge measures, see sidebar, “Knowledge Difference or Measurement Error?”) Knowledge scores for individual items vary from country to country, and no country consistently outperforms the others (figure 7-11). For the questions reported in figure 7-11, knowledge scores are relatively low in China, Russia, and Malaysia. Compared with the United States and the highly developed countries in Europe, Japanese scores are also relatively low.[16]

Science knowledge scores vary considerably across the EU-25 countries, with northern European countries, led by Sweden, recording the highest total scores on a set of 13 questions. For a smaller set of 4 items that were administered in both 1992 and 2005 in 12 European countries, each country performed better in 2005. In contrast, the U.S. data on science knowledge do not show upward trends over the same period. In Europe, as in the United States, men, younger adults, and more highly educated people tend to score higher on these questions. (For more details on scientific literacy in individual countries in Europe, see NSB 2008.)

Reasoning and Understanding the Scientific Process

Past NSF surveys have used questions on three general topics—probability, experimental design, and the scientific method—to assess trends in Americans’ understanding of the process of scientific inquiry. One set of questions tests how well respondents apply principles of probabilistic reasoning to a series of questions about a couple whose children

Table 7-5

Adult and student correct answers to factual knowledge questions

(Percent correct)

Factual questions	Field of study	Concepts measured	U.S. adult	Student		
			2008 General Social Survey	United States	International	Question source
1. *A farmer thinks that the vegetables on her farm are not getting enough water. Her son suggests that they use water from the nearby ocean to water the vegetables. Is this a good idea?*	Earth and space sciences	Water cycle; nature of the oceans and their effects on water and climate; location of water, its distribution, characteristics, and its effect and influence on human activity	86	61	NA	NAEP 2005, 4th grade
2. *Traits are transferred from generation to generation through the...*	Life sciences	Reproduction and heredity	80	86	74	TIMSS Science 2003, 8th grade
3. *How do most fish get the oxygen they need to survive?*	Life sciences	Change and evolution; adaptation and natural selection	76	78	NA	NAEP 2005, 8th grade
4. *What property of water is most important for living organisms?*	Physical sciences	Matter and its transformations	69	76	NA	NAEP 2000, 8th grade
5. *Which of the following is NOT an example of erosion?*	Earth and space sciences	Composition of the Earth; forces that alter the Earth's surface; rocks: their formation, characteristics, and uses; soil: its changes and uses; natural resources used by humankind; and forces within the Earth	55	37	NA	NAEP 2005, 8th grade
6. *Lightning and thunder happen at the same time, but you see the lightning before you hear the thunder. Explain why this is so.*	Physical sciences	Frames of reference, force and changes in position and motion, action and reaction, vibrations and waves as motion, electromagnetic radiation, and interactions of electomagnetic radiation with matter	45	36	NA	NAEP 2005, 8th grade
7. *A solution of hydrochloric acid (HCl) in water will turn blue litmus paper red. A solution of the base sodium hydroxide (NaOH) in water will turn red litmus paper blue. If the acid and base solutions are mixed in the right proportion, the resulting solution will cause neither red nor blue litmus paper to change color. Explain why the litmus paper does not change color in the mixed solution.*	Chemistry	Acids and bases	20	17	21	TIMSS 2003, 8th grade

NA = not available, question not asked

NAEP = National Assessment of Educational Progress; TIMSS = Trends in International Mathematics and Science Study

NOTES: Questions appeared in 2008 General Social Survey. Original sources of questions are NAEP and TIMSS. For complete questions, see sidebar: "New Science Knowledge Questions."

SOURCES: University of Chicago, National Opinion Research Center, General Social Survey (2008), see appendix table 7-12; NAEP, http://nces.ed.gov/nationsreportcard/itmrls/startsearch.asp, accessed 22 September 2009; and TIMSS, http://nces.ed.gov/timss/results03.asp, accessed 22 September 2009.

Science and Engineering Indicators 2010

Knowledge Difference or Measurement Error?

Surveys from different countries have tried to measure public knowledge about how children inherit the chromosomes that determine their sex. The data appear to indicate that Americans understand this topic better than their counterparts in other countries. The true-false question asked in the United States is "It is the father's gene that decides whether the baby is a boy or a girl." (True.) Europeans and Chinese have been asked the same question about the mother's gene. (False.) Although a knowledgeable survey respondent would treat these questions as equivalent, research on how people answer surveys suggests that they may not be. Survey methodologists have found that many respondents exhibit an acquiescence bias—a tendency to give a positive answer (e.g., true, yes, agree) to questions, independent of their content (Holbrook, Green, and Krosnick 2003; Krosnick 2000). Accordingly, respondents will seem more knowledgeable when the correct answer to a question is "true."

The 2008 GSS included an experiment to test whether observed national differences on this topic are real knowledge differences or are products of acquiescence bias. Some respondents were asked the usual U.S. question, while others got the international variant. The experiment indicated that the national differences result from knowledge differences and not from acquiescence bias. A larger proportion of respondents (71%) answered correctly when the right answer was false than when it was true (62%) (appendix tables 7-9 and 7-10).

have a one-in-four chance of suffering from an inherited disease.[17] A second set of questions deals with the logic of experimental design, asking respondents about the best way to design a test of a new drug for high blood pressure. An open-ended question probes what respondents think it means to "study something scientifically." Because probability, experimental design, and the scientific method are all central to scientific research, these questions are relevant to how respondents evaluate scientific evidence.

In 2008, 65% of Americans responded correctly to the two questions about probability, 38% to the questions testing the concept of experiment, and 22% to the questions testing the concept of scientific study. Scores on the probability questions fluctuate each year but are relatively stable over time; however, between 2006 and 2008 the combined scores of the two probability questions slightly declined. Scores in the other scientific process questions were generally higher than they were in the mid-1990s, but decreased somewhat in 2008 (appendix table 7-13). Performance on these questions is strongly associated with the different measures of science knowledge and education (appendix table 7-14). Older Americans and those with lower incomes, two groups that tend to have less education in the sciences, also score lower on the inquiry measures. Men and women obtain similar scores on these questions (tables 7-4 and 7-6).

The 2008 GSS included several additional questions on the scientific process that provide an opportunity to examine Americans' understanding of experimental design in more detail and benchmark their scores to national results of middle school students. From 29% to 57% of Americans responded correctly to questions measuring the concepts of scientific experiment and controlling variables (appendix tables 7-13 and 7-15). However, only 12% of Americans responded correctly to all the questions on this topic and nearly 20% of Americans did not respond correctly to any of them (figure 7-12).[18] These data suggest that relatively few Americans have a generalized understanding of experimental design that they can reliably apply to different situations.

The proportion of Americans with a strong grasp of experimental design does not vary by sex. However, Americans who answered at least three of four experimental knowledge questions correctly were more likely to have a college education or higher, have taken more courses in math and science, and have a clear understanding of the scientific method. They are also more likely to be in the top income bracket and to respond correctly to factual science knowledge and probability questions.

Adults' scores in the experimental knowledge questions are similar to middle school students in one question (question 2 in table 7-7) but lower in two others, out of the three questions where the comparison was possible.

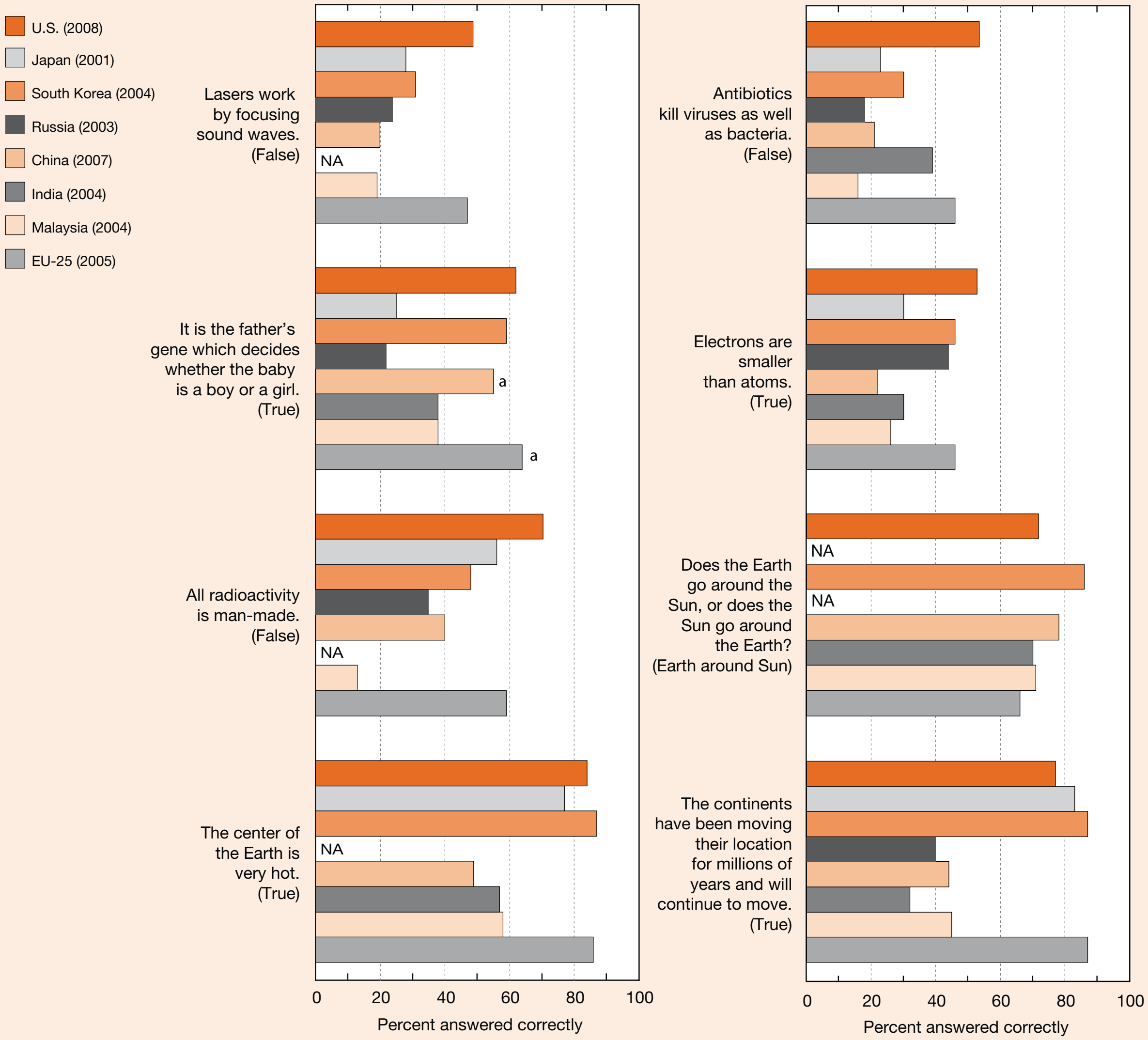
Understanding of Statistics and Charts

Americans encounter basic statistics and charts in everyday life. Many media reports cite studies in health, social, economic, and political trends. Understanding statistical concepts is important to understanding the meaning of these studies and consequently to scientific literacy (Crettaz von Roten 2006). The results from the 2008 GSS show that 77% of Americans can read a simple chart correctly and 66% understand the concept of "mean" in statistics. Understanding these two concepts is associated with formal education, the number of math and science courses taken, income, and verbal ability. Older respondents were less likely to respond correctly to these two questions (appendix table 7-15).

Pseudoscience

The results of 13 NSF-funded surveys conducted between 1979 and 2008 show a trend toward fewer Americans seeing astrology as scientific. In the 2008 GSS 63% of Americans indicated they believed that astrology was "not at all

Figure 7-11
Correct answers to scientific literacy questions, by country/region: Most recent year



NA = not available, question not asked

EU = European Union

[a]China and Europe surveys asked about "mother's gene" instead of "father's gene."

SOURCES: University of Chicago, National Opinion Research Center, General Social Survey (2008); Japan–Government of Japan, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology, The 2001 Survey of Public Attitudes Toward and Understanding of Science and Technology in Japan (2002); South Korea–Korea Science Foundation, Survey of Public Attitudes Toward and Understanding of Science and Technology (2004); Russia–Gokhberg L, Shuvalova O, *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education as Drivers of Economic Growth and Quality of Life*, British Council, Russia (2004); China–Wei H, Chao Z, Hongbin G, *Chinese Public Understanding of Science and Attitudes towards Science and Technology, 2007*, China Research Institute for Science Popularization, Chinese Ministry of Science and Technology (2008); India–National Council of Applied Economic Research, India Science Survey (2004); Malaysia–Malaysian Science and Technology Information Centre, Public Awareness of Science and Technology Malaysia 2004 (2005); and EU–European Commission, Research Directorate-General, Eurobarometer 224/Wave 63.1: Europeans, Science and Technology (2005).

Science and Engineering Indicators 2010

Table 7-6

Correct answers to questions about charts and statistics, reasoning/life sciences, and understanding of experiment/controlling variable by sex: 2008

(Percent)

Question	Both sexes	Men	Women
1. *Please look at card 3. Day-night rhythms dramatically affect our bodies. Probably no body system is more influenced than the nervous system. The figure on card 3 illustrates the number of errors made by shift workers in different portions of the 24-hour cycle. Based on the data illustrated in the figure, during which of these time periods did the most errors occur?*	77	80	73
2. *As part of a laboratory experiment, five students measured the weight of the same leaf four times. They recorded 20 slightly different weights. All of the work was done carefully and correctly. Their goal was to be as accurate as possible and reduce error in the experiment to a minimum. Which of the following is the BEST method to report the weight of the leaf?*	66	70	63
3. *Please look at card 1. The two objects shown there have the same mass, but object B loses heat more quickly than object A. Which combination of bodily features would be BEST suited to a small animal that lives in a cold climate and needs to minimize heat loss?*[a]	51	54	49
4. *Please look at card A. A gardener has an idea that a plant needs sand in the soil for healthy growth. In order to test her idea she uses two pots of plants. She sets up one pot of plants as shown on the top part of the card. Which one of the pictures on the bottom part of the card shows what she should use for the second pot?*[b]	51	49	53
5. *Please look at card 2. A student wants to find out if temperature affects the behavior of goldfish. He has four fish bowls and 20 goldfish. Which of the experiments on card 2 should he do?*	57	59	56
6. *Combined responses to two interrelated questions: (Question 1) What is the scientist trying to find out from this experiment? (Question 2, follow-up) Why did you choose that answer?*[c]	29	30	28

[a] Respondent can reach correct answer through both reasoning and knowledge of life sciences.

[b] Respondent can answer this question by using knowledge of experiment/controlling variable or knowledge in the life sciences.

[c] Data represent a composite of correct responses to both questions.

NOTE: For complete questions, see sidebar: "New Science Knowledge Questions Included in the General Social Survey: 2008."

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix table 7-15. Questions 1, 2, and 3 originally from American Council on Education, GED Testing Service, Science Official GED Practice Test (2006). Question 4 originally from Trends in International Mathematics and Science Study (TIMMS), Complete TIMSS 8 Science Concepts and Items 4, http://nces.ed.gov/timss/pdf/TIMSS8_Science_Items.pdf, accessed 22 September 2009. Questions 5 and 6 originally from American Association for the Advancement of Science, AAAS Project 2061, http://www.project2061.org/publications/2061Connections/2007/media/controlling_variables_poster.pdf, accessed 22 September 2009.

Science and Engineering Indicators 2010

scientific" and 28% said that it was only "sort of scientific." Respondents with more years of formal education were less likely to perceive astrology to be at all scientific. In 2008, 78% of college graduates indicated that astrology was "not at all scientific," compared with 60% of high school graduates. Those who scored highest on the factual knowledge measures were less likely to perceive astrology to be at all scientific (78%) than those who scored lowest (45%). Respondents who correctly understood the concept of scientific inquiry were more likely to say that astrology was not at all scientific (74%) than those who did not understand the concept (57%). However, the youngest age group (18–24) was less likely to say astrology is "not at all scientific" (49%) and more likely to say it was "sort of scientific" (44%) (appendix table 7-16).[19]

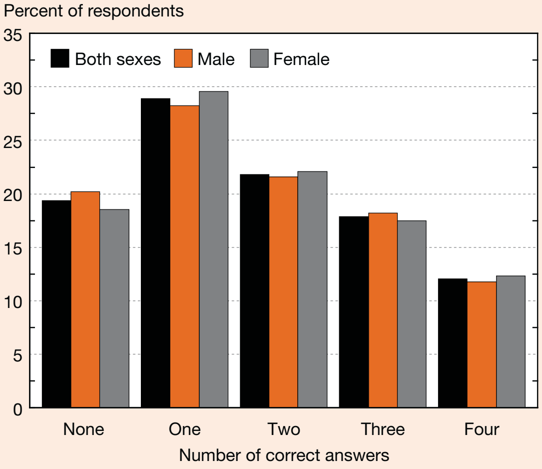
Public Attitudes About S&T in General

Generalized public support for S&T can make a difference in many ways. Public openness to technological change gives U.S. businesses opportunities to build a domestic customer base, create a foundation for worldwide technical competitiveness, and foster the national advantages that flow from pioneering innovations. Broad public and political support for long-term commitments to S&T research, especially in the face of pressing immediate needs, enables ambitious proposals for sustained federal S&T investments to reach fruition. Public confidence that S&E community leaders are trustworthy, S&E research findings are reliable, and S&E experts bring valuable judgment and knowledge to bear on public issues permits scientific knowledge to have influence over practical affairs. In addition, positive public perceptions of S&E occupations encourage young people to pursue S&E careers.

To be sure, claims of scientific and technological progress should be evaluated critically. But widespread public skepticism about S&T, going beyond the reasoned examination of particular cases, would represent a consequential change in American public opinion. Changing public opinion could affect national strategies that link progress in S&T to overall national progress.

Figure 7-12

Correct answers to four questions testing concept of experiment/controlling variable, by sex: 2008



NOTE: For the four questions testing concept of experiment/controlling variable included see "Understanding of experiment" in appendix table 7-13 and "Experiment/controlling variable" group in appendix table 7-15.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008).

Science and Engineering Indicators 2010

This section presents general indicators of public attitudes and orientations toward S&T in the United States and in other countries. It covers views of the promise of S&T and reservations about science, overall support for government funding of research, confidence in the leadership of the scientific community, perceptions of the proper influence of scientists over controversial public issues about which the research community claims expertise, perceptions about what it means to be scientific and which disciplines and practices are scientific, and views of S&E as occupations.

Promise and Reservations

NSF surveys dating back to 1979 show that Americans endorse the past achievements and future promise of S&T. In practically any major American social grouping, few individuals express serious doubt about the promise of science. In 2008, 43% of GSS respondents said that the benefits of scientific research strongly outweighed the harmful results and substantial percentages said that benefits either slightly outweighed harms (25%) or volunteered that the two were about equal (16%). Only 10% of respondents said that the harms either slightly or strongly outweighed benefits and the remainder said that they did not know. These numbers were generally consistent with those from earlier surveys (figure 7-13; appendix tables 7-17 and 7-18). Americans overwhelmingly agree that S&T will foster "more opportunities

Table 7-7

Adult and student correct answers to scientific process questions

(Percent correct)

		U.S. adult	Student		
Process question	Field of study	2008 General Social Survey	United States	International	Question source
1. *Please look at Card A. A gardener has an idea that a plant needs sand in the soil for healthy growth. In order to test her idea she uses two pots of plants. She sets up one pot of plants as shown on the top part of the card. Which one of the pictures on the bottom part of the card shows what she should use for the second pot?*[a]	Life sciences	51	70	58	TIMSS Science 2003, 8th grade
2. *Please look at Card 5. What is the scientist trying to find out from this experiment?*................................	Life sciences	40	38	NA	AAAS Project 2061
3. (Follow-up to question 2) *Why did you choose that answer?*	Life sciences	38	46	NA	AAAS Project 2061

NA = not available, question not asked

AAAS = American Association for the Advancement of Science; TIMSS = Trends in International Mathematics and Science Study.

[a] Respondent can answer this question by using knowledge of experiment/controlling variable or knowledge in the life sciences.

NOTES: Questions appeared in 2008 General Social Survey. Original sources of questions are TIMSS and AAAS Project 2061. For complete questions, see sidebar: "New Science Knowledge Questions Included in the General Social Survey: 2008."

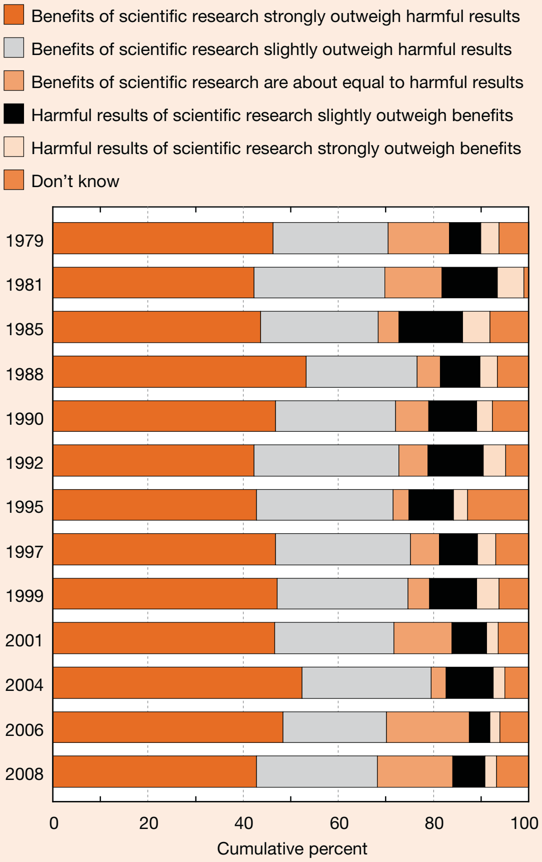
SOURCES: University of Chicago, National Opinion Research Center, General Social Survey (2008), see appendix table 7-15; TIMSS, http://nces.ed.gov/timss/results03.asp; Deboer GE, Gogos A. Unpublished results of national field test assessing middle school students' understanding of controlling variables, AAAS Project 2061.

Science and Engineering Indicators 2010

for the next generation," with about 89% expressing agreement in the 2008 GSS (appendix table 7-19). Agreement with this statement has been increasing moderately for over a decade.[20]

Eight annual Virginia Commonwealth University (VCU) Life Sciences Surveys show similar results. The percentage of Americans who agreed that "developments in science helped make society better" ranged between 83% and 90% (VCU Center for Public Policy 2006 and 2008). Similarly, between 2002 and 2008 the surveys asked respondents whether they believed that "scientific research is essential for improving the quality of human lives" and found that agreement ranged between 87% and 92%. During the same period, between 88% and 92% agreed that "new technology used in medicine allows people to live longer and better."

Figure 7-13
Public assessment of scientific research: 1979–2008



NOTE: Includes all years for which data collected.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1979–2001); University of Michigan, Survey of Consumer Attitudes (2004); and University of Chicago, National Opinion Research Center, General Social Survey (2006, 2008). See appendix tables 7-17 and 7-18.

Science and Engineering Indicators 2010

Americans who have more years of formal education and score higher on measures of science knowledge express more favorable attitudes about S&T. A review of numerous surveys from around the world found, other things being equal, a weak but consistent relationship between greater knowledge of science and more favorable attitudes toward science. This relationship was stronger in the United States than in any of the other countries in the study (Allum et al. 2008; for more details see NSB 2008). Optimism about science among the most interested and knowledgeable public, however, may not necessarily correspond with accurate expectations about the speed of scientific progress (see sidebar, "Public Expectations About Technological Advances").

Although data from other countries are not entirely comparable, they appear to indicate that Americans have somewhat more positive attitudes about the benefits of S&T than Europeans, Russians, and Japanese. Attitudes in China and South Korea are comparable with the U.S., and on some questions attitudes are even more favorable, but their reservations about science are somewhat higher (appendix table 7-18). In all of the countries and regions where survey data exist, statements about the achievements and promise of science elicit substantially more agreement than disagreement.

Both in the United States and abroad, respondents also express reservations about S&T. For eight years (2001–08), VCU Life Sciences Surveys have asked respondents whether they agree that "scientific research these days doesn't pay enough attention to the moral values of society." Each year, a majority has agreed; however, the percentage that agreed has dropped substantially, from 73% in 2001 to 56% in 2008. In the 2008 GSS, large minorities of survey respondents registered agreement with other statements expressing reservations about science, such as "science makes our way of life change too fast" (47% agree, 51% disagree). The proportion that agrees with this statement decreases with education, family income, and factual knowledge of science (appendix table 7-20). The question has been asked in numerous other countries (appendix table 7-18). Although levels of agreement with this statement in the United States appear to be similar to those in Russia, surveys in other countries record much higher levels of agreement.[21]

Federal Funding of Scientific Research

U.S. public opinion consistently and strongly supports federal spending on basic research. NSF surveys have repeatedly asked Americans whether "even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the Federal Government." Agreement with this statement has increased slightly since the early 1990s, with 84% favoring federal support in 2008 and only 12% opposing it (appendix tables 7-21 and 7-22).

Responses to a GSS question about federal spending on scientific research provide further evidence of increasing public support for federal spending on scientific research. Since 1981, the proportion of Americans who thought the

Public Expectations About Technological Advances

In the late 1970s and early 1980s, Jon Miller surveyed Americans about the technological breakthroughs they did and did not expect in the next 25 years and looked at the differences in the expectations of three different segments of the public with regard to S&T: the attentive, the interested, and the nonattentive (Miller 1983).

The attentive public included those citizens who were at least moderately interested and knowledgeable about S&T issues and remained informed in these areas. The interested public included individuals who were interested in S&T matters and perceived themselves to be at least moderately well informed, but were not very knowledgeable and did not keep up with information in these areas. The nonattentive public had little interest in, or knowledge about, S&T issues.

The findings showed that majorities of the attentive public, and to a large extent the interested public, thought it was "very likely" that within 25 years science would discover ways to accurately predict earthquakes, to economically desalinate seawater for human consumption, and to find more efficient cheap energy sources and a cure for common forms of cancer. In contrast, Americans who were not attentive to S&T issues leaned toward the "possible but not likely" answer (see table 7-A below).

At present seismologists can provide broad forecasts, but cannot yet accurately predict when and where earthquakes will happen. The cost of seawater desalination has become more competitive than in the past, but it is still not economically viable on a broad scale. Early detection, innovative surgery techniques, and new therapies have improved the prognosis for many types of cancers, but no cure has been found. Miller's survey data suggest that the attentive and interested publics were more optimistic than the nonattentive, but also, in these instances, less accurate in their expectations about the speed of scientific progress.

Table 7-A

Public expectations for future scientific achievements within next 25 years: 1979 and 1981

(Percent)

	Attentive public		Interested public		Nonattentive public	
How likely do you think it is that researchers will achieve… in the next 25 years or so?	1979 (*n* = 289)	1981 (*n* = 637)	1979 (*n* = 292)	1981 (*n* = 617)	1979 (*n* = 839)	1981 (*n* = 1,940)
	Percent responding "very likely"					
A way to predict when and where earthquakes will occur	72	63	54	63	46	NA
More efficient sources of cheap energy	81	74	60	65	50	NA
A cure for the common forms of cancer	58	59	48	61	43	NA
A way to put communities in outer space	28	21	18	23	13	NA
New ways of effectively reducing the crime rate	14	NA	17	NA	14	NA
A way to economically desalinate seawater for human consumption	64	63	47	63	39	NA
An economic theory to control inflation and reduce unemployment	NA	20	NA	28	NA	NA

NA = not available, question not asked

SOURCE: Miller JD, The American People and Science Policy: The Role of Public Attitudes in the Policy Process, New York: Pergamon Press, Inc. (1983).

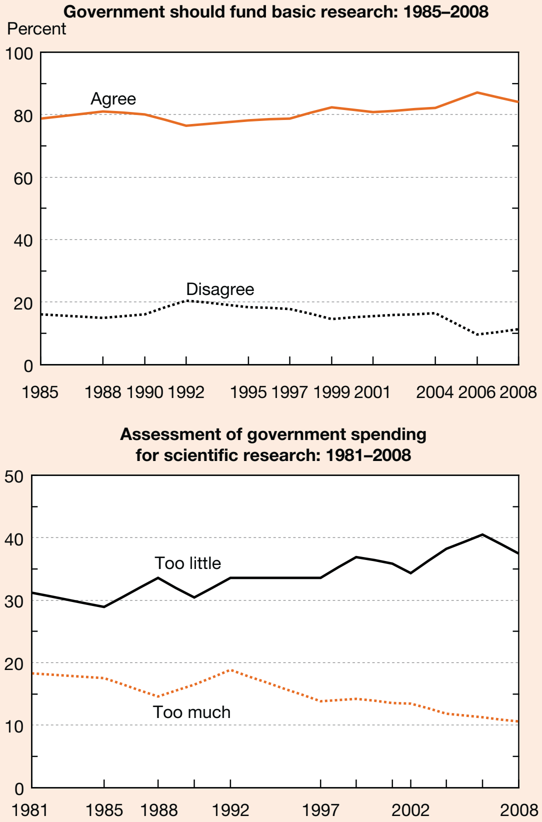
Science and Engineering Indicators 2010

government was spending too little on scientific research has increased, fluctuating between 29% and 34% in the 1980s, between 30% and 37% in the 1990s, and between 34% and 41% since 2001. In 2006 and 2008, only about 11% said that the government was spending too much in this area, the lowest levels registered since 1981 (figure 7-14; appendix tables 7-23 and 7-24).

Although support for federal research investment is at historically high levels, other kinds of federal spending generate even stronger public support. Support for increased spending is greater in numerous program areas, including health care (75%), education (74%), assistance to the poor (69%), environmental protection (66%), social security (59%), and mass transportation (46%). Still, based on the proportion of the U.S. population favoring increased spending, scientific research (38%) ranks well ahead of spending in national defense (24%), space exploration (14%), and assistance to foreign countries (11%).[22]

In other countries where similar though not precisely comparable questions have been asked, respondents also express strong support for government spending on basic scientific research. In 2005, 76% of Europeans agreed that "even if it brings no immediate benefits, scientific research which adds to knowledge should be supported by government," and only 7% disagreed. In 2007, 74% of Chinese agreed to a similar statement. Because both the European and the Chinese survey offered a middle option ("neither agree nor disagree"), these percentages are lower than figures for the

Figure 7-14
Public attitudes toward government funding of scientific research: Selected years, 1981–2008



Government should fund basic research: 1985–2008

Assessment of government spending for scientific research: 1981–2008

NOTES: Top panel: survey results in 1985, 1988, 1990, 1992, 1995, 1997, 1999, 2001, 2004, 2006, and 2008; other years extrapolated. Bottom panel: survey results in 1981, 1985, 1988, 1990, 1992, 1997, 1999, 2001, 2002, 2004, 2006, and 2008; other years extrapolated.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (years through 2001); University of Michigan, Survey of Consumer Attitudes (2004 in top panel); and University of Chicago, National Opinion Research Center, General Social Survey (2006, 2008 in top panel, 2002–08 in bottom panel). See appendix table 7-21 for top panel and appendix table 7-23 for bottom panel.

Science and Engineering Indicators 2010

United States, where no middle category was offered (appendix table 7-21). Agreement in South Korea, Malaysia, Japan, and Brazil reaches levels comparable to those in the United States and Europe.

Support for increased government spending on scientific research is relatively common in Europe as well. Over half of Europeans agreed in 2005 that their "government should spend more money on scientific research and less on other things." Although this proportion is nominally higher than the percentage of Americans who support more government spending, numerous context and wording differences between the questions leave responses open to substantially differing interpretations.[23] Public support for increased spending on scientific research was substantially greater in South Korea (67% in 2004) than in the United States (Korea Science Foundation 2004).

Confidence in the Science Community's Leadership

For the science-related decisions that citizens face, a comprehensive understanding of the relevant scientific research would require mastery and evaluation of a great deal of evidence. In addition to relying on direct evidence from scientific studies, citizens who want to draw on scientific evidence must consult the judgments of leaders and other experts whom they believe can speak authoritatively about the scientific knowledge that is relevant to an issue.

Public confidence in the leaders of the scientific community is one indicator of public willingness to rely on science. Since 1973, the GSS has tracked public confidence in the leadership of various institutions, including the scientific community. The GSS asks respondents whether they have "a great deal of confidence, only some confidence, or hardly any confidence at all" in the leaders of different institutions. In 2008, the percentage of Americans expressing "a great deal of confidence" in leaders of the scientific community (39%) was the same as those expressing "a great deal of confidence" in leaders of the medical community (39%) and higher than for all other institutions except the military (51%).

Conversely, the percentage expressing "hardly any confidence at all" was lower for scientific leaders than for leaders of any other institution about which this question was asked (table 7-8). Throughout the entire period in which this question has been asked, the percentage of Americans expressing a great deal of confidence in the leaders of the scientific community has fluctuated within a relatively narrow range, hovering between 35% and 45% (appendix table 7-25). In contrast, for some other institutions (e.g., the military), confidence has shown more variability over the past three decades.

Science usually ranks second or third in the public confidence surveys, with medicine or the military ranking first. The consistently high confidence in the leadership of the scientific community contrasts with a general decline in confidence in other institutional leaders over the years. The medical community, for example, has seen a long-term decline in confidence. Over half of Americans expressed a great deal of confidence in medical leaders in the mid-1970s, compared with about 40% in recent years. Thirty years ago confidence in the medical community was higher than confidence in scientific leaders. However, since 2002 science has scored as well as or better than medicine on this indicator, although the scores for the two fields remain very close.

Influence on Public Issues

Government support for scientific research derives partly from the notion that science can support policymakers in

Table 7-8
Public confidence in institutional leaders: 2008
(Percent)

Type of institution	Level of confidence in leaders: A great deal	Some	Hardly any	Don't know
Military	51	37	10	1
Medicine	39	50	11	*
Scientific community	39	51	6	4
U.S. Supreme Court	31	53	14	2
Education	29	54	15	1
Organized religion	20	53	25	2
Banks and financial institutions	19	60	21	1
Major companies	16	66	16	2
Organized labor	12	57	27	4
Congress	10	51	37	2
Executive branch of federal government	10	49	38	3
Television	9	51	39	1
Press	9	45	45	1

* = <0.5% responded

NOTE: Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2008). See appendix table 7-25.

Science and Engineering Indicators 2010

making many public decisions. Science can play this role more effectively if the general public supports the use of scientific knowledge in such decisions and shares the view that science is relevant.

In 2006, the GSS asked about the appropriate influence of science on four public policy issues to which scientific research might be considered relevant—global climate change, research using human embryonic stem cells, federal income taxes, and genetically modified (GM) foods. Survey respondents were asked how much influence a group of scientists with relevant expertise (e.g., medical researchers, economists) should have in deciding about each issue, how well the scientists understood the issue, and to what extent the scientists would “support what is best for the country as a whole versus what serves their own narrow interests.” The same questions were asked about elected officials and either religious leaders (for stem cell research) or business leaders (for the other issues). Respondents were also asked a question about their perception of the level of consensus among the scientists regarding a largely factual aspect of the issue (e.g., “the existence and causes of global warming” or “the importance of stem cell research”) and a question that probed their attitude regarding each issue.

The GSS data indicate that Americans believe that scientists should have a relatively large amount of influence on public decisions concerning these issues (table 7-9). For the four issues, the percentage who said that scientists should have either “a great deal” or “a fair amount” of influence ranged from 85% (“global warming”) to 72% (“income taxes”). For each issue, the percentage was greater for scientists than for either of the other leadership groups. The contrast among the groups was more pronounced for the three issues that dealt with biological or geophysical phenomena than for income taxes, where elected officials ranked closely behind economists.

Americans also give scientists relatively high marks for understanding the four issues (table 7-10). The GSS asked respondents to rate each leadership group’s understanding of a largely factual aspect of each issue on a five-point scale ranging from “very well” to “not at all.” For the three issues dealing with biological or geophysical phenomena, the differences in perceived understanding were large: between 64% and 74% of the public placed the relevant scientists in one of the top two categories, whereas only 9% to 14% placed any of the other groups in those categories. The contrast among groups was smaller for the tax issue, with economists (52%) ranking ahead of business leaders (44%) and elected officials (28%).

Patterns for the question about which groups would “support what is best for the country as a whole versus what serves their own narrow interests” were similar. For each issue, Americans placed the scientific group in one of the top two categories much more often than they placed either of the other leadership groups in those categories.

One factor that may limit the influence of scientific knowledge and the scientific community over public issues is the perception that significant scientific disagreement exists, making scientific knowledge uncertain (Krosnick et al. 2006). GSS respondents were asked to rate the degree of scientific consensus on a largely factual aspect of each of the four issues using a five-point scale ranging from “near complete agreement” to “no agreement at all.” The degree of perceived consensus of medical researchers on “the importance of stem cells for research” was the only item for

Table 7-9
Preferred groups for influencing decisions about public issues: 2006

(Percent)

	Preferred degree of influence				
Public issue/group	A great deal	A fair amount	A little	None at all	Don't know
Global warming					
Environmental scientists	47	38	7	3	4
Elected officials	17	33	33	13	4
Business leaders	10	22	38	25	5
Stem cell research					
Medical researchers	39	41	11	4	5
Elected officials	11	35	32	15	6
Religious leaders	8	21	36	29	6
Federal income taxes					
Economists	21	51	18	4	6
Elected officials	21	40	24	11	4
Business leaders	9	37	36	13	4
Genetically modified foods					
Medical researchers	41	40	10	3	5
Elected officials	7	30	37	21	5
Business leaders	3	16	41	35	5

NOTES: Responses to: *How much influence should each of the following groups have in deciding: global warming policy; government funding for stem cell research; reducing federal income taxes; restricting sale of genetically modified foods?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-21 in National Science Board, *Science and Engineering Indicators 2008* (NSB 08-01A) (2008).

Science and Engineering Indicators 2010

Table 7-10
Perceived understanding of public issues by various groups: 2006

(Percent)

	Degree of understanding (on scale of 1 to 5)				
Public issue/group	Very well 5	4	3	2	Not at all 1	Don't know
Global warming						
Environmental scientists	44	22	22	4	4	4
Business leaders	4	8	30	32	22	4
Elected officials	5	7	31	29	24	4
Stem cell research						
Medical researchers	50	24	15	3	3	6
Religious leaders	6	8	26	29	25	6
Elected officials	3	7	35	26	22	6
Federal income taxes						
Economists	33	19	29	7	7	5
Business leaders	15	29	33	12	6	4
Elected officials	10	18	34	19	15	5
Genetically modified foods						
Medical researchers	32	32	18	8	5	6
Business leaders	4	7	24	31	28	6
Elected officials	3	6	24	33	29	5

NOTES: Responses to: *How well do the following groups understand: causes of global warming; importance of stem cell research; effects of reducing federal income taxes; risks posed by genetically modified foods?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-22 in National Science Board, *Science and Engineering Indicators 2008* (NSB 08-01A) (2008).

Science and Engineering Indicators 2010

which more than half of respondents (52%) chose one of the two points near the "complete agreement" end of the scale (table 7-11). In the case of the perceived consensus of environmental scientists on "the existence and causes of global warming," 42% chose one of these two points denoting a high degree of consensus. Lower proportions of respondents chose one of these two points when asked about the extent to which medical researchers agree on "the risks and benefits of genetically modified foods" (28%) or economists on "the effects of reducing federal income taxes" (20%).

With a few exceptions, responses to these questions do not differ markedly among demographic groups. Americans with higher incomes, more education, and more science knowledge tend to have more favorable perceptions of the knowledge, impartiality, and level of agreement among scientists. For a more detailed presentation of these data and further discussion of this subject, see NSB 2008.

What Makes an Activity Scientific

The label "scientific" is usually considered a favorable one. When research studies claim to be scientific, they claim to produce valid knowledge; when occupations claim to be scientific, they claim their practitioners have systematic expertise. It is important for the public to be able to scrutinize these claims critically and use reasonable criteria to judge them, because not all claims that an activity is scientific are equally warranted.

In 2006, the GSS included two batteries of questions that probed what characteristics Americans associate with scientific studies and what disciplines and practices Americans consider scientific. These indicators provide insight into how Americans discriminate between more and less scientific endeavors. (Data from these questions are reported in greater detail in NSB 2008.)

Attributes That Make Something Scientific

One group of questions asked how important each of eight characteristics is in "making something scientific." These characteristics can be divided into three groups:

- Features of the research process:
  - The conclusions are based on solid evidence.
  - The researchers carefully examine different interpretations of the results, even ones they disagree with.
  - Other scientists repeat the experiment and find similar results.
- Aspects of the credentials and institutional settings that lend credibility to the research:
  - The people who do the research have advanced degrees in their field.
  - The research is done by scientists employed in a university setting.
  - The research takes place in a laboratory.
- External validation by other belief systems:
  - The results of the research are consistent with common sense.
  - The results of the research are consistent with religious beliefs.

Americans were most likely to consider features of the research process to be very important. Over two-thirds said that "conclusions based on solid evidence" (80%), "carefully examin[ing] different interpretations of the results" (73%), and "replication of results by other scientists" (67%) were very important in making something scientific.

Americans thought that researcher qualifications were almost as important, with 62% classifying "the people who do it have advanced degrees in their field" as very important.

Table 7-11
Perceived scientific consensus on public issues: 2006
(Percent)

	Degree of consensus (on scale of 1 to 5)					
Group/public issue	Near complete agreement 5	4	3	2	No agreement at all 1	Don't know
Medical researchers on importance of stem cells for research	19	33	29	4	5	9
Environmental scientists on existence and causes of global warming	14	28	35	9	6	9
Medical researchers on risks and benefits of genetically modified foods	9	19	41	11	7	13
Economists on effects of reducing federal income taxes	5	15	40	14	13	13

NOTES: Responses to: *To what extent do [people in group] agree on [public issue]?* Detail may not add to total because of rounding.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix table 7-24, National Science Board, *Science and Engineering Indicators 2008* (NSB 08-01A) (2008).

Science and Engineering Indicators 2010

Institutional settings often associated with research, such as laboratories (41%) and universities (33%), ranked lower. Respondents viewed these settings as similar in importance to having results that were "consistent with common sense." Most Americans viewed consistency with religion as either not at all important (39%) or not too important (31%) to making something scientific.

Response patterns for this group of questions are related to the respondent's education level (figure 7-15). Although Americans at all levels of education rated research process characteristics as most important, more highly educated Americans gave these characteristics the highest ratings. In contrast, individual credentials, institutional auspices, and consistency with other beliefs were seen as less important among more highly educated respondents than among others. As a result of these divergent patterns, the gap in importance between process characteristics and other attributes is wide at higher levels of education but relatively narrow for people with less schooling (figure 7-15). (For more details, see NSB 2008.)

Which Fields Are Scientific

The 2006 GSS asked Americans about eight fields of research or practice and whether they were "very scientific, pretty scientific, not too scientific, or not scientific at all."

Practically all Americans (98%) perceived medicine as "very" or "pretty" scientific, even though it is focused more on practical service delivery and less on research than other listed fields, including biology and physics. Nonetheless, both of these disciplines were also overwhelmingly seen as either "very" or "pretty" scientific (94% for biology and 90% for physics). Americans with more years of education and more classroom exposure to science and mathematics were more likely to believe that these two fields were relatively scientific, particularly physics.

Engineering, a discipline which like medicine involves the application of science and mathematics to develop solutions to practical problems, ranked below the other three fields on this measure; 77% perceived engineering as "very" or "pretty" scientific.

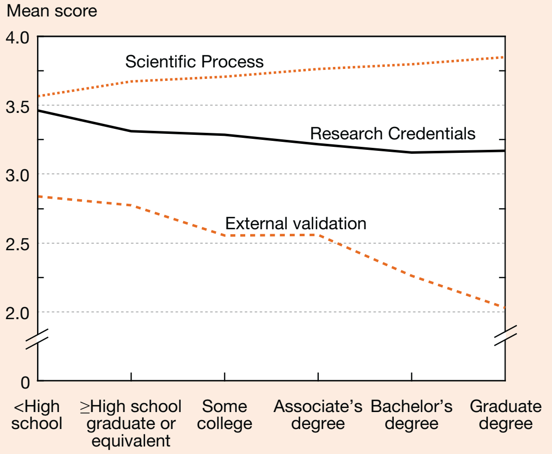
About 50% of Americans said that the two social science disciplines on the list (economics and sociology) were "very" or "pretty" scientific. Accounting and history were less likely to be placed at the scientific end of the scale; respondents with less education were more likely than others to classify history as relatively scientific. A similar question on the 2005 Eurobarometer about an overlapping set of fields produced generally similar results (EC 2005).

Views of S&E Occupations

Data on public esteem for S&E occupations are an indicator of the attractiveness of these occupations and their ability to recruit talented people into their ranks. Such data may also have a bearing on the public's sense that S&E affects the nation's well-being in the future.

Figure 7-15

Importance of scientific process, research credentials, and external validation to public's belief that something is scientific, by education level: 2006



NOTES: Responses to how important each of eight statements is to making something scientific—very important, pretty important, not too important, not important at all (where 4 = very important and 1 = not important at all). Mean importance scores for process, credentials, and external validation are computed averages of responses to all statements in category. Process statements: (1) *The conclusions are based on solid evidence;* (2) *The researchers carefully examine different interpretations of the results, even ones they disagree with;* (3) *Other scientists repeat the experiment, and find similar results.* Credentials statements: (1) *The people who do it have advanced degrees in their field;* (2) *It is done by scientists employed in a university setting;* (3) *The research takes place in a laboratory.* External validation statements: (1) *The results of the research are consistent with common sense;* (2) *The results of the research are consistent with religious beliefs.*

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2006). See appendix tables 7-25 and 7-26 in National Science Board, *Science and Engineering Indicators 2008* (NSB 08-01A) (2008).

Science and Engineering Indicators 2010

For over 30 years, the Harris Poll (Harris Interactive 2008b) has asked about the prestige of a large number of occupations, including scientists and engineers (table 7-12). In 2008, 56% of Americans said that scientists had "very great prestige," and 40% expressed this view about engineers. Most occupations in the surveys ranked well below engineers.[24]

Between 1977 and 2008, the percentage of survey respondents attributing "very great prestige" to scientists has fluctuated between 51% and 66%. There has not been a clear trend over the years. The comparable score for engineers increased from 30% in 2007 to 40% in 2008, the highest level in thirteen surveys since the question was first asked in 1977.

Scientists ranked higher in prestige than almost all occupations in the Harris surveys. In recent years, their ranking was comparable with that of nurses, doctors, firefighters, and teachers and ahead of military and police officers. Engineers' standing is high and comparable to occupations

Table 7-12

Prestige of various occupations: Selected years, 1977–2008

(Percent)

Occupation	1977	1982	1992	1997	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008
Firefighter	NA	NA	NA	NA	NA	NA	NA	NA	55	48	56	63	61	57
Scientist	66	59	57	51	55	56	53	51	57	52	56	54	54	56
Doctor	61	55	50	52	61	61	61	50	52	52	54	58	52	53
Nurse	NA	NA	NA	NA	NA	NA	NA	NA	47	44	50	55	50	52
Teacher	29	28	41	49	53	53	54	47	49	48	47	52	54	52
Military officer	NA	22	32	29	34	42	40	47	46	47	49	51	52	46
Police officer	NA	NA	34	36	41	38	37	40	42	40	40	43	46	46
Farmer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	36	41	41
Priest/minister/clergy	41	42	38	45	46	45	43	36	38	32	36	40	42	40
Engineer	34	30	37	32	34	32	36	34	28	29	34	34	30	40
Member of Congress	NA	NA	24	23	25	33	24	27	30	31	26	28	26	28
Architect	NA	NA	NA	NA	26	26	28	27	24	20	27	27	23	28
Lawyer	36	30	25	19	23	21	18	15	17	17	18	21	22	24
Athlete	26	20	18	21	20	21	22	21	17	21	23	23	16	20
Journalist	17	16	15	15	15	16	18	19	15	14	14	16	13	18
Union leader	NA	NA	12	14	16	16	17	14	15	16	15	12	13	18
Business executive	18	16	19	16	18	15	12	18	18	19	15	11	14	17
Actor	NA	NA	NA	NA	NA	NA	NA	NA	13	16	16	12	9	16
Entertainer	18	16	17	18	19	21	20	19	17	16	18	18	12	15
Accountant	NA	13	14	18	17	14	15	13	15	10	13	17	11	15
Banker	17	17	17	15	18	15	16	15	14	15	15	17	10	15
Stockbroker	NA	NA	NA	NA	NA	NA	NA	NA	8	10	8	11	12	10
Real estate agent/broker	NA	NA	NA	NA	NA	NA	NA	NA	6	5	9	6	5	6

NA = not available, question not asked

NOTES: Responses to *I am going to read off a number of different occupations. For each, would you tell me if you feel it is an occupation of very great prestige, considerable prestige, some prestige, or hardly any prestige at all?* Data reflect responses of “very great prestige.”

SOURCE: Prestige Paradox: High Pay Doesn’t Necessarily Equal High Prestige: Teachers’ Prestige Increases the Most Over 30 Years, Harris Poll, Harris Interactive (5 August 2008), http://www.harrisinteractive.com/harris_poll/index.asp?PID=939, accessed 22 September 2009.

Science and Engineering Indicators 2010

clustered just below the top group (including clergy, military officers, and police officers).

Prestige appears to reflect perceived service orientation and public benefit more than high income or celebrity; for instance, the proportions of respondents who attributed “very great prestige” to entertainers or actors were 15% and 16%, respectively (table 7-12). Americans are more likely to trust people in prestigious occupations (including scientists) to tell the truth (Harris Interactive 2006).

Some evidence suggests that Americans rate scientific careers more positively than is the case in at least some other countries. In 2004, a little over 50% of South Koreans said they would feel happy if their son or daughter wanted to become a scientist. Among Chinese, science (40%) ranked close to medicine (41%) and teaching (43%) as an occupation that survey respondents hoped their children will pursue (CRISP 2008). In the United States, 80% of those surveyed in 2001 expressed positive views regarding their children becoming scientists.

In 2006, the majority of Israelis said they would be pleased if their children became scientists (77%), engineers (78%), or physicians (78%) (Yaar 2006).

Public Attitudes About Specific S&T-Related Issues

Public attitudes can affect the speed and direction of S&T development. When science plays a substantial role in a national policy controversy, more than the specific policies under debate may be at stake. The policy debate may also shape public opinion and government decisions about investments in general categories of research. Less directly, a highly visible debate involving science may shape overall public impressions of either the credibility of science or the proper role of science in other, less visible public decisions.

Likewise, public attitudes about emerging areas of research and new technologies may have an impact on innovation. The climate of opinion concerning new research areas could influence levels of public and private investment in related technological innovations and, eventually, the adoption of new technologies and the growth of industries based on these technologies.

For these reasons, survey responses about policy controversies involving science, specific research areas, and emerging technologies are relevant. In addition, responses about relatively specific matters provide a window into the practical decisions through which citizens translate more general attitudes into actions, although, like all survey responses, how these responses relate to actual behavior remains uncertain. More generally, even in democratic societies, public opinion about new scientific and technological developments does not translate directly into actions or policy. Instead, it filters through institutions that selectively measure what the public believes and either magnify or minimize the effects of divisions in public opinion on public discourse and government policy (Jasanoff 2005).

Attitudes toward policy issues always involve a multitude of factors and not just knowledge or understanding of relevant science. Values, morals, judgments of prudence, and numerous other factors can come strongly into play. Judgments about scientific fact are often secondary. In assessing the same issue, different people may find different considerations relevant.

This section begins with data on environmental issues, including global climate change and nuclear power. It then covers attitudes toward recent and novel technologies, including medical biotechnology, agricultural biotechnology (i.e., GM food), and nanotechnology. Data on cloning and stem cell research follow, and the section concludes with recent data on attitudes toward science and mathematics education and toward scientific research on animals.

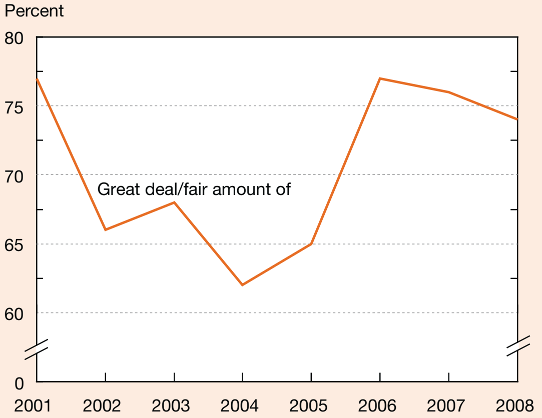
Environment and Climate Change

The Gallup Organization's annual survey on environmental issues indicates that Americans have become somewhat more concerned about environmental quality in the last 4 years (figure 7-16). Between 2004 and 2008, the percentage of Americans expressing "a great deal" or "a fair amount" of worry about the "quality of the environment" rose from 62% to 74%, returning approximately to its 2001 level (Saad 2008b).

Despite the rise in "worry" about the environment, concern about this issue barely registers when surveys ask Americans to name the country's top problem. In surveys conducted in the first quarter of 2009, only about 2% of Americans mentioned the environment or pollution in an open-ended question asking "What do you think is the most important problem facing this country today?" (The Gallup Organization 2009a, 2009b). In close-ended questions, worry about the environment ranked lower than worry about the economy (90%), the availability and affordability of either energy (82%) or healthcare (81%), and crime and violence (80%). The proportion of Americans worried about the quality of the environment was similar to the proportion worried about Social Security (75%), future terrorist attacks (73%), and hunger and homelessness (73%) and higher than the percentage worried about illegal immigration (70%), unemployment (68%), drug use (67%), and race relations (45%).

In the 2008 GSS, the majority of Americans (66%) believed that the government is spending too little to reduce pollution and only a handful thought it spent too much (8%, appendix table 7-23). The proportion who believed that the government is spending too little in this policy area has fluctuated between 60% and 67% since 1997 and is still lower than it was in 1988 and 1990 (76% for both years). The trend in support for environmental protection was less evident when Americans were asked about tradeoffs between environmental protection and economic growth (figure 7-17). In March 2009, only 42% of Americans indicated that the protection of the environment should take precedence over economic growth (down from about 70% in 1990–91 and in 2000).

Figure 7-16
Worry about quality of environment: 2001–08



NOTES: Poll conducted annually in March. Survey asked Americans how much they worry about the quality of the environment and other domestic issues. Figure combines percentage saying they worry "a great deal" and "a fair amount."

SOURCES: Saad L, Economic Anxiety Surges in Past Year, The Gallup Poll (28 March 2008), http://www.gallup.com/poll/105802/Economic-Anxiety-Surges-Past-Year.aspx, accessed 23 September 2009. Saad L, Americans See Environment Getting Worse, The Gallup Poll (20 April 2006) http://www.gallup.com/poll/22471/Americans-See-Environment-Getting-Worse.aspx, accessed 3 June 2009.

Science and Engineering Indicators 2010

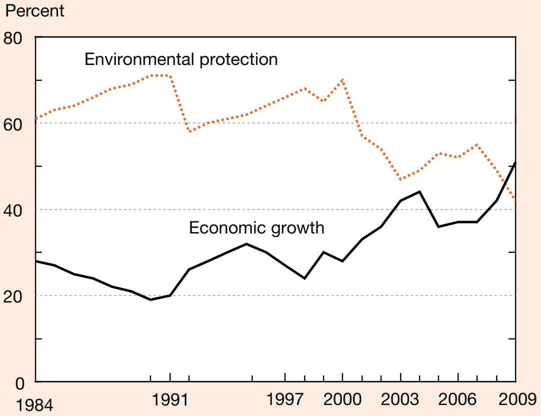
However, when asked about various proposals to protect the environment in Gallup surveys conducted between 2001 and 2007 (table 7-13), strong majorities endorsed government spending to develop alternate sources of fuel for automobiles and to develop solar and wind power. Majorities also favored different environmentally friendly measures such as setting higher emissions and pollution standards for business and industry and enforcing federal environmental regulations more strongly. Lower proportions favored expanding the use of nuclear energy and opening up the Arctic National Wildlife Refuge in Alaska for oil exploration (The Gallup Organization 2009a).

National data on the use of biofuels for energy consumption is scarce, but one survey found that 70% of Americans thought using ethanol was "mostly a good idea" (Broder and Connelly 2007).

Climate change, sometimes referred to as global warming (see sidebar "'Climate Change' Versus 'Global Warming'"), has recently become more prominent among environmental issues for the American public. Since 2000, Gallup has asked Americans how much they personally worry about eight environmental issues. The percentage of Americans who said they worried "a great deal" about "global warming" decreased from 40% in 2000 to 26% in 2004, but increased to 34% in 2008 (Saad 2009). Even with this increase, "global warming" still ranked eighth among these issues. The percentage of Americans worrying "a great deal" about this issue was lower than the percentage of Americans worrying "a great deal" about water-related environmental issues such as "pollution of drinking water" (59%), "pollution of rivers, lakes, and reservoirs" (52%), "contamination of soil and water by toxic waste" (52%), "maintenance of the

Figure 7-17

Public priorities for environmental protection versus economic growth: 1984–2009



NOTES: Responses to *With which one of these statements about the environment and the economy do you most agree—protection of the environment should be given priority, even at the risk of curbing economic growth (or) economic growth should be given priority, even if the environment suffers to some extent?* Poll conducted in 1984, 1990–92, 1995, 1997–2009; other years extrapolated.

SOURCE: Newport F, Americans: Economy Takes Precedence Over Environment (19 March 2009), http://www.gallup.com/poll/116962/Americans-Economy-Takes-Precedence-Over-Environment.aspx?version=print, accessed 23 September 2009.

Science and Engineering Indicators 2010

"Climate Change" Versus "Global Warming"

The terms "climate change" and "global warming" are often used interchangeably. Scientists increasingly prefer the term "climate change," which conveys the idea that more than a rise in temperatures is occurring (National Academies 2008b). However, most survey data registers opinion about global warming, not about climate change.

Limited research in the United States and Europe suggests that variations in terminology do not significantly affect survey responses on this issue. A large sample of voluntary survey respondents in the United States, randomly divided into two groups, was asked "If nothing is done to reduce climate change/global warming in the future, how serious a problem do you think it will be?" The two groups responded similarly, regardless of which term was used (Villar and Krosnick 2009).

Two similar European experiments also showed that the two terms made little or no difference in perceptions of the problem. In one, respondents were asked to identify "the most serious problem currently facing the world as a whole" from a list that included either "global warming" or "climate change." In the other, the choice of term did not affect how Europeans rated the seriousness of the problem "at this moment" (EC 2008b).

Table 7-13

Public approval of specific environmental proposals: 2001–07

(Percent)

Environmental proposal	2001	2002	2003	2006	2007
Spending government money to develop alternate sources of fuel for automobiles	NA	NA	NA	85	86
Setting higher emissions and pollution standards for business and industry	81	83	80	77	84
More strongly enforcing federal environmental regulations	77	78	75	79	82
Spending more government money on developing solar and wind power	79	NA	NA	77	81
Setting higher auto emissions standards for automobiles	75	72	73	73	79
Imposing mandatory controls on carbon dioxide emissions and other greenhouse gases	NA	NA	75	75	79
Expanding use of nuclear energy	44	45	43	55	50
Opening Arctic National Wildlife Refuge in Alaska for oil exploration	40	40	41	49	41

NA = not available, question not asked

NOTES: Responses to: *I am going to read some specific environmental proposals. For each one, please say whether you generally favor or oppose it. How about...?* Data reflect responses of "favor." Table includes all years for which data collected; question asked in March of each year.

SOURCE: Gallup's Pulse of Democracy: The Environment, http://www.gallup.com/poll/1615/Environment.aspx, accessed 22 September 2009.

Science and Engineering Indicators 2010

nation's fresh water supply for household needs" (49%), and also "air pollution" (45%). Response categories in surveys, however, are not always distinct and may evoke overlapping associations in respondents. "Air pollution," for example, is related to carbon emissions and climate change.

Recent data show additional signs that awareness of climate change is increasing. Since 2004, Gallup surveys registered gradual increases in the percentage of Americans who say they understand the "global warming" issue "very well" or "fairly well," from 68% in 2004 to 80% in 2008 (The Gallup Organization 2009a). In addition, the number of Americans who say that the effects of "global warming" have already begun to occur has been steadily increasing since 2004 and was at an all time high in 2008 at 61%. The percentage of Americans who believe that most scientists think "global warming" is occurring has also been rising for over a decade. Most Americans think that "the increases in the Earth's temperature over the last century" are largely the result of human activities rather than natural changes; that percentage has been stable since 2001, hovering between 58% and 61% (The Gallup Organization 2009a).

Nuclear Power

In the debate over America's sources of energy, nuclear power has been a controversial subject. On the one hand, nuclear power is an appealing option to meet energy needs due to its low emissions of greenhouse gases and other atmospheric pollutants. On the other hand, there are serious concerns about this technology, such as risks in the operation of nuclear plants, the disposal of nuclear waste, and nuclear proliferation.

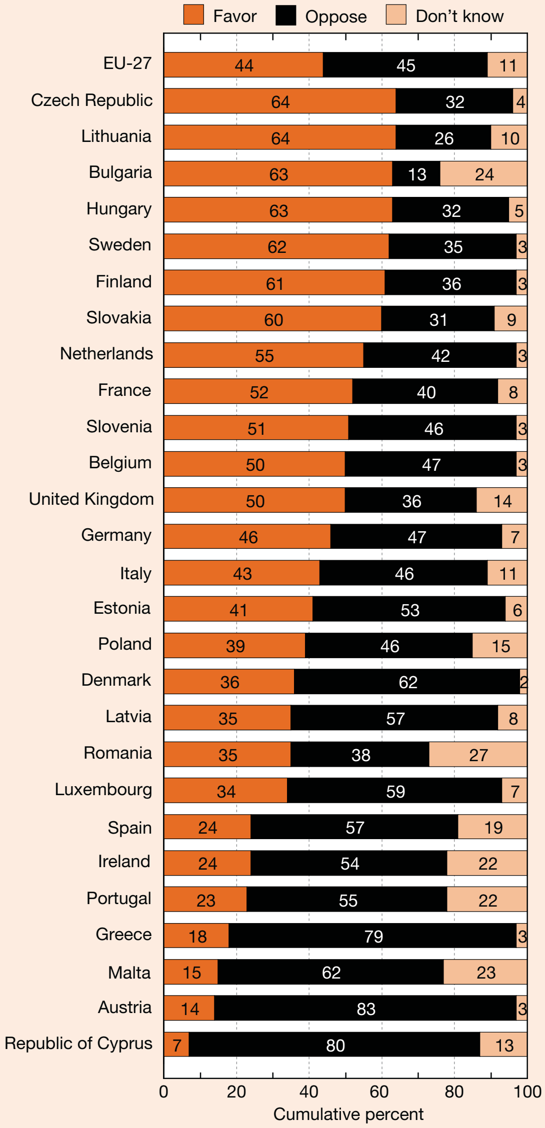
Overall, support for nuclear power is lower than for conservation-based energy strategies (table 7-13), but it has grown in the last 2 years. American public opinion has been fairly evenly divided since the mid-1990s, but the proportion of Americans who favor the use of nuclear power as one of the ways to provide electricity for the U.S. increased from 53% in 2007 to 59% in 2009 (Jones 2009). A substantial minority of Americans (42%) thinks nuclear power plants are not safe and prior surveys indicate that three out of five Americans oppose the construction of a nuclear energy plant in their local communities.[25]

Despite some differences in wording between the Eurobarometer and the U.S. questions, a 2008 report shows that European public opinion on nuclear energy is divided but support for energy production by nuclear power stations has grown since 2005 (EC 2008a). Support for nuclear energy varies a great deal among countries in this region. In general, citizens of countries that have operational nuclear power plants are considerably more likely to support nuclear energy than citizens of other countries (figure 7-18).[26]

Biotechnology and Its Medical Applications

Recent advances in recombinant DNA technology enable the manipulation of genetic material to produce plants and animals with desirable characteristics. The most recent American data on attitudes in this area are from 2005. They show that Americans, Canadians, and Europeans have similarly favorable attitudes toward biotechnology in general and medical applications in particular. A study that collected U.S. and Canadian data found that about two-thirds

Figure 7-18
European attitudes towards energy production by nuclear power: 2008



NOTES: Responses to *Are you in favor, fairly in favor, fairly opposed, or totally opposed to energy production by nuclear power stations?*

SOURCE: European Commission, Research Directorate-General for Energy and Transport, Special Eurobarometer 297/Wave 69.1, Attitudes Towards Radioactive Waste, Table QB2 (2008). Fieldwork completed 18 February–22 March 2008, http://ec.europa.eu/public_opinion/archives/ebs/ebs_297_en.pdf, accessed 3 June 2009.

Science and Engineering Indicators 2010

of survey respondents in each country registered favorable attitudes (Canadian Biotechnology Secretariat 2005).[27]

Few Americans (about 1 in 10) consider themselves "very familiar" with biotechnology and Canadians report slightly less familiarity. Without a strong knowledge base to use in evaluating information, their assessment of the credibility of information sources is an important element in forming their judgments about information on this topic. In both the United States and Canada, scientific journals and government-funded scientists were the top-rated institutions that could provide information about biotechnology. Conversely, privately owned mass media, biotechnology company executives, and religious and political leaders ranked near the bottom in both countries. (For more detail on this subject, see NSB 2008.)

Genetically Modified Food

Although the introduction of GM crops has provoked much less controversy in the United States than in Europe, U.S. popular support for this application of biotechnology is limited. According to a 2008 CBS/*New York Times* poll, 44% of Americans indicated they had not heard much about GM ingredients added to foods to make them taste better and last longer. However, 87% believed that these foods should be labeled and 53% expected that it was "not very likely" or "not at all likely" that they would buy food that was labeled as such.

Overall, these results are consistent with a series of five surveys conducted by the Pew Initiative on Food and Biotechnology between 2001 and 2006. These studies consistently found that only about one-fourth of U.S. consumers favored "the introduction of genetically modified foods into the U.S. food supply" (Mellman Group, Inc. 2006). The proportion of U.S. survey respondents reporting a negative reaction to the phrase "genetically modified food" (44%) was more than twice the 20% that reported a positive reaction (Canadian Biotechnology Secretariat 2005). Nonetheless, consumers in the United States expressed more favorable views than Europeans, with Canadians falling somewhere in between (Gaskell et al. 2006).

Although the FDA proposed guidelines for the approval process for genetically engineered animals in September 2008 (Maugh and Kaplan 2008), past surveys have generally found that in the U.S. residents are even more wary of genetic modification of animals than they are of genetic modification of plants (Mellman Group, Inc. 2005). Many express support for regulatory responses, but this support appears to be quite sensitive to the way issues are framed. Thus, whereas 29% expressed a great deal of confidence in "the Food and Drug Administration or FDA," only about half as many expressed the same confidence when the question was posed about "government regulators" (Mellman Group, Inc. 2006). (Additional findings from earlier U.S. surveys can be found in NSB 2006 and NSB 2008.)

Nanotechnology

Nanotechnology involves manipulating matter at unprecedentedly small scales to create new or improved products that can be used in a wide variety of ways. Nanotechnology has been the focus of relatively large public and private investments for almost a decade, and innovations based on nanotechnology are increasingly common. However, relative to other new technologies, nanotechnology is still in an early stage of development and the degree of risk remains uncertain (Chatterjee 2008, Barlow et al. 2009).

Data from the 2008 GSS indicated that overall familiarity with nanotechnology is similar to its 2006 level. The proportion of Americans who had heard "a lot" or "some" about nanotechnology remained virtually unchanged (5% and 15% in both 2006 and 2008), but the proportion of those who had heard "a little" or "nothing at all" declined slightly (appendix table 7-26). These numbers are similar to those reported by the Project on Emerging Nanotechnologies based on a national survey conducted in August 2008 (Peter D. Hart Research Associates 2008). While the questions asked are not strictly comparable, familiarity with nanotechnology in the 2006 GSS was similar to that in Europe in 2005, in which 44% of survey respondents said they had heard of it (Gaskell et al. 2006).

Despite increased federal funding and more than 600 nanotechnology products already on the market (The National Academies 2008a),[28] nanotechnology knowledge levels were not high (appendix table 7-11) and remained similar to 2006, even among the minority of GSS respondents who had heard of nanotechnology. In 2008, 63% of the respondents who had heard at least a little about this technology correctly indicated that the statement "nanotechnology involves manipulating extremely small units of matter, such as individual atoms, in order to produce better materials" was true, but many (29%) said they did not know, and a few (8%) thought this statement was false. Almost half (47%) did not know whether the statement "the properties of nanoscale materials often differ fundamentally and unexpectedly from the properties of the same materials at larger scales" was true, while 41% correctly answered true and the remaining 12% answered false. A third of the respondents answered both questions correctly.

When nanotechnology is defined in surveys, Americans express favorable expectations for it. After receiving a brief explanation of nanotechnology, GSS respondents were asked about the likely balance between the benefits and harms of nanotechnology. Similar to 2006, in 2008 38% said the "benefits will outweigh the harmful results" and only 9% expected the harms to predominate (appendix table 7-27). In 2008, however, the proportion of Americans who said they did not know whether the benefits of nanotechnology would outweigh the harmful results or vice versa increased, and the proportion who expected the benefits to be equal to the harmful results decreased. The fact that about half of respondents either gave a neutral response (12%) or said they did not know (40%) suggests that these opinions are open to change as Americans become more familiar with this technology.

Favorable expectations for nanotechnology are associated with more education, greater science knowledge, and greater familiarity with nanotechnology. Men are also more likely to have favorable expectations than women (appendix table 7-27). In these aspects, patterns are similar to those for responses concerning S&T in general.

In the GSS data, favorable attitudes toward nanotechnology are also associated with greater familiarity with it. That is, Americans who say they are more familiar with nanotechnology are more likely to believe that its benefits will outweigh the risks. However, this association does not mean that when people become more familiar their attitudes necessarily become positive. Some data suggest that when individuals who report knowing little or nothing about nanotechnology hear a balanced statement of its risks and benefits, they develop less favorable opinions of it (Peter D. Hart Research Associates, Inc. 2008). Furthermore, recent research suggests that attitudes toward nanotechnology are likely to vary depending on the context in which it is applied, with energy applications viewed much more positively than those in health and human enhancements (Pidgeon et al. 2009).

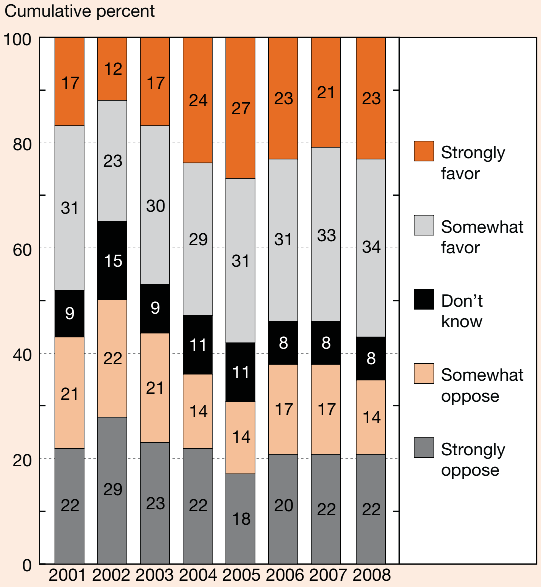
Stem Cell Research and Human Cloning

Unlike most issues involving scientific research, studies using embryonic stem cells have generated considerable public controversy. In the case of stem cell research, strongly held views about moral fundamentals determine many people's attitudes. There is less reason to believe that this is the case for certain other S&T issues, such as nuclear power.

Although a majority of the public supports such research, a substantial minority is opposed to it. When surveys ask about medical technologies that could be derived from embryonic stem cell research in the context of expected health benefits, public response is relatively positive. But technologies that involve cloning human embryos evoke consistently strong and negative responses.

Since 2004, the majority of the American public has favored "medical research that uses stem cells from human embryos" (VCU Center for Public Policy 2008). Support grew continuously from 2002 (35% in favor) to 2005 (58% in favor) and remained at a similar level in 2008 (figure 7-19). In eight annual Gallup surveys between 2002 and 2009, the percentage of Americans who found such research "morally acceptable" ranged from 52% to 64%, and the percentage saying it was "morally wrong" from 30% to 39% (Saad 2008a; The Gallup Organization 2009c). Similarly, in five Pew surveys conducted between August 2004 and August 2007, a consistent but slim majority agreed that it was "more important to continue stem cell research that might produce new medical cures than to avoid destroying the human embryos used in the research" while about a third said not destroying embryos was more important (Pew Forum on Religion and Public Life 2008).

Figure 7-19
Public attitudes toward stem cell research: 2001–08



NOTES: Responses to *On the whole, how much do you favor or oppose medical research that uses stem cells from human embryos?* Most recent question asked 24 November–7 December 2008.

SOURCE: Virginia Commonwealth University (VCU), VCU Center for Public Policy, VCU Life Sciences Survey (2008), http://www.vcu.edu/lifesci/centers/cen_lse_surveys.html, accessed 23 September 2009.

Science and Engineering Indicators 2010

Support for stem cell research is higher when the question inquires about research that uses stem cells from sources that do not involve human embryos. Seven out of ten respondents favored this type of research in 2008, down slightly from 75% in 2007 (VCU Center for Public Policy 2008). Support also increased when the question was framed as an emotionally compelling personal issue ("If you or a member of your family had a condition such as Parkinson's Disease, or a spinal cord injury, would you support the use of embryonic stem cells in order to pursue a treatment for that condition?"). In this case, 70% of Americans support treatments that use stem cells and only 21% do not (VCU Center for Public Policy 2006). Responses become more mixed when questions mention "cloning technology" that is used only to help medical research develop new treatments for disease. However, opinion is decidedly negative when the question asks about cloning or genetically altering animals without mention of a medical purpose (table 7-14).

Americans are overwhelmingly opposed to human cloning. In a 2008 VCU survey, the idea of cloning or genetically altering humans was rejected by 78% of Americans (VCU Center for Public Policy 2008). The specter of reproductive cloning can generate apprehension about therapeutic cloning. Asked how concerned they were that "the use of human cloning technology to create stem cells for human therapeutic purposes will lead to a greater chance of human reproductive cloning," over two-thirds of Americans said they were either very (31%) or somewhat (37%) concerned (VCU Center for Public Policy 2006).

In 2008, about two-thirds of Americans were "very clear" (23%) or "somewhat clear" (41%) about the difference between stem cells that come from human embryos, stem cells that come from adults, and stem cells that come from other sources (VCU Center for Public Policy 2008). However, public attitudes toward cloning technology are not grounded in a strong grasp of the difference between reproductive and therapeutic cloning (see glossary for the definitions). Most Americans (64%) said they were not clear ("not very clear" or "not clear at all") about this distinction, with 26% saying they were "somewhat clear" and only 8% characterizing themselves as "very clear" about it. The number of Americans who professed greater comprehension in 2008 was lower than it was when VCU began asking this question in 2002, despite, or perhaps because of, the increased visibility of stem cell research as a public issue.

Support for stem cell research is strongest among people with more years of formal education. Americans who are more religious and more politically conservative are more likely to oppose such research (VCU Center for Public Policy 2008).

A recent international survey on attitudes toward stem cell research in a dozen European countries, the United States, Japan, and Israel found that awareness, knowledge, and attitudes about this type of research vary widely (Fundacion BBVA 2008). Overall, Americans are more aware of stem cell research than residents of most other countries and more often respond correctly to knowledge questions on this subject. Americans are somewhat more likely than residents of several countries in Europe to believe that stem cell research is immoral (appendix table 7-28).

Science and Mathematics Education

In much public discourse about how Americans will fare in an increasingly S&T-driven world, quality education in science and mathematics is seen as crucial for both individuals and the nation as a whole.

In the 2008 GSS, majorities of Americans in all demographic groups agreed that the quality of science and mathematics education in American schools is inadequate. Their level of agreement increases with education, science knowledge, income, and age (appendix table 7-29). Dissatisfaction with the quality of math and science education increased from 63% in 1985 to 70% in 2008, but is still below its peak in 1992 (75%) (figure 7-20; appendix table 7-30).

In addition, the proportion of Americans who indicated they believe the government is spending too little money in improving education in the biannual GSS surveys has been consistently over 70% since the early 1980s. Along with improving health care, this is one of the two top areas where the public feels government spending is too low (figure 7-20, appendix table 7-23).

Scientific Research on Animals

The medical research community conducts experimental tests on animals in order to advance scientific understanding of biological processes and test the effectiveness of drugs and procedures that may eventually be used to improve human health.

Most Americans support at least some kinds of animal research. Nearly two-thirds said they favored "using animals in medical research" (VCU Center for Public Policy

Table 7-14

Public opinion on medical technologies derived from stem cell research: Most recent year

(Percent)

Question	Favor	Oppose
1. *If you or a member of your family had a condition such as Parkinson's Disease, or a spinal cord injury, would you support the use of embryonic stem cells in order to pursue a treatment for that condition?* (Yes or no)..................	70	21
2. *Do you favor or oppose medical research that uses stem cells from sources that do NOT involve human embryos?* (Strongly favor, somewhat favor, somewhat oppose, strongly oppose)..	70	22
3. *Do you favor or oppose using human cloning technology IF it is used ONLY to help medical research develop new treatments for disease?* (Strongly favor, somewhat favor, somewhat oppose, or strongly oppose)	52	45
4. *The technology now exists to clone or genetically alter animals. How much do you favor or oppose allowing the same thing to be done in humans?* (Strongly favor, somewhat favor, somewhat oppose, or strongly oppose)........	17	78

NOTES: Question 1 asked 7–21 November 2006. Questions 2, 3, 4 asked 24 November–7 December 2008. Detail does not add to total because "don't know" responses not shown.

SOURCE: Virginia Commonwealth University (VCU), Center for Public Policy, VCU Life Sciences Survey (question 1, 2006; questions 2, 3, 4, 2008), http://www.vcu.edu/lifesci/centers/cen_lse_surveys.html, accessed 22 September 2009.

Science and Engineering Indicators 2010

2007). According to a different survey conducted by Gallup, the majority of respondents supported this kind of research: 64% opposed “banning all medical research on laboratory animals” and 59% opposed “banning all product testing on laboratory animals” (Newport 2008).

However, opposition has grown in the past two decades. When asked whether scientists should be allowed to do “research that causes pain and injury to animals like dogs and chimpanzees” if it produces new information about human health problems, between 42% and 45% of Americans in the early 1990s disagreed. This proportion increased to 51% in 2001 and 58% in 2008 (figure 7-21, appendix tables 7-31 and 7-32).[29] Annual surveys conducted by Gallup since 2001 show a similar pattern. While a majority of Americans say that “medical testing on animals is morally acceptable,” this percentage decreased from 65% in 2001 to 56% in 2008 (Saad 2008a). Men are more likely than women to approve this kind of research (appendix table 7-31).

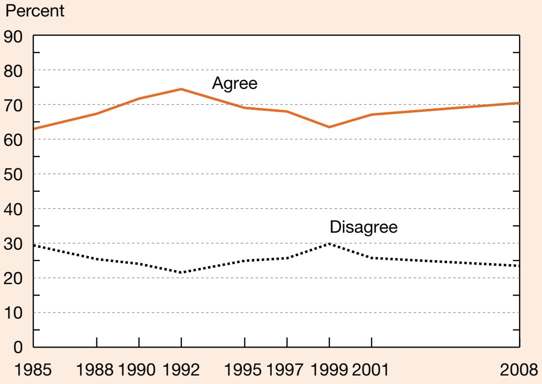
Past NSF surveys suggest that the public is more comfortable with the use of mice in scientific experiments than the use of dogs and chimpanzees (NSB 2002). In 2001 68% of Americans agreed that scientists should be allowed to do research that causes pain and injury to animals like mice if it produces new information about human health problems, compared to 44% who expressed agreement when the question focused on dogs and chimpanzees (NSB 2002).

While recent comparable international data are lacking, a survey conducted by Gallup in 2003 showed that Americans and Canadians were more likely to tolerate scientific research on animals than the British. When asked: “Regardless of whether or not you think it should be legal, please tell me whether you personally believe that in general medical testing on animals is morally acceptable or morally wrong,” the majority of adults in the U.S. and Canada believed it was morally acceptable (63% and 59%, respectively). In contrast, the majority of British respondents thought it was morally wrong (54%) (Mason Kiefer 2003).

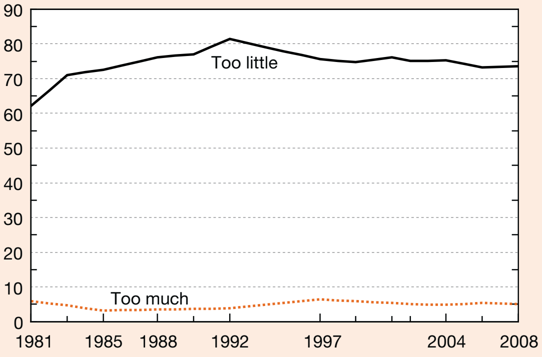
Figure 7-20

Public attitudes toward education in America: Selected years, 1981–2008

Perception that the quality of science and mathematics education in American schools is inadequate: 1985–2008



Assessment of government spending for education: 1981–2008



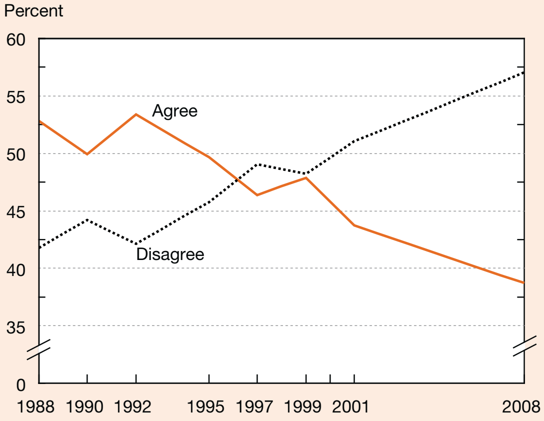
NOTES: Top panel: survey results in 1985, 1988, 1990, 1992, 1995, 1997, 1999, 2001, and 2008; other years extrapolated. Bottom panel: survey results in 1981, 1983, 1985, 1988, 1990, 1992, 1997, 1999, 2001, 2002, 2004, 2006, and 2008; other years extrapolated.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (years through 2001); and University of Chicago, National Opinion Research Center, General Social Survey (2008 in top panel, 2002–08 in bottom panel). See appendix table 7-30 for top panel and appendix table 7-23 for bottom panel.

Science and Engineering Indicators 2010

Figure 7-21

Public attitudes toward conducting human health research that may inflict pain or injury to animals: Selected years, 1988–2008



NOTES: Responses to *Scientists should be allowed to do research that causes pain and injury to animals like dogs and chimpanzees if it produces new information about human health problems.* Table includes all years for which data collected. Survey results from 1988, 1990, 1992, 1995, 1997, 1999, 2001, 2008; other years extrapolated.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1988–2001); and University of Chicago, National Opinion Research Center, General Social Survey (2008).

Science and Engineering Indicators 2010

Conclusion

In assessing public knowledge and attitudes concerning S&T, two kinds of standards for judgment are possible. One standard involves comparing a country's knowledge and attitudes with those recorded in the past or in other countries. The second standard involves assessing what a technologically advanced society requires (either today or in the future) to compete in the world economy and enable its citizens to better take advantage of scientific progress in their own lives.

By the first standard, the survey data provide little or no evidence of declining knowledge or increasingly negative attitudes. Relative to Americans in the recent past, today's Americans score as well on knowledge measures and tend to be more skeptical about scientific claims for pseudoscience, such as astrology. In addition, three decades of U.S. data consistently show that Americans endorse the past achievements and future promise of S&T, are optimistic about new technologies, and are favorably predisposed to increasing government investment in science. When Americans compare science with other institutions, science's relative ranking is as or more favorable than in the past. In addition, the prestige of the engineering profession grew in the last year.

When the data are examined using other countries as a benchmark, the United States compares favorably. Compared with adult residents of other developed countries, Americans appear to know as much or more about science, and they express as much or more optimism about technology.

By the second standard, trend data show that significant minorities of Americans cannot answer relatively simple knowledge questions about S&T, they express basic misconceptions about emerging technologies such as biotechnology and nanotechnology, and they believe that relatively great scientific uncertainty surrounds the existence and causes of global climate change. Sizable parts of the population express reservations about how the speed of technological change affects our way of life or the use of animals in medical research.

Regardless of the standard used in assessing public knowledge and attitudes, one pattern in the data stands out: more highly educated Americans tend to know more about S&T, express more favorable attitudes about S&T, and make discriminations that are more consistent with those likely to be made by scientists and engineers themselves. Thus, for example, they focus more heavily on process criteria when evaluating whether something is scientific, and their classification of fields as more and less scientific more closely resembles a classification that would be found in a university catalog. Whether this association is causal is uncertain. Although greater knowledge may affect attitudes and perspectives, pre-existing attitudes and perspectives may affect whether or not people acquire the kinds of knowledge available to them in school.

Notes

1. Data from Pew show that the proportion of Americans who read the newspaper declined from 40% to 34% between 2006 and 2008 and that newspapers would have lost more readers if they did not have online versions. Most of the loss in newspaper readership since 2006 has come from those who read the print version of the newspaper—in 2008, 27% said they had read only the print version of a daily newspaper the day before compared to 34% in 2006 (Pew Research Center for the People and the Press 2008).

2. In 2001 this question was part of a single-purpose telephone survey focused on science and technology. In 2008 these data were collected as part of a face-to face multipurpose survey covering a broad range of behavior and attitudes. It is unclear whether these differences in data collection or a change in public opinion account for the decline in interest observed between 2001 and 2008. In interviews conducted over the phone, respondents may be more likely to respond to questions in a socially desirable way (Holbrook, Green, and Krosnick 2003). In addition, a single purpose survey may suggest to respondents that science and technology are important.

3. In interpreting survey data that use the phrase "science and technology," it is important to take into account the uncertainties surrounding its meaning and the different associations Americans make when they hear it.

4. The peak in the coverage of the category "Science, space, and technology" in 1999 illustrated in figure 7-6 includes major network coverage of stories about the so-called millennium bug and business issues from the dot.com boom such as the rise of Internet commerce and the browser antitrust wars.

5. The question on interest in new scientific discoveries included in the 2005 Eurobarometer (EC 2005) was the same three-category question asked in the United States between 1979 and 2001 and in 2008 ("very interested," "moderately interested," and "not at all interested"). The question asked in the 2007 Eurobarometer (EC 2007) was different because it asked about interest in "scientific research" rather than "new scientific discoveries" and gave respondents four options ("very interested," "fairly interested," "not very interested," and "not at all interested"). Thus, the data in this sidebar are not strictly comparable to earlier Eurobarometer surveys or to the U.S. data question on interest.

6. In Brazil the survey asked respondents about their interest in "medicine and health" issues and "environmental issues" and the question categories included "very interested," "a little interested," and "not at all interested."

7. In the past, interest in space exploration has consistently ranked low both in the United States and around the world, relative to other S&T topics. Surveys in Russia, China, and Japan have documented this general pattern. However, though there are new U.S. data on this subject, there have been no recent surveys documenting interest in space exploration in other countries.

8. People can become involved with S&T through many other nonclassroom activities. Examples of such activities

include participating in government policy processes, going to movies that feature S&T, bird-watching, and building computers. Nationally representative data on this sort of involvement with S&T are unavailable.

9. In the 2008 GSS, respondents received two similar introductions to this question. Response patterns did not vary depending on which introduction was given.

10. Survey items that test factual knowledge sometimes use easily comprehensible language at the cost of scientific precision. This may prompt some highly knowledgeable respondents to feel that the items blur or neglect important distinctions, and in a few cases may lead respondents to answer questions incorrectly. In addition, the items do not reflect the ways that established scientific knowledge evolves as scientists accumulate new evidence. Although the text of the factual knowledge questions may suggest a fixed body of knowledge, it is more accurate to see scientists as making continual, often subtle, modifications in how they understand existing data in light of new evidence.

11. Formal schooling and verbal skills are positively associated. In the 2008 GSS data, verbal skills contributed to factual knowledge even when controlling for education.

12. Among respondents with comparable formal education, attending informal science institutions was associated with greater knowledge.

13. The two nanotechnology questions were asked only of respondents who said they had some familiarity with nanotechnology, and a sizable majority of the respondents who ventured a response different from "don't know" answered the questions correctly. To measure nanotechnology knowledge more reliably, researchers would prefer a scale with more than two questions.

14. The questions were selected from the Trends in Mathematics and Science Studies (TIMSS), National Assessment of Educational Progress (NAEP), practice General Educational Development (GED) exams, and AAAS Project 2061.

15. The scoring of the open-ended questions closely followed the scoring of the corresponding test administered to middle-school students.

For the NAEP question "Lightning and thunder happen at the same time, but you see the lightning before you hear the thunder. Explain why this is so," the question was scored as follows:

- Complete: The response provided a correct explanation including the relative speeds at which light and sound travel. For example, "Sound travels much slower than light so you see the light sooner at a distance."
- Partial: The response addressed speed and used terminology such as thunder for sound and lightning for light, or made a general statement about speed but did not indicate which is faster. For example, "One goes at the speed of light and the other at the speed of sound."
- Unsatisfactory/Incorrect: Any response that did not relate or mention the faster speed of light or its equivalent, the slower speed of sound. For example: "Because the storm was further out." or "Because of static electricity."

For the TIMSS question "A solution of hydrochloric acid (HCl) in water will turn blue litmus paper red. A solution of the base sodium hydroxide (NaOH) in water will turn red litmus paper blue. If the acid and base solutions are mixed in the right proportion, the resulting solution will cause neither red nor blue litmus paper to change color. Explain why the litmus paper does not change color in the mixed solution," the question was scored as follows:

- Correct: The response had to refer to a neutralization or a chemical reaction that results in products that do not react with litmus paper. Three kinds of answers were classified as correct:
  - The response referred explicitly to the formation of water (and salt) from the neutralization reaction (e.g., "Hydrochloric acid and sodium hydroxide will mix together to form water and salt, which is neutral.")
  - The response referred to neutralization (or the equivalent) even if the specific reaction is not mentioned (e.g., "The mixed solution is neutral, so litmus paper does not react.")
  - The response referred to a chemical reaction taking place (implicitly or explicitly) to form products that do not react with litmus paper (or a similar substance), even if neutralization was not explicitly mentioned (e.g., "The acid and base react, and the new chemicals do not react with litmus paper.")
- Partially correct: The response mentioned only that acids and bases are "balanced," "opposites," "cancel each other out," or only that it changes to a salt without mentioning the neutralization reaction. These answers suggest that the respondent remembered the concept but the terminology they used was less precise, or that the answer was partial. For example, "they balance each other out."
- Incorrect: The response did not mention any of the above or is too partial or incomplete, and/or uses terminology that is too imprecise. For example, "Because they are base solutions—the two bases mixed together there is no reaction." or "There is no change. Both colors change to the other."

16. In its own international comparison of scientific literacy, Japan ranked itself 10th among the 14 countries it evaluated (National Institute of Science and Technology Policy 2002).

17. Early NSF surveys used additional questions to measure understanding of probability. Through a process similar to that described in note 12, Bann and Schwerin (2004) identified a smaller number of questions that could be administered to develop a comparable indicator. These questions were administered in 2004 and 2006, and appendix tables 7-13 and 7-14 record combined probability responses using these questions; appendix table 7-13 also shows responses to individual probability questions in each year.

18. Figure 7-12 includes four questions on experimental design included in appendix tables 7-13 and 7-15. Two of these four questions include a question on experimental design and a follow-up question asking "why"; correct responses to these two questions represent the combined responses and are incorporated into the figure as one question.

19. The pseudoscience section focuses on astrology because of the availability of long-term national trend indicators on this subject. Other examples of pseudoscience include the belief in lucky numbers, the existence of unidentified flying objects (UFOs), extrasensory perception (ESP), or magnetic therapy.

20. Methodological issues make fine-grained comparisons of data from different survey years suspect. For instance, although the question content and interviewer instructions were identical in 2004 and 2006, the percentage of respondents who volunteered "about equal" (an answer not among the choices given)" was substantially different. This difference may have been produced by the change from telephone interviews in 2004 to in-person interviews in 2006 (though telephone interviews in 2001 produced results that are similar to those in 2006). More likely, customary interviewing practices in the three different organizations that administered the surveys affected their interviewers' willingness to accept responses other than those that were specifically offered on the interview form, including "don't know" responses.

21. There are large differences among European countries. The lowest support for this statement is found in Iceland, with 38% expressing agreement. Other countries where less than half of residents agree include Ireland (42%), Finland (44%), Denmark (44%), the United Kingdom (45%), and the Netherlands (47%).

22. This type of survey question asks respondents about their assessment of government spending in several areas without mentioning the possible negative consequences of spending (e.g., higher taxes, less money available for higher priority expenditures). A question that focused respondents' attention on such consequences might yield response patterns less sympathetic to greater government funding.

23. Unlike the U.S. question, the European question joins two logically independent ideas—more spending on science and less spending on other priorities. In addition, because nations begin from different levels of spending, survey responses cannot be read as indicating different views about the proper level of spending in this area, nor do they indicate the strength of sentiment in different countries. Differences in the connotations of questions posed in different languages add further complexities. Perhaps for some or all of these reasons, variations among European countries in responses to this question are large, with about two-thirds of respondents agreeing in Italy, Spain, and France, but less than one-third in Finland and the Netherlands.

24. There are many different types of specializations within occupations and prestige may well vary within the same occupation or industry.

25. The two questions from the 2009 Gallup survey were each asked to half the sample (N=500).

26. Countries with nuclear plants include Belgium, Bulgaria, the Czech Republic, Finland, France, Germany, Hungary, Lithuania, the Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Two exceptions to this pattern are Romania and Spain, both of which have operational nuclear power plants but where the level of support for nuclear energy is below the EU-27 average. An earlier Eurobarometer study showed that the Spaniards and the Romanians were less aware of the fact that their countries have nuclear power plants than respondents in other countries with nuclear plants in operation. This low level of awareness regarding the operation of a nuclear plant in their country may lead to a less positive attitude about nuclear energy.

27. A 2006 Canadian survey showed little or no change from 2005 (Decima Research 2006).

28. According to a recent report from The National Academies, more than 600 products involving nanotechnology are already on the market; most of them are health and fitness products such as skin care products and cosmetics (The National Academies, 2008a).

29. The increase in the proportion of respondents who disagree with this statement may be related to methodological issues, because of the changes in data collection discussed above.

Glossary

Biotechnology: The use of living things to make products.

Climate change: Any distinct change in measures of climate lasting for a long period of time. Climate change means major changes in temperature, rainfall, snow, or wind patterns lasting for decades or longer. Climate change may result from natural factors or human activities.

EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

EU-25: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

EU-27: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

Genetically modified food: A food product containing some quantity of any genetically modified organism as an ingredient.

Global warming: An average increase in temperatures near the Earth's surface and in the lowest layer of the atmosphere. Increases in temperatures in the Earth's atmosphere can contribute to changes in global climate patterns. Global warming can be considered part of climate change along with changes in precipitation, sea level, etc.

Nanotechnology: Manipulating matter at unprecedentedly small scales to create new or improved products that can be used in a wide variety of ways.

Reproductive cloning: Technology used to generate genetically identical individuals with the same nuclear DNA as another individual.

Therapeutic cloning: Use of cloning technology in medical research to develop new treatments for diseases; differentiated from human reproductive cloning.

References

Allum N, Sturgis P, Tabourazi D, Brunton-Smith I. 2008. Science knowledge and attitudes across cultures: A meta-analysis. *Public Understanding of Science* 17(January):35–54.

American Council on Education 2006. GED Tests of General Educational Development. Science Official GED Practice Test. Washington: DC: GED Testing Service.

Bann CM, Schwerin MJ. 2004. Public knowledge and attitudes scale construction: Development of short forms. Research Triangle Park, NC: National Science Foundation, Division of Science Resources Statistics.

Barlow S, Chesson A, Collins JD, Flynn A, Hardy A, Jany KD, Knaap A, Kuiper H, Larsen JC, Le Neindre P, Schans J, Schlatter J, Silano V, Skerfving S, Vannier P. 2009. The potential risks arising from nanoscience and nanotechnologies on food and feed safety. Parma, Italy: European Food Safety Authority. http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1211902361968.htm. Accessed 22 June 2009.

Broder JM, Connelly M. 2007. Public remains split on response to warming. *New York Times.* http://www.nytimes.com/2007/04/27/washington/27poll.html?pagewanted=1&_r=1. Accessed 9 October 2009.

Canadian Biotechnology Secretariat. 2005. Canada–U.S. Survey on Biotechnology. Ottawa, Ontario.

Chatterjee R. 2008. The continuing uncertainty of nano risks and regulations. *Environmental Science & Technology* 42(21):7733. http://pubs.acs.org/doi/pdfplus/10.1021/es802396x. Accessed 22 June 2009.

China Research Institute for Science Popularization (CRISP). 2008. Chinese public understanding of science and attitudes towards science and technology. Beijing, China.

Chinese Ministry of Science and Technology. 2002. Public scientific literacy and attitudes towards S&T. *China Science and Technology Indicators 2002.* Beijing, China.

Cole J. 2007. Surveying the digital future: Year 6. Los Angeles, CA: University of Southern California Annenberg School, Center for the Digital Future. http://www.digitalcenter.org/pages/site_content.asp?intGlobalId=20. Accessed 25 June 2009.

Crettaz von Roten F. 2006. Do we need a public understanding of statistics? *Public Understanding of Science* 15:243–249.

Decima Research. 2006. Emerging technologies tracking research. Industry Canada. http://www.bioportal.gc.ca/ENGLISH/View.asp?pmiid=524&x=837. Accessed 26 June 2009.

European Commission (EC). 2005. Europeans, science and technology. Eurobarometer 224/Wave 63.1. http://ec.europa.eu/public_opinion/archives/ebs/ebs_224_report_en.pdf. Accessed 22 June 2009.

European Commission (EC). 2007. Scientific research in the media. Eurobarometer 282/Wave 67.2. http://ec.europa.eu/public_opinion/archives/ebs/ebs_282_en.pdf. Accessed 22 June 2009.

European Commission (EC). 2008a. Attitudes towards radioactive waste. Special Eurobarometer 297/Wave 69.1. http://ec.europa.eu/public_opinion/archives/ebs/ebs_297_en.pdf. Accessed 22 June 2009.

European Commission (EC). 2008b. Europeans' attitudes towards climate change. Special Eurobarometer 300/Wave 69.2. http://ec.europa.eu/public_opinion/archives/ebs/ebs_300_full_en.pdf. Accessed 6 August 2009.

Falk JH, Storksdieck M, Dierking LD. 2007. Investigating public science interest and understanding: Evidence for the importance of free-choice learning. *Public Understanding of Science* 16(October):455–469.

Friedman, A, editor. 2008. *Framework for evaluating impacts of informal science education projects.* Washington, DC: National Science Foundation.

Fundacion BBVA. 2008. BBVA Foundation international study on attitudes towards stem cell research and hybrid embryos. http://www.fbbva.es/TLFU/dat/international_study_biotechnology_08.pdf. Accessed 23 June 2009.

The Gallup Organization. 2009a. Environment. http://www.gallup.com/poll/1615/Environment.aspx. Accessed 9 October 2009.

The Gallup Organization. 2009b. Most important problem. http://www.gallup.com/poll/1675/Most-Important-Problem.aspx. Accessed 9 October 2009.

The Gallup Organization. 2009c. Stem Cell Research. http://www.gallup.com/poll/21676/Stem-Cell-Research.aspx. Accessed 20 October 2009.

Gaskell G, Stares S, Allansdottir A, Allum A, Corchero C, Fischler C, Hampel J, Jackson J, Kronberger N, Mejlgaard N, Revuelta G, Schreiner C, Torgerson H, Wagner W. 2006. Eurobarometer 224/Wave 64.3. Europeans and biotechnology in 2005: Patterns and trends. Brussels: European Commission. http://ec.europa.eu/research/biosociety/pdf/eb_64_3_final_report_second_edition_july_06.pdf. Accessed 17 June 2009.

Gokhberg L, Shuvalova O. 2004. *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education as Drivers of Economic Growth and Quality of Life.* Moscow, Russia: The British Council-Russia.

Harris Interactive. 2006. Doctors and teachers most trusted among 22 occupations and professions: Fewer adults trust the President to tell the truth. http://www.harrisinteractive.com/harris_poll/index.asp?PID=688. Accessed 19 June 2009.

Harris Interactive. 2008a. Four out of five adults now use the Internet. http://www.harrisinteractive.com/harris_poll/index.asp?PID=973. Accessed 23 June 2009.

Harris Interactive. 2008b. Prestige paradox: High pay doesn't necessarily equal high prestige: Teachers' prestige increases the most over 30 years. The Harris Poll. http://www.harrisinteractive.com/harris_poll/index.asp?PID=939. Accessed 23 June 2009.

Holbrook AL, Green MD, Krosnick JA. 2003. Mode effects on satisficing and social desirability. *Public Opinion Quarterly* 67(1):79–125.

Horrigan J. 2006. The Internet as a resource for news and information about science. http://www.pewinternet.org/Reports/2006/The-Internet-as-a-Resource-for-News-and-Information-about-Science.aspx. Accessed 17 June 2009.

Internet World Statistics. 2009. http://www.internetworldstats.com/stats.htm. Accessed 20 October 2009.

Jasanoff S. 2005. *Designs on Nature: Science and Democracy in Europe and the United States.* Princeton: Princeton University Press.

Jones JM. 2009, March 20. Support for nuclear energy inches up to a new high: Majority believes nuclear plants are safe. The Gallup Organization. http://www.gallup.com/poll/117025/Support-Nuclear-Energy-Inches-New-High.aspx. Accessed 20 October 2009.

Korea Foundation for the Advancement of Science and Creativity (KOFAC). 2009. Survey of public attitudes toward an understanding of science and technology 2008. Seoul, Korea.

Korea Science Foundation. 2004. Survey on public attitudes of science and technology 2004. Seoul, Korea.

Krosnick JA. 2000. The threat of satisficing in surveys: The shortcuts respondents take in answering questions. *Survey Methods Newsletter* 20(1):4–8.

Krosnick JA, Holbrook AL, Lowe L, Visser, PS. 2006. The origins and consequences of democratic citizens' policy agendas: A study of popular concern about global warming. *Climatic Change* 77(July):7–43.

Losh, SC. 2009. Generation, education, gender and ethnicity in American digital divides. In: Ferro E, Dwivedi YK, Gil-Garcia JR, Williams MD, editors. *IGI Handbook: Overcoming Digital Divides: Constructing an Equitable and Competitive Information Society.* Hershey, PA: IGI Global.

Losh, SC. 2010. Age, generational, and educational effects on American adult public understanding of science. In: Bauer MW, Shukla R and Allum N, editors. *The Culture of Science—How does the public relate to science across the globe?* New York: Routledge. Forthcoming.

Malaysian Science and Technology Information Centre (MASTIC), Ministry of Science, Technology and the Environment. 2004. Public awareness of science and technology Malaysia 2004. http://www.mastic.gov.my/servlets/sfs;jsessionid=C12A6B8942252F13AFF9629775A74049?s=16ii7KxhiMVMSmF9R2Z&t=/contentManager/onStory&i=1108620651187&b=1108620651187&l=0&e=UTF-8&active=no&ParentID=1116297677695&sort=Price&StoryID=1145866808812. Accessed 23 June 2009.

Malhotra N, Krosnick JA, Haertel E. 2007. The psychometric properties of the GSS Wordsum Vocabulary Test. GSS Methodological Report 11.

Mason Kiefer, H. 2003. Americans, Britons at odds on animal testing. The Gallup Poll. http://www.gallup.com/poll/9178/Americans-Britons-Odds-Animal-Testing.aspx. Accessed 9 October 2009.

Maugh II TH, Kaplan K. 2008, September 19. FDA proposes approval process for genetically engineered animals. *Los Angeles Times.* http://articles.latimes.com/2008/sep/19/science/sci-genetic19. Accessed 9 October 2009.

Mellman Group, Inc. 2005. Recent findings. http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/News/Press_Releases/Food_and_Biotechnology/PIFB_Public_Sentiment_GM_Foods2005.pdf. Accessed 23 June 2009.

Mellman Group, Inc. 2006. Review of public opinion research. http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Public_Opinion/Food_and_Biotechnology/2006summary.pdf. Accessed 23 June 2009.

Miller JD. 1983. The American people and science policy: The role of public attitudes in the policy process. New York: Pergamon Press Inc.

Ministry of Science and Technology (MCT) of Brazil. 2006. Public perceptions of science and technology. http://www.mct.gov.br/upd_blob/0013/13511.pdf. Accessed 23 June 2009.

The National Academies. 2008a. Review of the federal strategy for nanotechnology-related environmental safety research. Washington, DC: The National Academies Press. http://books.nap.edu/openbook.php?record_id=12559&page=R1. Accessed 18 June 2009.

The National Academies. 2008b. Understanding and responding to climate change: Highlights of National Academies report. Washington DC: The National Academies Press. http://dels.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf. Accessed 6 August 2009.

National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology. 2002. The 2001 survey of public attitudes toward and understanding of science and technology in Japan. Tokyo, Japan.

National Research Council. 2009. *Learning Science in Informal Environments: People, Places, and Pursuits.* Committee on Learning Science in Informal Environments.

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors. Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Science Board (NSB). 2002. *Science and Engineering Indicators 2002.* NSB-02-01A. Arlington, VA: National Science Foundation.

National Science Board (NSB). 2006. *Science and Engineering Indicators 2006.* NSB 06-01; NSB 06-01A. Arlington, VA: National Science Foundation.

National Science Board (NSB). 2008. *Science and Engineering Indicators 2008.* NSB 08-01; NSB 08-01A. Arlington, VA: National Science Foundation.

Newport F. 2008. Post-Derby tragedy: 38% support banning animal racing. http://www.gallup.com/poll/107293/PostDerby-Tragedy-38-Support-Banning-Animal-Racing.aspx. Accessed 9 October 2009.

Organisation for Economic Co-operation and Development (OECD). 2003. The PISA 2003 assessment framework—Mathematics, reading, science and problem solving knowledge and skills. Paris.

Peter D. Hart Research Associates, Inc. 2008. Awareness of and attitudes toward nanotechnology and synthetic biology: A report of findings based on a national survey among adults. Conducted on behalf of the Project on Emerging Nanotechnologies. The Woodrow Wilson International Center for Scholars. http://www.nanotechproject.org/process/assets/files/7040/final-synbioreport.pdf. Accessed 23 June 2009.

Pew Forum on Religion and Public Life. 2008. Declining majority of Americans favor embryonic stem cell research. http://pewforum.org/docs/?DocID=317. Accessed 9 October 2009.

Pew Research Center for the People and the Press. 2008. Key news audiences now blend online and traditional sources. Audience segments in a changing news environment. (Aug 17 2008) http://people-press.org/report/444/news-media. Accessed 24 June 2009.

Pidgeon N, Harthorn BH, Bryant K, Rogers-Hayden T. 2009. Deliberating the risks of nanotechnologies for energy and health applications in the United States and United Kingdom. *Nature Nanotechnology* 4:95–98.

Project for Excellence in Journalism (PEJ). 2008. The state of the news media: An annual report on American journalism. http://www.stateofthemedia.org/2008/. Accessed 18 June 2009.

Project for Excellence in Journalism (PEJ). 2009. The state of the news media: An annual report on American journalism. http://www.stateofthemedia.org/2009/. Accessed 9 October 2009.

Roth W-M, Lee S. 2002. Scientific literacy as collective praxis. *Public Understanding of Science* 11:33–56.

Saad L. 2008a. Cultural tolerance for divorce grows to 70%. The Gallup Poll. http://www.gallup.com/poll/107380/Cultural-Tolerance-Divorce-Grows-70.aspx. Accessed 9 October 2009.

Saad L. 2008b. Economic anxiety surges in past year: Economy ties healthcare as American's top issue concern. The Gallup Poll. http://www.gallup.com/poll/105802/Economic-Anxiety-Surges-Past-Year.aspx. Accessed 23 June 2009.

Saad L. 2009. Water pollution Americans' top green concern: Worry about environmental problems has edged up since 2004. The Gallup Poll. http://www.gallup.com/poll/117079/Water-Pollution-Americans-Top-Green-Concern.aspx. Accessed 22 June 2009.

Shukla R. 2005. *India Science Report: Science Education, Human Resources, and Public Attitude toward Science and Technology.* New Delhi, India: National Council of Applied Economic Research.

Tyndall Report. 2009. Tyndallreport.com. Accessed 9 October 2009.

Villar A, Krosnick JA. 2009. "Global Warming" vs. "Climate Change": Does word choice matter? Unpublished manuscript. Stanford CA: Stanford University.

Virginia Commonwealth University (VCU) Center for Public Policy. 2006. Opinions shifting on stem cell research; opposition to cloning continues. VCU Life Sciences Survey. http://www.vcu.edu/lifesci/images2/ls_survey_2006_report.pdf. Accessed June 23 2009.

Virginia Commonwealth University (VCU) Center for Public Policy. 2007. Widespread support for non-embryonic stem cell research but continued need for both kinds of research. VCU Life Sciences Survey. http://www.vcu.edu/lifesci/images2/survey2007.pdf. Accessed June 23 2009.

Virginia Commonwealth University (VCU) Center for Public Policy. 2008. VCU survey finds support for genetic research, testing, and government spending on scientific research. VCU Life Sciences Survey. http://www.vcu.edu/lifesci/images2/survey2008.pdf. Accessed June 23 2009.

Yaar E. 2006. Science and technology in the Israeli consciousness. Samuel Neaman Institute. Haifa, Israel. http://www.neaman.org.il/Neaman/publications/publication_item.asp?fid=757&parent_fid=488&iid=3428. Accessed 22 June 2009.

Chapter 8
State Indicators

Elementary/Secondary Education

Higher Education

Workforce

Financial Research and Development Inputs

R&D Outputs

Science and Technology in the Economy

List of Tables

List of Figures

Introduction

Chapter Overview

To address the interest of the policy and research communities in the role of science and technology (S&T) in state and regional economic development, this chapter presents findings on state trends in S&T education, the employed workforce, finance, and research and development. This chapter includes 52 indicators for individual states, the District of Columbia, and Puerto Rico.

Although data for Puerto Rico are reported whenever available, they frequently were collected by a different source, making it unclear whether the methodology used for data collection and analysis is comparable with that used for the states. For this reason, Puerto Rico was neither ranked with the states nor assigned a quartile value that could be displayed on the maps. Data for United States territories and protectorates, such as American Samoa, Guam, Northern Mariana Islands, and Virgin Islands, were available only on a sporadic basis and for fewer than one-quarter of the indicators and thus are not included.

The indicators are designed to present information about various aspects of state S&T infrastructure. The data used to calculate the indicators were gathered from public and private sources. When possible, data covering a 10-year span are provided to identify meaningful trends. However, consistent data were not always available for the 10-year period, and data are given only for the years in which comparisons are appropriate. Most indicators contain data for 2006–07; some contain data for 2008.

Ready access to accurate and timely information is an important tool for formulating effective S&T policies at the state level. By studying the programs and performance of their peers, state policymakers may be able to better assess and enhance their own programs and performance. Corporations and other organizations considering investments at the state level may also benefit from this information. The tables are intended to provide quantitative data that may be relevant to technology-based economic development. More generally, the chapter aims to foster further consideration of the appropriate uses of state-level indicators.

Types of Indicators

Fifty-two indicators are included in this chapter and grouped into the following areas:

- Elementary and secondary education
- Higher education
- Workforce
- Financial R&D inputs
- Research and development outputs
- S&T in the economy

The first two areas address state educational attainment. Student achievement is expressed in terms of performance, which refers to the average state score on a standardized test, and proficiency, which is expressed as the percentage of students who have achieved at least the expected level of competence on the standardized test.

Comparable state-level performance data are not available for high school students. Instead, mastery of college-level material through performance on Advanced Placement Exams has been included as a measure of the skills being developed by the top-performing high school students. Other indicators in education focus on state spending, teacher salaries, student costs, and undergraduate and graduate degrees in S&E. Three indicators measure the level of education in the populations of individual states.

Workforce indicators focus on the level of S&E training in the employed labor force. These indicators reflect the higher education level of the labor force and the degree of specialization in S&E disciplines and occupations.

Financial indicators address the sources and level of funding for R&D. They show how much R&D is being performed relative to the size of a state's business base. New indicators in this edition focus on state government agency funding for R&D. This section enables readers to compare the extent to which R&D is conducted by industrial, academic, or state agency performers.

The final two sections provide measures of outputs. The first focuses on the work products of the academic community. It includes the number of new doctorates conferred, the publication of academic articles, and patent activity from the academic community and from all sources in the state.

The second section of output indicators examines the robustness of a region's S&T-related economic activity. These indicators include venture capital activity, Small Business Innovation Research awards, and high-technology business activity. Although data that adequately address both the quantity and quality of R&D results are difficult to find, these indicators offer a reasonable information base.

Data Sources and Considerations

Raw data for each indicator are presented in the tables. Each table provides an average value for all states, labeled "United States." For most indicators, the state average was calculated by summing the values for the 50 states and the District of Columbia for both the numerator and the denominator and then dividing the two. Any alternate approach is indicated in the notes at the bottom of the table.

The values for most indicators are expressed as ratios or percentages to facilitate comparison between states that differ substantially in size. For example, an indicator of higher education achievement is not defined as the absolute number of degrees conferred in a state because sparsely populated states are unlikely to have or need as extensive a higher education system as states with larger populations. Instead, the indicator is defined as the number of degrees per number of residents in the college-age cohort, which measures the intensity of educational services relative to the size of the resident population.

Readers must exercise caution when evaluating the indicator values for the District of Columbia. Frequently, the indicator value for the District of Columbia is appreciably different from the indicator values for any of the states. The District of Columbia is unique because it is an urban region with a large federal presence and many universities. In addition, it has a large student population and provides employment for many individuals who live in neighboring states. Indicator values can be quite different depending on whether data attributed to the District of Columbia are based on where people live or where they work.

Key Elements for Indicators

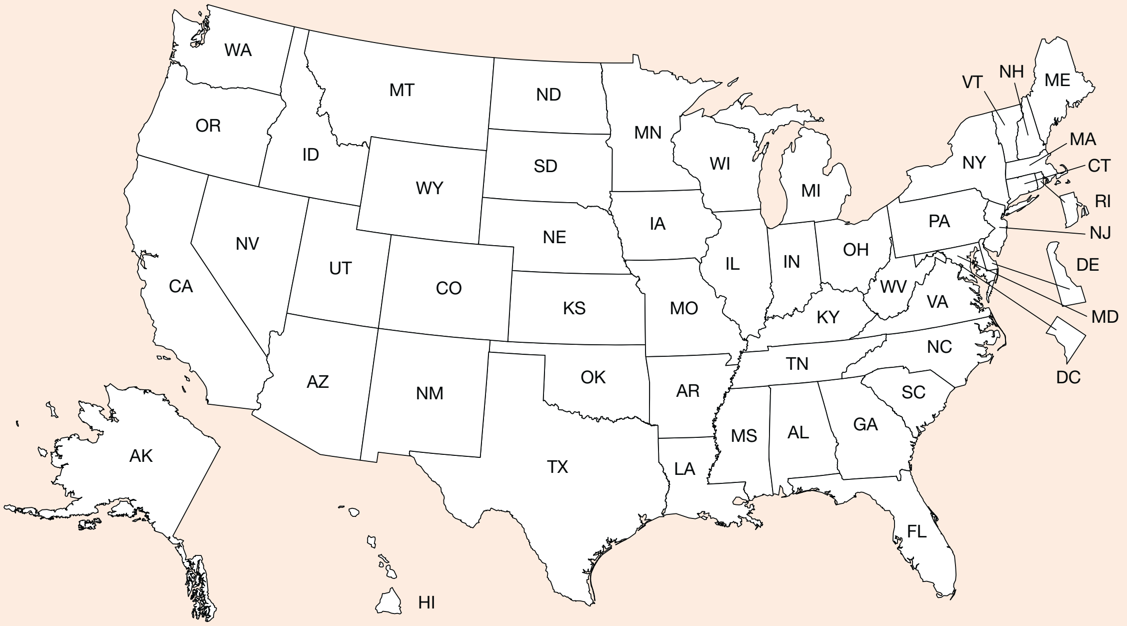
Six key elements are provided for each indicator. The first element is a map color-coded to show in which quartile each state placed on that indicator for the latest year that data were available. This helps the reader quickly grasp geographic patterns. The sample map below shows the outline of each state. On the indicator maps, the darkest color indicates states that rank in the first or highest quartile, and white indicates states that rank in the fourth or lowest quartile. Cross-hatching indicates states for which no data are available.

The second element is a quartiles table. States are listed alphabetically by quartile. The range of indicator values for that quartile is shown at the top of the column. Ties at quartile breaks were resolved by moving the tied states into one quartile. All of the indicators are broad measures, and several rely on sample estimates that have a margin of error. Small differences in state values generally carry little useful information.

In 1978, Congress initiated the Experimental Program to Stimulate Competitive Research (EPSCoR) at the National Science Foundation to build R&D capacity in states that have historically been less competitive in receiving federal R&D funding. Subsequently, several federal agencies established similar programs, the largest of which is the Institutional Development Award (IDeA) program at the National Institutes of Health.

The quartiles table identifies states in the EPSCoR group—those identified as eligible for EPSCoR-like programs by least five federal agencies or departments. The 24 EPSCoR states are Alabama, Alaska, Arkansas, Delaware, Hawaii, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Vermont, West Virginia,

Figure 8-A
U.S. map and list of abbreviations



AK	Alaska
AL	Alabama
AR	Arkansas
AZ	Arizona
CA	California
CO	Colorado
CT	Connecticut
DC	District of Columbia
DE	Delaware
FL	Florida
GA	Georgia
HI	Hawaii
IA	Iowa
ID	Idaho
IL	Illinois
IN	Indiana
KS	Kansas
KY	Kentucky
LA	Louisiana
MA	Massachusetts
MD	Maryland
ME	Maine
MI	Michigan
MN	Minnesota
MO	Missouri
MS	Mississippi
MT	Montana
NC	North Carolina
ND	North Dakota
NE	Nebraska
NH	New Hampshire
NJ	New Jersey
NM	New Mexico
NV	Nevada
NY	New York
OH	Ohio
OK	Oklahoma
OR	Oregon
PA	Pennsylvania
RI	Rhode Island
SC	South Carolina
SD	South Dakota
TN	Tennessee
TX	Texas
UT	Utah
VA	Virginia
VT	Vermont
WA	Washington
WI	Wisconsin
WV	West Virginia
WY	Wyoming

and Wyoming. The EPSCoR Program is discussed further in chapter 5, “Academic Research and Development,” in the sidebar “EPSCoR: The Experimental Program to Stimulate Competitive Research.” The remaining 26 states are considered states in the non-EPSCoR group.

The third element, at the bottom of the map box, is a short citation for the data source. The full citation appears under the table on the facing page.

The fourth element, in a shaded box on the lower left side of the page, is a summary of findings that includes the national average and comments on national and state trends and patterns for the particular indicator. Although most of the findings are directly related to the data, some represent interpretations that are meant to stimulate further investigation and discussion.

The fifth element, on the lower right side of the page, is a description of the indicator and includes information pertaining to the underlying data.

The final element is the data table, which appears on the facing page. Up to three years of data and the calculated values of the indicator are presented for each state, the District of Columbia, and Puerto Rico. Puerto Rico is included in the data table only when data are available.

For selected indicators, the data table has been expanded to include the average data and indicator value for the 50 states and the District of Columbia, and the averages for the EPSCoR and non-EPSCoR states. These averages have been calculated in two ways. The first two lines, “EPSCoR states” and “Non-EPSCoR states,” treat each group as a single geographical unit, ignoring the division of that unit into separate states. The ratio for the group is calculated by totaling the numerator value of each of the states in the group and the denominator value of each of the states in the group and dividing to compute an average. For example, the EPSCoR states average of R&D by gross domestic product by state is calculated by summing the R&D of all the EPSCoR states, summing the gross domestic product of these states, and dividing to compute an average. States with more R&D and a larger gross domestic product affect this average more than smaller ones do, just as data on California affect U.S. totals more than data on Wyoming do.

The third and fourth lines, “Average EPSCoR state value” and “Average non-EPSCoR state value,” represent the average of the individual state ratios for an indicator. The average EPSCoR state value for R&D by gross domestic product by state is calculated by summing the ratios for the 24 EPSCoR states and dividing by 24. All state ratios count equally in this computation.

High-Technology Industries

To define high-technology industries, this chapter uses a modification of the approach employed by the Bureau of Labor Statistics (BLS) (Hecker 2005). BLS’s approach is based on the intensity of high-technology employment within an industry.

High-technology occupations include scientific, engineering, and technician occupations. These occupations employ workers who possess an in-depth knowledge of the theories and principles of science, engineering, and mathematics, which is generally acquired through postsecondary education in some field of technology. An industry is considered a high-technology industry if employment in technology-oriented occupations accounts for a proportion of that industry’s total employment that is at least twice the 4.9% average for all industries (i.e., 9.8% or higher).

In this chapter, the category “high-technology industries” refers only to private sector businesses. In contrast, BLS includes the “Federal Government, excluding Postal Service” in its listing of high-technology industries.

Each industry is defined by a four-digit code that is based on the listings in the 2002 North American Industry Classification System (NAICS). The 2002 NAICS codes contain a number of additions and changes from the previous 1997 NAICS codes that were used to classify business establishments in data sets covering the period 1998–2002, and therefore cannot be applied to data sets from earlier years.

The list of high-technology industries used in this chapter includes the 46 four-digit codes from the 2002 NAICS listing shown in table 8-A.

Appendix Tables

Additional data tables pertaining to the indicators in this chapter have been included in the appendix. These tables provide supplemental information to assist the reader in evaluating the data used in an indicator. The appendix tables contain state-level data on the performance of students in different racial/ethnic and gender groups on the National Assessment of Educational Progress (NAEP) evaluations. Additional data on the coefficient of variation for data sources in the chapter also are presented in the appendix tables when they are available.

Reference

Hecker D. 2005. High-technology employment: A NAICS-based update. *Monthly Labor Review* 128(7):57–72.

Table 8-A

2002 NAICS codes that constitute high-technology industries

NAICS code	Industry
1131, 32	Forestry
2111	Oil and gas extraction
2211	Electric power generation, transmission, and distribution
3241	Petroleum and coal products manufacturing
3251	Basic chemical manufacturing
3252	Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing
3254	Pharmaceutical and medicine manufacturing
3255	Paint, coating, and adhesive manufacturing
3259	Other chemical product and preparation manufacturing
3332	Industrial machinery manufacturing
3333	Commercial and service industry machinery manufacturing
3336	Engine, turbine, and power transmission equipment manufacturing
3339	Other general purpose machinery manufacturing
3341	Computer and peripheral equipment manufacturing
3342	Communications equipment manufacturing
3343	Audio and video equipment manufacturing
3344	Semiconductor and other electronic component manufacturing
3345	Navigational, measuring, electromedical, and control instruments manufacturing
3346	Manufacturing and reproducing magnetic and optical media
3353	Electrical equipment manufacturing
3364	Aerospace product and parts manufacturing
3369	Other transportation equipment manufacturing
4234	Professional and commercial equipment and supplies, merchant wholesalers
4861	Pipeline transportation of crude oil
4862	Pipeline transportation of natural gas
4869	Other pipeline transportation
5112	Software publishers
5161	Internet publishing and broadcasting
5171	Wired telecommunications carriers
5172	Wireless telecommunications carriers (except satellite)
5173	Telecommunications resellers
5174	Satellite telecommunications
5179	Other telecommunications
5181	Internet service providers and Web search portals
5182	Data processing, hosting, and related services
5211	Monetary authorities, central bank
5232	Securities and commodity exchanges
5413	Architectural, engineering, and related services
5415	Computer systems design and related services
5416	Management, scientific, and technical consulting services
5417	Scientific research and development services
5511	Management of companies and enterprises
5612	Facilities support services
8112	Electronic and precision equipment repair and maintenance

NAICS = North American Industry Classification System

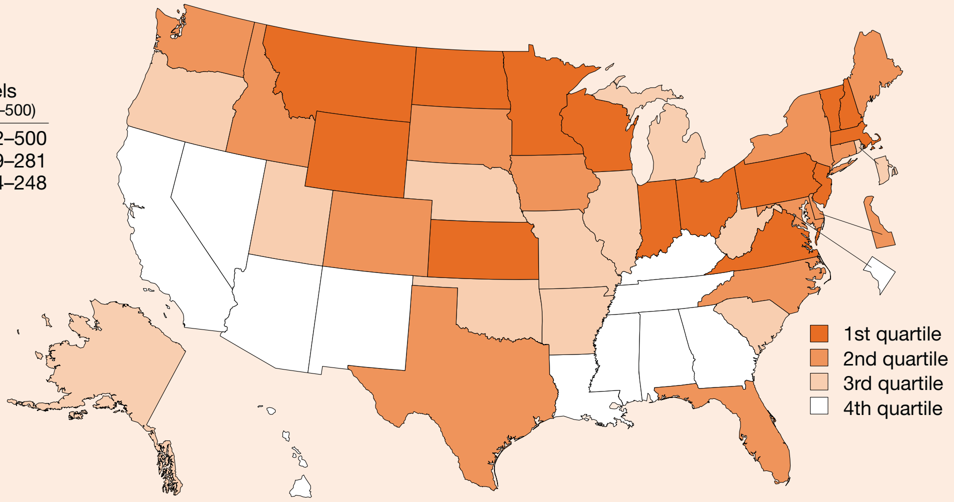
Science and Engineering Indicators 2010

Fourth Grade Mathematics Performance

Figure 8-1
Average fourth grade mathematics performance: 2007

Achievement levels
(Scores range from 0–500)

Advanced 282–500
Proficient 249–281
Basic............ 214–248



1st quartile (252–244)	2nd quartile (243–240)	3rd quartile (239–236)	4th quartile (235–214)
Indiana	Colorado	Alaska ‡	Alabama ‡
Kansas ‡	Connecticut	Arkansas ‡	Arizona
Massachusetts	Delaware ‡	Illinois	California
Minnesota	Florida	Michigan	District of Columbia
Montana ‡	Idaho ‡	Missouri	Georgia
New Hampshire ‡	Iowa	Nebraska ‡	Hawaii ‡
New Jersey	Maine ‡	Oklahoma ‡	Kentucky ‡
North Dakota ‡	Maryland	Oregon	Louisiana ‡
Ohio	New York	Rhode Island ‡	Mississippi ‡
Pennsylvania	North Carolina	South Carolina ‡	Nevada ‡
Vermont ‡	South Dakota ‡	Utah	New Mexico ‡
Virginia	Texas	West Virginia ‡	Tennessee
Wisconsin	Washington		
Wyoming ‡			

‡ EPSCoR state

NOTE: See figure 8-2 text for explanation of achievement levels.

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-1.

Findings

- In 2007, the nationwide average mathematics score of fourth grade public school students was 239, a significant increase from 224 in 2000.
- For the 41 jurisdictions that participated in both the 2000 and 2007 mathematics assessments, the average score for public school fourth graders showed a statistically significant increase between 2000 and 2007. Only the District of Columbia reported an average score in 2007 that was below the 2000 national average of 224.
- The entire fourth grade student sample, including students performing at the 10th, 25th, 50th, 75th, and 90th percentiles, demonstrated statistically significant gains in mathematics scores between 2000 and 2007.
- The states with the highest average mathematics scores for fourth graders were concentrated in the northern United States. A number of EPSCoR states were included in this group.
- The gaps in mathematics scores between white fourth graders and black or Hispanic fourth graders narrowed significantly between 2000 and 2007. The gender gap in fourth grade mathematics scores, although much smaller, showed no significant change between 2000 and 2007.

This indicator represents each state's average score on the National Assessment of Educational Progress (NAEP) in mathematics for its fourth grade students in public schools. The NAEP mathematics assessment is a federally authorized measure of student performance in which all 50 states and the District of Columbia participated in 2007.

Student performance is presented in terms of average scores on a scale from 0 to 500. Higher scores indicate that fourth graders are demonstrating a stronger foundation for adult mathematics competency. An average score designated as NA (not available) indicates that the state either did not participate in the assessment or did not have a representative sample of fourth graders that was large enough for reporting state-level results.

NAEP allows students with disabilities or limited English-language proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-1
Average fourth grade mathematics performance, by state: 2000, 2005, and 2007
(Score out of 500)

State	2000	2005	2007
United States	224*	237*	239
Alabama	217*	225*	229
Alaska	NA	236	237
Arizona	219*	230	232
Arkansas	216*	236	238
California	213*	230	230
Colorado	NA	239	240
Connecticut	234*	242	243
Delaware	NA	240*	242
District of Columbia	192*	211*	214
Florida	NA	239*	242
Georgia	219*	234	235
Hawaii	216*	230*	234
Idaho	224*	242	241
Illinois	223*	233*	237
Indiana	233*	240*	245
Iowa	231*	240*	243
Kansas	232*	246	248
Kentucky	219*	231*	235
Louisiana	218*	230	230
Maine	230*	241	242
Maryland	222*	238	240
Massachusetts	233*	247*	252
Michigan	229*	238	238
Minnesota	234*	246	247
Mississippi	211*	227	228
Missouri	228*	235*	239
Montana	228*	241*	244
Nebraska	225*	238	238
Nevada	220*	230	232
New Hampshire	NA	246*	249
New Jersey	NA	244*	249
New Mexico	213*	224*	228
New York	225*	238*	243
North Carolina	230*	241	242
North Dakota	230*	243*	245
Ohio	230*	242	245
Oklahoma	224*	234*	237
Oregon	224*	238	236
Pennsylvania	NA	241*	244
Rhode Island	224*	233	236
South Carolina	220*	238	237
South Dakota	NA	242	241
Tennessee	220*	232	233
Texas	231*	242	242
Utah	227*	239	239
Vermont	232*	244*	246
Virginia	230*	240*	244
Washington	NA	242	243
West Virginia	223*	231*	236
Wisconsin	NA	241*	244
Wyoming	229*	243	244
Puerto Rico	NA	NA	NA

*significantly different ($p < .05$) from 2007 when only one jurisdiction or the nation is being examined; NA = not available

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

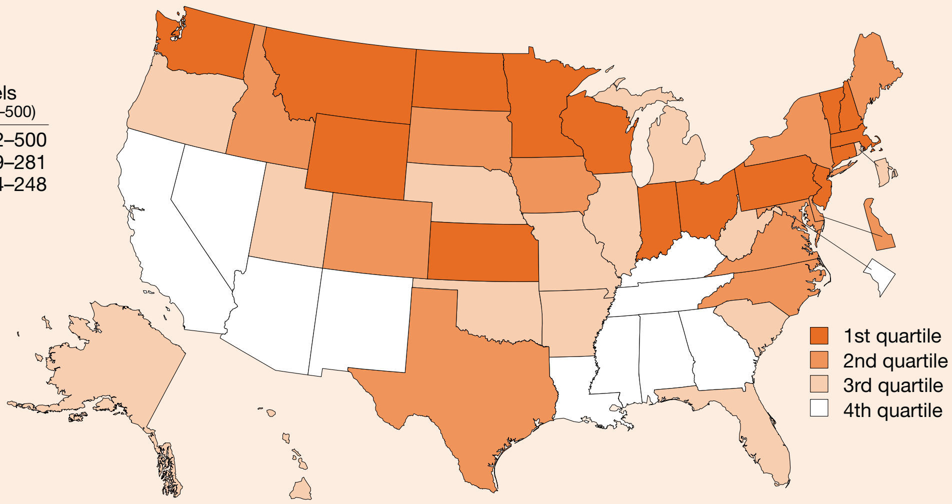
Science and Engineering Indicators 2010

Fourth Grade Mathematics Proficiency

Figure 8-2
Students reaching proficiency in fourth grade mathematics: 2007
(Percent; scores of 249 and above indicate proficiency)

Achievement levels
(Scores range from 0–500)

Advanced	282–500
Proficient	249–281
Basic.............	214–248



1st quartile (58%–44%)	2nd quartile (43%–40%)	3rd quartile (39%–33%)	4th quartile (32%–14%)
Connecticut	Colorado	Alaska ‡	Alabama ‡
Indiana	Delaware ‡	Arkansas ‡	Arizona
Kansas ‡	Idaho ‡	Florida	California
Massachusetts	Iowa	Hawaii ‡	District of Columbia
Minnesota	Maine ‡	Illinois	Georgia
Montana ‡	Maryland	Michigan	Kentucky ‡
New Hampshire ‡	New York	Missouri	Louisiana ‡
New Jersey	North Carolina	Nebraska ‡	Mississippi ‡
North Dakota ‡	South Dakota ‡	Oklahoma ‡	Nevada ‡
Ohio	Texas	Oregon	New Mexico ‡
Pennsylvania	Virginia	Rhode Island ‡	Tennessee
Vermont ‡		South Carolina ‡	
Washington		Utah	
Wisconsin		West Virginia ‡	
Wyoming ‡			

‡ EPSCoR state

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-2.

Findings

- In 2007, 39% of fourth grade public school students nationwide performed at or above the proficient level in mathematics, which represents a statistically significant increase from 22% in 2000. Several states more than doubled the percentage of their students performing at or above the proficient level.
- Of the 41 jurisdictions that participated in both the 2000 and 2007 assessments, all showed significant increases in mathematics proficiency levels for public school fourth graders in 2007.
- The states with the highest percentages of fourth-graders who were proficient in mathematics are concentrated in the northern United States. A number of EPSCoR states were included in this group.
- Substantial differences in mathematics proficiency exist among racial/ethnic groups of fourth graders. The gaps increased between 2000 and 2007 as blacks and Hispanics failed to match the gains made in mathematics proficiency by whites. The gender gap among fourth graders is much smaller and remained unchanged between 2000 and 2007.

This indicator represents the proportion of a state's fourth grade students in public schools that has met or exceeded the proficiency standard in mathematics.

The National Assessment of Educational Progress (NAEP) provides a federally authorized measure of student performance in mathematics. The National Assessment Governing Board sets performance standards that provide a context for interpreting NAEP results. The standards define "proficiency" as well as performance levels that indicate greater ("advanced") and lesser ("basic") accomplishment. For the fourth grade, the proficient level (scores 249–281) represents solid academic performance and demonstrates competency over challenging subject-matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (282–500) signifies superior performance. The basic level (214–248) denotes partial mastery of knowledge and skills that are prerequisite for proficient work.

Approximately 198,000 fourth grade students in 7,800 schools participated in the 2007 NAEP mathematics assessment. A designation of NA (not available) indicates that the state either did not participate in the assessment or did not have a representative sample of fourth graders that was large enough for reporting state-level results.

Table 8-2

Students reaching proficiency in fourth grade mathematics, by state: 2000, 2005, and 2007

(Percent)

State	2000	2005	2007
United States	22*	35*	39
Alabama	13*	21*	26
Alaska	NA	34	38
Arizona	16*	28	31
Arkansas	14*	34	37
California	13*	28	30
Colorado	NA	39	41
Connecticut	31*	43	45
Delaware	NA	36*	40
District of Columbia	5*	10*	14
Florida	NA	37*	37
Georgia	17*	30	32
Hawaii	14*	27*	33
Idaho	20*	41	40
Illinois	20*	32*	36
Indiana	30*	38*	46
Iowa	26*	37*	43
Kansas	29*	47	51
Kentucky	17*	26*	31
Louisiana	14*	24	24
Maine	23*	39	42
Maryland	21*	38	40
Massachusetts	31*	49*	58
Michigan	28*	37	37
Minnesota	33*	47	51
Mississippi	9*	19	21
Missouri	23*	31*	38
Montana	24*	38*	44
Nebraska	24*	36	38
Nevada	16*	26*	30
New Hampshire	NA	47*	52
New Jersey	NA	46*	52
New Mexico	12*	19*	24
New York	21*	36*	43
North Carolina	25*	40	41
North Dakota	25*	40*	46
Ohio	25*	43	46
Oklahoma	16*	29	33
Oregon	23*	37	35
Pennsylvania	NA	41*	47
Rhode Island	22*	31*	34
South Carolina	18*	36	36
South Dakota	NA	40	41
Tennessee	18*	28	29
Texas	25*	40	40
Utah	23*	37	39
Vermont	29*	44*	49
Virginia	24*	40	42
Washington	NA	42	44
West Virginia	17*	25*	33
Wisconsin	NA	40*	47
Wyoming	25*	42	44
Puerto Rico	NA	NA	NA

*significantly different ($p < .05$) from 2007 when only one jurisdiction or the nation is being examined; NA = not available

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

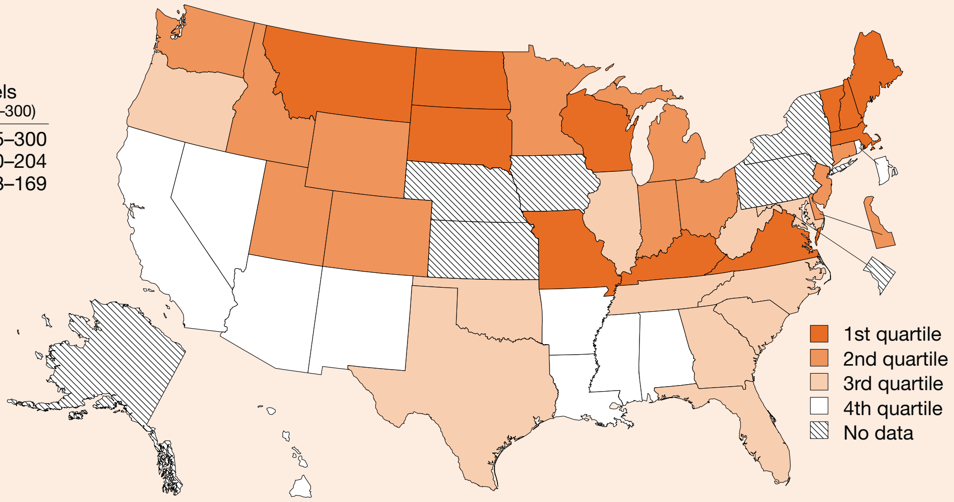
Science and Engineering Indicators 2010

Fourth Grade Science Performance

Figure 8-3
Average fourth grade science performance: 2005

Achievement levels
(Scores range from 0–300)

Advanced 205–300
Proficient 170–204
Basic............. 138–169



1st quartile (161–158)	2nd quartile (157–152)	3rd quartile (151–148)	4th quartile (147–133)	No data
Kentucky ‡	Colorado	Florida	Alabama ‡	Alaska ‡
Maine ‡	Connecticut	Georgia	Arizona	District of Columbia
Massachusetts	Delaware ‡	Illinois	Arkansas ‡	Iowa
Missouri	Idaho ‡	Maryland	California	Kansas ‡
Montana ‡	Indiana	North Carolina	Hawaii ‡	Nebraska ‡
New Hampshire ‡	Michigan	Oklahoma ‡	Louisiana ‡	New York
North Dakota ‡	Minnesota	Oregon	Mississippi ‡	Pennsylvania
South Dakota ‡	New Jersey	South Carolina ‡	Nevada ‡	
Vermont ‡	Ohio	Tennessee	New Mexico ‡	
Virginia	Utah	Texas	Rhode Island ‡	
Wisconsin	Washington	West Virginia ‡		
	Wyoming ‡			

‡ EPSCoR state

NOTE: See figure 8-4 text for explanation of achievement levels.

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-3.

Findings

- In 2005, the nationwide average science score of fourth grade public school students was 149, an increase from 145 in 2000.
- Of the 36 states that participated in both the 2000 and 2005 science assessments, 20 reported increases in average scores of their public school fourth graders, but only 9 of these increases were statistically significant.
- Students performing at the 10th, 25th, and 50th percentiles demonstrated gains in science scores between 2000 and 2005, whereas students performing at the 75th and 90th percentiles showed no statistically significant change in average score.
- The states with the highest average science scores for fourth graders were concentrated in the northern United States. A number of EPSCoR states were included in this group.
- The gaps in science scores between white fourth graders and black or Hispanic fourth graders narrowed significantly between 2000 and 2005. The gender gap in fourth grade science scores, although much smaller, remained unchanged between 2000 and 2005.

This indicator represents each state's average score on the National Assessment of Educational Progress (NAEP) in science for its fourth grade students in public schools. The NAEP science assessment is a federally authorized measure of student performance in which 44 states participated in 2005.

Student performance is presented in terms of average scores on a scale from 0 to 300. Higher scores indicate that fourth graders are demonstrating a stronger foundation for adult science competency. An average score designated as NA (not available) indicates that the state either did not participate in the assessment or did not have a representative sample of fourth graders that was large enough for reporting state-level results.

NAEP allows students with disabilities or limited English-language proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-3
Average fourth grade science performance, by state: 2000 and 2005
(Score out of 300)

State	2000	2005
United States	145*	149
Alabama	143	142
Alaska	NA	NA
Arizona	140	139
Arkansas	145	147
California	129*	137
Colorado	NA	155
Connecticut	156	155
Delaware	NA	152
District of Columbia	NA	NA
Florida	NA	150
Georgia	142*	148
Hawaii	136*	142
Idaho	152	155
Illinois	150	148
Indiana	154	152
Iowa	159	NA
Kansas	NA	NA
Kentucky	152*	158
Louisiana	139	143
Maine	161	160
Maryland	145*	149
Massachusetts	161	160
Michigan	152	152
Minnesota	157	156
Mississippi	133	133
Missouri	157	158
Montana	160	160
Nebraska	150	NA
Nevada	142	140
New Hampshire	NA	161
New Jersey	NA	154
New Mexico	140	141
New York	148	NA
North Carolina	147	149
North Dakota	160	160
Ohio	155	157
Oklahoma	151	150
Oregon	148	151
Pennsylvania	NA	NA
Rhode Island	148	146
South Carolina	140*	148
South Dakota	NA	158
Tennessee	145*	150
Texas	145*	150
Utah	154	155
Vermont	160	160
Virginia	155*	161
Washington	NA	153
West Virginia	149	151
Wisconsin	NA	158
Wyoming	156	157
Puerto Rico	NA	NA

*significantly different from 2005 when only one jurisdiction or the nation is being examined;
NA = not available

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 science scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

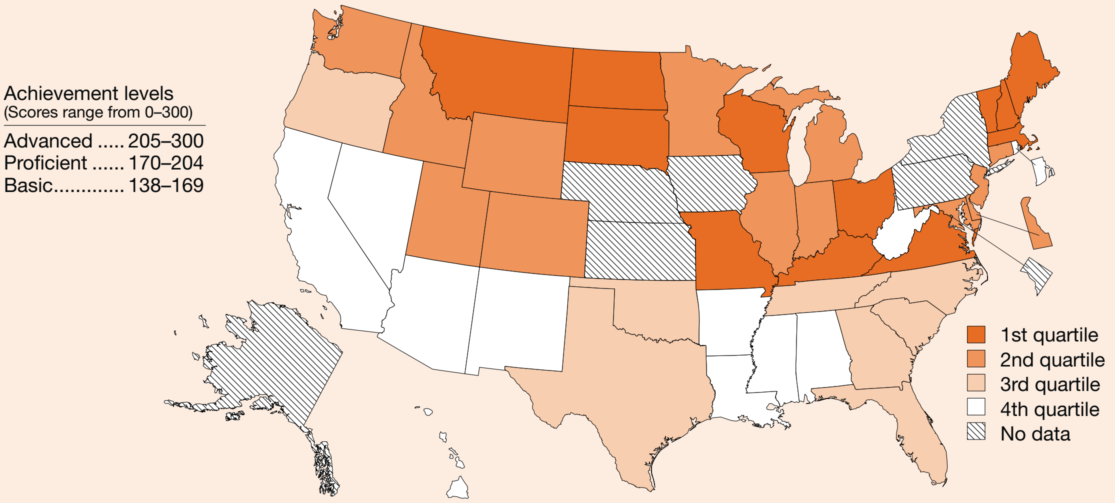
Science and Engineering Indicators 2010

Fourth Grade Science Proficiency

Figure 8-4

Students reaching proficiency in fourth grade science: 2005

(Percent; scores of 170 and above indicate proficiency)



1st quartile (40%–35%)

Kentucky ‡
Maine ‡
Massachusetts
Missouri
Montana ‡
New Hampshire ‡
North Dakota ‡
Ohio
South Dakota ‡
Vermont ‡
Virginia
Wisconsin

2nd quartile (33%–27%)

Colorado
Connecticut
Delaware ‡
Idaho ‡
Illinois
Indiana
Maryland
Michigan
Minnesota
New Jersey
Utah
Washington
Wyoming ‡

3rd quartile (26%–25%)

Florida
Georgia
North Carolina
Oklahoma ‡
Oregon
South Carolina ‡
Tennessee
Texas

4th quartile (24%–12%)

Alabama ‡
Arizona
Arkansas ‡
California
Hawaii ‡
Louisiana ‡
Mississippi ‡
Nevada ‡
New Mexico ‡
Rhode Island ‡
West Virginia ‡

No data

Alaska ‡
District of Columbia
Iowa
Kansas ‡
Nebraska ‡
New York
Pennsylvania

‡ EPSCoR state

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-4.

Findings

- In 2005, 27% of fourth grade public school students nationwide performed at or above the proficient level in science, which is not significantly different from 26% in 2000.
- Of the 36 states that participated in both the 2000 and 2005 science assessments, only 4 states showed increases that were statistically significant.
- The states with the highest percentage of fourth graders who demonstrated science proficiency are located in the northern United States. A number of EPSCoR states were included in this group.
- Substantial differences in science proficiency exist between racial/ethnic groups of fourth graders. The gender gap is much smaller and remained unchanged between 2000 and 2005.

This indicator represents the proportion of a state's fourth grade students in public schools that has met or exceeded the proficiency standard in science.

The National Assessment of Educational Progress (NAEP) provides a federally authorized measure of student performance in science. The National Assessment Governing Board sets performance standards that provide a context for interpreting NAEP results. The standards define "proficiency" as well as performance levels that indicate greater ("advanced") and lesser ("basic") accomplishment. For the fourth grade, the proficient level (scores 170–204) represents solid academic performance and demonstrates competency over challenging subject-matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (205–300) signifies superior performance. The basic level (138–169) denotes partial mastery of knowledge and skills that are prerequisite for proficient work. A National Academy of Sciences panel evaluated the process used to establish the standards for the science assessment and urged that they be considered developmental and interpreted with caution.

Approximately 147,700 fourth grade students in 8,500 schools participated in the 2005 NAEP science assessment. A designation of NA (not available) indicates that the state either did not participate in the assessment or did not have a representative sample of fourth graders that was large enough for reporting state-level results.

Table 8-4

Students reaching proficiency in fourth grade science, by state: 2000 and 2005

(Percent)

State	2000	2005
United States	26	27
Alabama	22	21
Alaska	NA	NA
Arizona	22	18
Arkansas	23	24
California	13*	17
Colorado	NA	32
Connecticut	35	33
Delaware	NA	27
District of Columbia	NA	NA
Florida	NA	26
Georgia	23	25
Hawaii	16	19
Idaho	29	29
Illinois	31	27
Indiana	32	27
Iowa	36	NA
Kansas	NA	NA
Kentucky	28*	36
Louisiana	18	20
Maine	37	36
Maryland	24	27
Massachusetts	42	38
Michigan	32	30
Minnesota	34	33
Mississippi	13	12
Missouri	34	36
Montana	36	37
Nebraska	26	NA
Nevada	19	17
New Hampshire	NA	37
New Jersey	NA	32
New Mexico	17	18
New York	24	NA
North Carolina	23	25
North Dakota	36	36
Ohio	31	35
Oklahoma	26	25
Oregon	27	26
Pennsylvania	NA	NA
Rhode Island	25	23
South Carolina	20*	25
South Dakota	NA	35
Tennessee	24	26
Texas	23	25
Utah	31	33
Vermont	38	38
Virginia	32*	40
Washington	NA	28
West Virginia	24	24
Wisconsin	NA	35
Wyoming	31	32
Puerto Rico	NA	NA

*significantly different from 2005 when only one jurisdiction or the nation is being examined;
NA = not available

NOTE: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 4 science scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

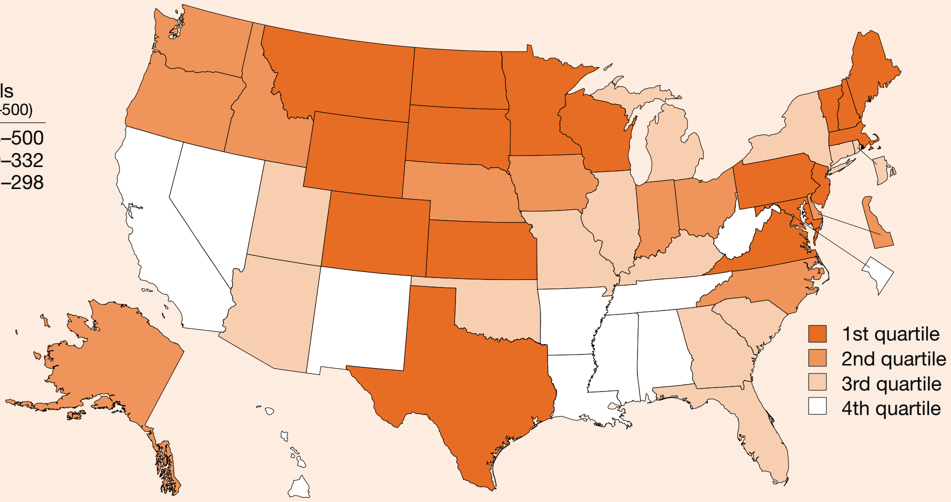
Science and Engineering Indicators 2010

Eighth Grade Mathematics Performance

Figure 8-5
Average eighth grade mathematics performance: 2007

Achievement levels
(Scores range from 0–500)

Advanced 333–500
Proficient 299–332
Basic............. 262–298



1st quartile (298–286)	2nd quartile (285–283)	3rd quartile (282–275)	4th quartile (274–248)
Colorado	Alaska ‡	Arizona	Alabama ‡
Kansas ‡	Delaware ‡	Connecticut	Arkansas ‡
Maine ‡	Idaho ‡	Florida	California
Maryland	Indiana	Georgia	District of Columbia
Massachusetts	Iowa	Illinois	Hawaii ‡
Minnesota	Nebraska ‡	Kentucky ‡	Louisiana ‡
Montana ‡	North Carolina	Michigan	Mississippi ‡
New Hampshire ‡	Ohio	Missouri	Nevada ‡
New Jersey	Oregon	New York	New Mexico ‡
North Dakota ‡	Washington	Oklahoma ‡	Tennessee
Pennsylvania		Rhode Island ‡	West Virginia ‡
South Dakota ‡		South Carolina ‡	
Texas		Utah	
Vermont ‡			
Virginia			
Wisconsin			
Wyoming ‡			

‡ EPSCoR state

NOTE: See figure 8-6 text for explanation of achievement levels.

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-5.

Findings

- In 2007, the nationwide average mathematics score of eighth grade public school students was 280, a statistically significant increase from 272 in 2000.
- Of the 40 jurisdictions that participated in both the 2000 and 2007 mathematics assessments, 35 reported statistically significant increases.
- The entire eighth grade student sample, including students performing at the 10th, 25th, 50th, 75th, and 90th percentiles, demonstrated statistically significant gains in mathematics scores between 2000 and 2007.
- States with high average mathematics scores for eighth graders frequently included those in the New England and North Central regions of the United States. A number of EPSCoR states were included in this group.
- The gaps in mathematics scores between white eighth graders and black or Hispanic eighth graders narrowed significantly between 2000 and 2007. The gender gap in eighth grade mathematics scores, although much smaller, remained unchanged between 2000 and 2007.

This indicator represents each state's average score on the National Assessment of Educational Progress (NAEP) in mathematics for its eighth grade students in public schools. The NAEP mathematics assessment is a federally authorized measure of student performance in which all 50 states and the District of Columbia participated in 2007.

Student performance is presented in terms of average scores on a scale from 0 to 500. Higher scores indicate that eighth graders are demonstrating a stronger foundation for adult mathematics competency. An average score designated as NA (not applicable) indicates that the state either did not participate in the assessment or did not have a representative sample of eighth graders that was large enough for reporting state-level results.

NAEP allows students with disabilities or limited English-language proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests taken with accommodations offered.

Table 8-5

Average eighth grade mathematics performance, by state: 2000, 2005, and 2007

(Score out of 500)

State	2000	2005	2007
Average EPSCoR state value	270	275	278
Average non-EPSCoR state value	274	280	282
United States	272 *	278*	280
Alabama	264	262	266
Alaska	NA	279*	283
Arizona	269 *	274	276
Arkansas	257 *	272	274
California	260 *	269	270
Colorado	NA	281*	286
Connecticut	281	281	282
Delaware	NA	281*	283
District of Columbia	235 *	245*	248
Florida	NA	274	277
Georgia	265 *	272	275
Hawaii	262 *	266*	269
Idaho	277 *	281*	284
Illinois	275 *	278	280
Indiana	281 *	282*	285
Iowa	NA	284	285
Kansas	283 *	284*	290
Kentucky	270 *	274*	279
Louisiana	259 *	268*	272
Maine	281 *	281*	286
Maryland	272 *	278*	286
Massachusetts	279 *	292*	298
Michigan	277	277	277
Minnesota	287 *	290	292
Mississippi	254 *	262	265
Missouri	271 *	276*	281
Montana	285	286	287
Nebraska	280 *	284	284
Nevada	265 *	270	271
New Hampshire	NA	285*	288
New Jersey	NA	284*	289
New Mexico	259 *	263*	268
New York	271 *	280	280
North Carolina	276 *	282	284
North Dakota	282 *	287*	292
Ohio	281 *	283	285
Oklahoma	270 *	271*	275
Oregon	280	282	284
Pennsylvania	NA	281*	286
Rhode Island	269 *	272*	275
South Carolina	265 *	281	282
South Dakota	NA	287	288
Tennessee	262 *	271*	274
Texas	273 *	281*	286
Utah	274 *	279	281
Vermont	281 *	287*	291
Virginia	275 *	284*	288
Washington	NA	285	285
West Virginia	266 *	269	270
Wisconsin	NA	285	286
Wyoming	276 *	282*	287
Puerto Rico	NA	NA	NA

*significantly different ($p < .05$) from 2007 when only one jurisdiction or the nation is being examined;
NA = not available;
EPSCoR = Experimental Program to Stimulate Competitive Research

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores for public schools only. For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

SOURCE: National Center for Education Statistics, NAEP (various years).

Science and Engineering Indicators 2010

Eighth Grade Mathematics Proficiency

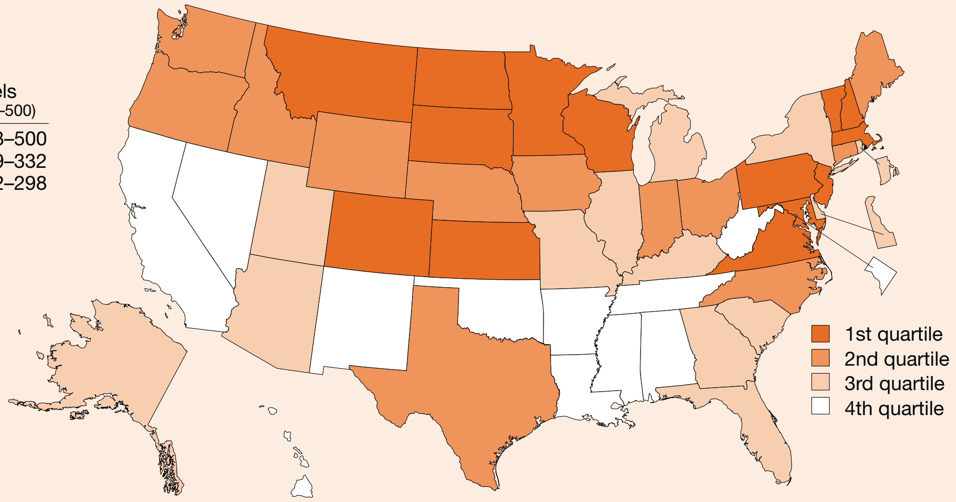
Figure 8-6

Students reaching proficiency in eighth grade mathematics: 2007

(Percent; scores of 299 and above indicate proficiency)

Achievement levels
(Scores range from 0–500)

Achievement level	Scores
Advanced	333–500
Proficient	299–332
Basic	262–298



1st quartile (51%–37%)

- Colorado
- Kansas ‡
- Maryland
- Massachusetts
- Minnesota
- Montana ‡
- New Hampshire ‡
- New Jersey
- North Dakota ‡
- Pennsylvania
- South Dakota ‡
- Vermont ‡
- Virginia
- Wisconsin

2nd quartile (36%–34%)

- Connecticut
- Idaho ‡
- Indiana
- Iowa
- Maine ‡
- Nebraska ‡
- North Carolina
- Ohio
- Oregon
- Texas
- Washington
- Wyoming ‡

3rd quartile (32%–25%)

- Alaska ‡
- Arizona
- Delaware ‡
- Florida
- Georgia
- Illinois
- Kentucky ‡
- Michigan
- Missouri
- New York
- Rhode Island ‡
- South Carolina ‡
- Utah

4th quartile (24%–8%)

- Alabama ‡
- Arkansas ‡
- California
- District of Columbia
- Hawaii ‡
- Louisiana ‡
- Mississippi ‡
- Nevada ‡
- New Mexico ‡
- Oklahoma ‡
- Tennessee
- West Virginia ‡

‡ EPSCoR state

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-6.

Findings

- In 2007, 31% of eighth grade public school students nationwide performed at or above the proficient level in mathematics, which represents a significant increase from 25% in 2000.
- Of the 39 states that participated in both the 2000 and 2007 assessments, 30 showed statistically significant increases in mathematics proficiency among public school eighth graders in 2007.
- States with the highest percentages of eighth graders demonstrating proficiency in mathematics were located in the North Central and mid-Atlantic regions. A number of EPSCoR states were included in this group.
- Substantial differences in mathematics proficiency exist among racial/ethnic groups of eighth graders, and the gaps between whites and blacks or Hispanics increased slightly between 2000 and 2007. The gender gap in mathematics proficiency among eighth graders is much smaller and increased slightly between 2000 and 2007.

This indicator represents the proportion of a state's eighth grade students in public schools that has met or exceeded the proficiency standard in mathematics.

The National Assessment of Educational Progress (NAEP) provides a federally authorized measure of student performance in mathematics. The National Assessment Governing Board sets a performance standard that provides a context for interpreting NAEP results. The standards define "proficiency" as well as performance levels that indicate greater ("advanced") and lesser ("basic") accomplishment. For the eighth grade, the proficient level (scores 299–332) represents solid academic performance and demonstrates competency over challenging subject-matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (333–500) signifies superior performance. The basic level (262–298) denotes partial mastery of knowledge and skills that are prerequisite for proficient work.

Approximately 153,000 eighth grade students in 6,900 schools participated in the 2007 NAEP mathematics assessment. A designation of NA (not available) indicates that the state either did not participate in the assessment or did not have a representative sample of eighth graders that was large enough for reporting state-level results.

Table 8-6

Students reaching proficiency in eighth grade mathematics, by state: 2000, 2005, and 2007

(Percent)

State	2000	2005	2007
United States	25*	28*	31
Alabama	16	15	18
Alaska	NA	29	32
Arizona	20*	26	26
Arkansas	13*	22	24
California	17*	22*	24
Colorado	NA	32*	37
Connecticut	33	35	35
Delaware	NA	30	31
District of Columbia	6	7	8
Florida	NA	26	27
Georgia	19*	23	25
Hawaii	16*	18*	21
Idaho	26*	30*	34
Illinois	26*	29	31
Indiana	29*	30*	35
Iowa	NA	34	35
Kansas	34*	34*	40
Kentucky	20*	23*	27
Louisiana	11*	16	19
Maine	30	30*	34
Maryland	27*	30*	37
Massachusetts	30*	43*	51
Michigan	28	29	29
Minnesota	39	43	43
Mississippi	9*	14	14
Missouri	21*	26*	30
Montana	36	36	38
Nebraska	30*	35	35
Nevada	18*	21	23
New Hampshire	NA	35	38
New Jersey	NA	36*	40
New Mexico	12*	14*	17
New York	24*	31	30
North Carolina	27*	32	34
North Dakota	30*	35*	41
Ohio	30*	34	35
Oklahoma	18	20	21
Oregon	31	33	35
Pennsylvania	NA	31*	38
Rhode Island	22*	24*	28
South Carolina	17*	30	32
South Dakota	NA	36	39
Tennessee	16*	21	23
Texas	24*	31*	35
Utah	25*	30	32
Vermont	31*	38*	41
Virginia	25*	33	37
Washington	NA	36	36
West Virginia	17	17	19
Wisconsin	NA	36	37
Wyoming	23*	29*	36
Puerto Rico	NA	NA	NA

*significantly different ($p < .05$) from 2007 when only one jurisdiction or the nation is being examined; NA = not available

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 mathematics scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

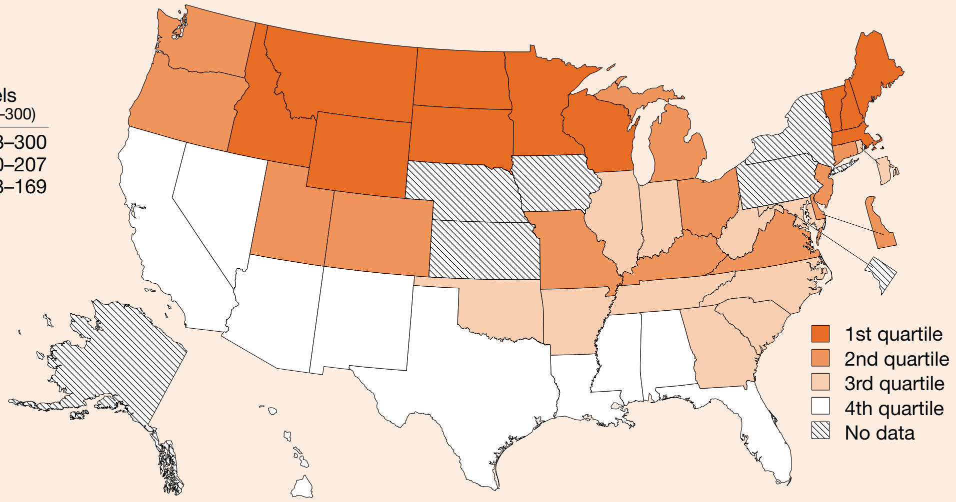
Science and Engineering Indicators 2010

Eighth Grade Science Performance

Figure 8-7
Average eighth grade science performance: 2005

Achievement levels
(Scores range from 0–300)

Advanced 208–300
Proficient 170–207
Basic............. 143–169



1st quartile (163–158)	2nd quartile (155–152)	3rd quartile (150–144)	4th quartile (143–132)	No data
Idaho ‡	Colorado	Arkansas ‡	Alabama ‡	Alaska ‡
Maine ‡	Connecticut	Georgia	Arizona	District of Columbia
Massachusetts	Delaware ‡	Illinois	California	Iowa
Minnesota	Kentucky ‡	Indiana	Florida	Kansas ‡
Montana ‡	Michigan	Maryland	Hawaii ‡	Nebraska ‡
New Hampshire ‡	Missouri	North Carolina	Louisiana ‡	New York
North Dakota ‡	New Jersey	Oklahoma ‡	Mississippi ‡	Pennsylvania
South Dakota ‡	Ohio	Rhode Island ‡	Nevada ‡	
Vermont ‡	Oregon	South Carolina ‡	New Mexico ‡	
Wisconsin	Utah	Tennessee	Texas	
Wyoming ‡	Virginia	West Virginia ‡		
	Washington			

‡ EPSCoR state

NOTE: See figure 8-8 text for explanation of achievement levels.

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-7.

Findings

- Of the 36 states that participated in both the 2000 and 2005 science assessments, 10 states reported 2005 average scores that were significantly higher than those in 2000 and 4 states reported average scores that were significantly lower.
- States with the highest average science scores for eighth graders were concentrated in the northern United States. A number of EPSCoR states were included in this group.
- The gaps in science scores between white eighth graders and black or Hispanic eighth graders did not change significantly between 2000 and 2005.

This indicator represents each state's average score on the National Assessment of Educational Progress (NAEP) in science for its eighth grade students in public schools. The NAEP science assessment is a federally authorized measure of student performance in which 44 states participated in 2005.

Student performance is presented in terms of average scores on a scale from 0 to 300. Higher scores indicate that eighth graders are demonstrating a stronger foundation for adult science competency. An average score designated as NA (not applicable) indicates that the state either did not participate in the assessment or did not have a representative sample of eighth graders that was large enough for reporting state-level results.

NAEP allows students with disabilities or limited English-language proficiency to use certain accommodations (e.g., extended time, individual testing, or small group testing). All data presented here represent scores from tests that offered these accommodations.

Table 8-7

Average eighth grade science performance, by state: 2000 and 2005

(Score out of 300)

State	2000	2005
United States	148	147
Alabama	143*	138
Alaska	NA	NA
Arizona	145*	140
Arkansas	142	144
California	129*	136
Colorado	NA	155
Connecticut	153	152
Delaware	NA	152
District of Columbia	NA	NA
Florida	NA	141
Georgia	142	144
Hawaii	130*	136
Idaho	158	158
Illinois	148	148
Indiana	154*	150
Iowa	NA	NA
Kansas	NA	NA
Kentucky	150*	153
Louisiana	134*	138
Maine	158	158
Maryland	146	145
Massachusetts	158*	161
Michigan	155	155
Minnesota	159	158
Mississippi	134	132
Missouri	154	154
Montana	164	162
Nebraska	158	NA
Nevada	141*	138
New Hampshire	NA	162
New Jersey	NA	153
New Mexico	139	138
New York	145	NA
North Carolina	145	144
North Dakota	159*	163
Ohio	159	155
Oklahoma	149	147
Oregon	154	153
Pennsylvania	NA	NA
Rhode Island	148	146
South Carolina	140*	145
South Dakota	NA	161
Tennessee	145	145
Texas	143	143
Utah	154	154
Vermont	159*	162
Virginia	151*	155
Washington	NA	154
West Virginia	146	147
Wisconsin	NA	158
Wyoming	156*	159
Puerto Rico	NA	NA

*significantly different from 2005 when only one jurisdiction or the nation is being examined; NA = not available

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores for public schools only.

SOURCE: National Center for Education Statistics, NAEP (various years).

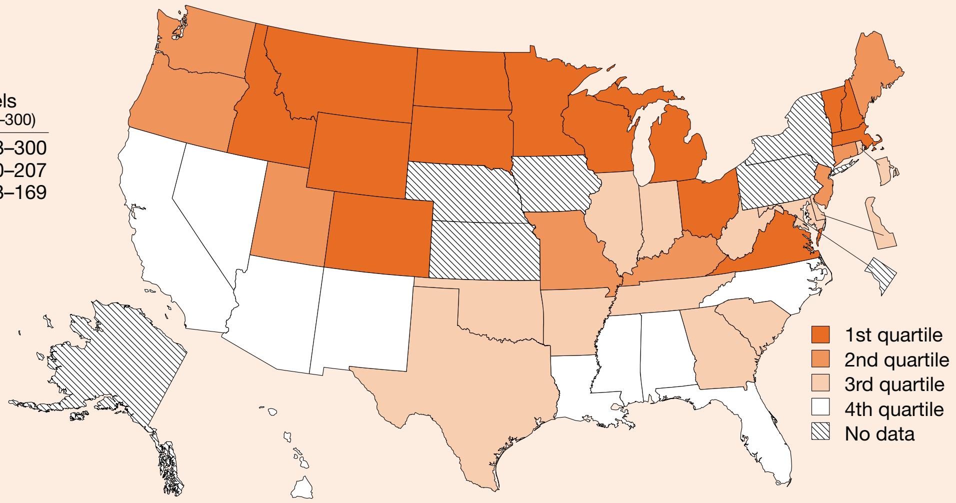
Science and Engineering Indicators 2010

Eighth Grade Science Proficiency

Figure 8-8
Students reaching proficiency in eighth grade science: 2005
(Percent; scores of 170 and above indicate proficiency)

Achievement levels
(Scores range from 0–300)

Advanced 208–300
Proficient 170–207
Basic............. 143–169



1st quartile (43%–35%)	2nd quartile (34%–31%)	3rd quartile (29%–23%)	4th quartile (22%–14%)	No data
Colorado	Connecticut	Arkansas ‡	Alabama ‡	Alaska ‡
Idaho ‡	Kentucky ‡	Delaware ‡	Arizona	District of Columbia
Massachusetts	Maine ‡	Georgia	California	Iowa
Michigan	Missouri	Illinois	Florida	Kansas ‡
Minnesota	New Jersey	Indiana	Hawaii ‡	Nebraska ‡
Montana ‡	Oregon	Maryland	Louisiana ‡	New York
New Hampshire ‡	Utah	Oklahoma ‡	Mississippi ‡	Pennsylvania
North Dakota ‡	Washington	Rhode Island ‡	Nevada ‡	
Ohio		South Carolina ‡	New Mexico ‡	
South Dakota ‡		Tennessee	North Carolina	
Vermont ‡		Texas		
Virginia		West Virginia ‡		
Wisconsin				
Wyoming ‡				

‡ EPSCoR state

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress. See table 8-8.

Findings

- Of the 36 states that participated in both the 2000 and 2005 science assessments for public school eighth graders, 4 states showed significant increases in science proficiency in 2005.
- Unlike math proficiency, science proficiency did not increase between 2000 and 2005.
- The states with the highest percentages of eighth graders who were proficient in science are concentrated in the northern United States. A number of EPSCoR states were included in this group.
- The nationwide percentage of students who performed at or above the proficient level in science was identical for fourth and eighth graders in 2005.

This indicator represents the proportion of a state's eighth grade students in public schools that has met or exceeded the proficiency standard in science.

The National Assessment of Educational Progress (NAEP) provides a federally authorized measure of student performance in science. The National Assessment Governing Board sets performance standards that provide a context for interpreting NAEP results. The standards define "proficiency" as well performance levels that indicate greater ("advanced") and lesser ("basic") accomplishment. For the eighth grade, the proficient level (scores 170–207) represents solid academic performance and demonstrates competency over challenging subject-matter knowledge, its application to real-world situations, and mastery of appropriate analytical skills. The advanced level (208–300) signifies superior performance. The basic level (143–169) denotes partial mastery of knowledge and skills that are prerequisite for proficient work. A National Academy of Sciences panel evaluated the process used to establish the standards for the science assessment and urged that they be considered developmental and interpreted with caution.

Approximately 143,400 eighth grade students in 6,400 schools participated in the 2005 NAEP science assessment. A designation of NA (not available) indicates that the state either did not participate in the assessment or did not have a representative sample of eighth graders that was large enough for reporting state-level results.

Table 8-8

Students reaching proficiency in eighth grade science, by state: 2000 and 2005

(Percent)

State	2000	2005
United States	29	27
Alabama	23	19
Alaska	NA	NA
Arizona	23	20
Arkansas	22	23
California	14*	18
Colorado	NA	35
Connecticut	35	33
Delaware	NA	29
District of Columbia	NA	NA
Florida	NA	21
Georgia	23	25
Hawaii	14	15
Idaho	37	36
Illinois	29	27
Indiana	33	29
Iowa	NA	NA
Kansas	NA	NA
Kentucky	28	31
Louisiana	18	19
Maine	35	34
Maryland	27	26
Massachusetts	39	41
Michigan	35	35
Minnesota	41	39
Mississippi	15	14
Missouri	33	33
Montana	44	42
Nebraska	38	NA
Nevada	22	19
New Hampshire	NA	41
New Jersey	NA	33
New Mexico	20	18
New York	28	NA
North Carolina	25	22
North Dakota	38*	43
Ohio	39	35
Oklahoma	25	25
Oregon	34	32
Pennsylvania	NA	NA
Rhode Island	27	26
South Carolina	20	23
South Dakota	NA	41
Tennessee	24	25
Texas	23	23
Utah	34	33
Vermont	39	41
Virginia	29*	35
Washington	NA	33
West Virginia	24	23
Wisconsin	NA	39
Wyoming	34*	37
Puerto Rico	NA	NA

*significantly different from 2005 when only one jurisdiction or the nation is being examined; NA = not available

NOTES: National average for United States is reported value in National Assessment of Educational Progress (NAEP) reports. NAEP grade 8 science scores for public schools only.

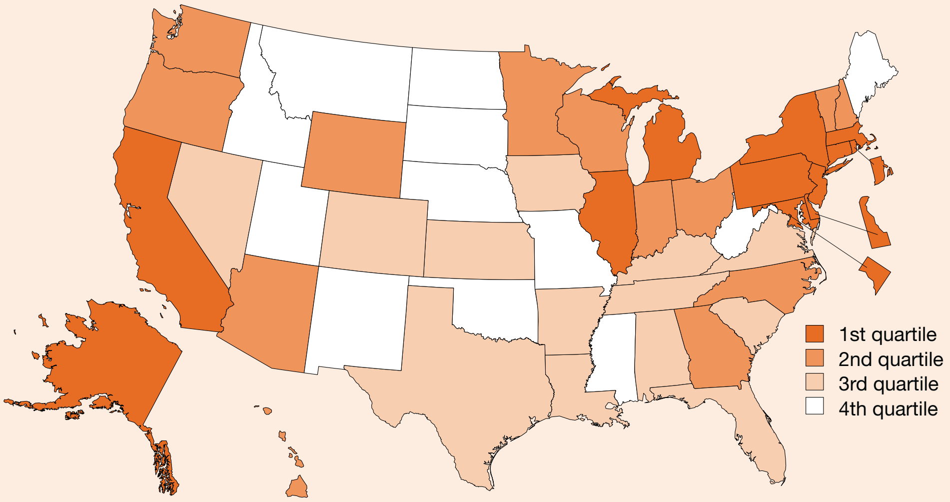
SOURCE: National Center for Education Statistics, NAEP (various years).

Science and Engineering Indicators 2010

Public School Teacher Salaries

Figure 8-9

Public school teacher salaries: 2007



1st quartile ($63,640–$54,658)	2nd quartile ($51,937–$45,941)	3rd quartile ($45,833–$42,816)	4th quartile ($42,798–$35,378)
Alaska ‡	Arizona	Alabama ‡	Idaho ‡
California	Georgia	Arkansas ‡	Maine ‡
Connecticut	Hawaii ‡	Colorado	Mississippi ‡
Delaware ‡	Indiana	Florida	Missouri
District of Columbia	Minnesota	Iowa	Montana ‡
Illinois	New Hampshire ‡	Kansas ‡	Nebraska ‡
Maryland	North Carolina	Kentucky ‡	New Mexico ‡
Massachusetts	Ohio	Louisiana ‡	North Dakota ‡
Michigan	Oregon	Nevada ‡	Oklahoma ‡
New Jersey	Vermont ‡	South Carolina ‡	South Dakota ‡
New York	Washington	Tennessee	Utah
Pennsylvania	Wisconsin	Texas	West Virginia ‡
Rhode Island ‡	Wyoming ‡	Virginia	

‡ EPSCoR state

SOURCE: National Center for Education Statistics, *Digest of Education Statistics*. See table 8-9.

Findings

- During the 2006–07 academic year, salaries for public school teachers nationwide averaged $50,816, ranging from a state low of $35,378 to a high of $63,640.
- Between 1997 and 2007, average teacher salaries across the nation rose by 32% in terms of current dollars. Average teacher salaries remained essentially flat when expressed in constant dollars.
- The highest salaries for teachers are found in states with a high cost of living.
- Teachers in EPSCoR states tended to receive lower average salaries, placing them predominantly in the bottom half of the state rankings.
- High salaries for public school teachers do not necessarily correspond to high student achievement scores on the NAEP mathematics and science tests.

This indicator measures the average base salary of all full-time public school teachers. The year is the end date of the academic year. For example, 2007 data represent salaries for the 2006–07 academic year. The figures (given in current dollars) include salaries for teachers with varying amounts of teaching experience and various kinds and levels of formal education.

Public school teacher salaries may reflect a range of factors, including the value that the state places on primary and secondary education, the state's cost of living, the teachers' experience and education level, and the local supply and demand in the job market. Relatively low teacher salaries may hinder recruitment into the teaching profession.

Table 8-9
Public school teacher salaries, by state: 1997, 2002, and 2007

(Dollars)

State	1997	2002	2007
United States	38,509	44,604	50,816
Alabama	32,549	39,268	43,389
Alaska	50,647	49,418	54,658
Arizona	33,350	36,966	45,941
Arkansas	29,975	35,389	44,245
California	43,474	53,870	63,640
Colorado	36,175	40,222	45,833
Connecticut	50,426	54,300	60,822
Delaware	41,436	48,363	54,680
District of Columbia	45,012	47,049	59,000
Florida	33,881	38,719	45,308
Georgia	36,042	44,073	49,905
Hawaii	35,842	41,951	51,922
Idaho	31,818	37,482	42,798
Illinois	42,679	50,000	58,246
Indiana	38,575	44,195	47,831
Iowa	33,275	38,230	43,130
Kansas	35,837	36,673	43,334
Kentucky	33,950	37,847	43,646
Louisiana	28,347	35,437	42,816
Maine	33,800	37,100	41,596
Maryland	41,148	46,200	56,927
Massachusetts	43,806	50,293	58,624
Michigan	44,251	52,037	54,895
Minnesota	37,975	43,330	49,634
Mississippi	27,720	32,800	40,182
Missouri	34,342	37,695	41,839
Montana	29,950	34,379	41,225
Nebraska	31,768	36,236	42,044
Nevada	37,340	41,524	45,342
New Hampshire	36,867	38,911	46,527
New Jersey	49,349	54,575	59,920
New Mexico	29,715	36,490	42,780
New York	49,560	53,081	58,537
North Carolina	31,225	42,959	46,410
North Dakota	27,711	31,709	38,822
Ohio	38,831	44,492	51,937
Oklahoma	29,270	35,412	42,379
Oregon	40,900	43,886	50,911
Pennsylvania	47,429	50,599	54,970
Rhode Island	43,019	49,758	55,956
South Carolina	32,659	38,943	44,133
South Dakota	26,764	31,295	35,378
Tennessee	33,789	38,554	43,816
Texas	32,644	39,293	44,897
Utah	31,750	37,414	40,566
Vermont	37,200	38,802	48,370
Virginia	35,837	41,262	44,727
Washington	37,860	43,483	47,882
West Virginia	33,159	36,751	40,531
Wisconsin	38,950	43,114	47,901
Wyoming	31,721	37,841	50,692
Puerto Rico	NA	NA	NA

NA = not available

NOTES: National average for United States is reported value in *Digest of Education Statistics*. Average salaries reported in current dollars.

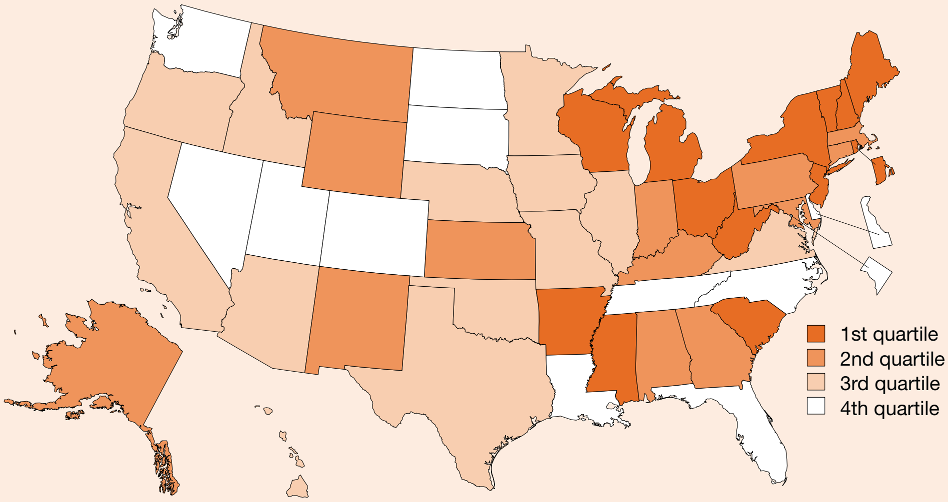
SOURCE: National Center for Education Statistics, *Digest of Education Statistics* (various years).

Science and Engineering Indicators 2010

Elementary and Secondary Public School Current Expenditures as Share of Gross Domestic Product

Figure 8-10

Elementary and secondary public school current expenditures as share of gross domestic product: 2007



1st quartile (5.28%–3.87%)	2nd quartile (3.86%–3.54%)	3rd quartile (3.52%–3.14%)	4th quartile (3.09%–1.22%)
Arkansas ‡	Alabama ‡	Arizona	Colorado
Maine ‡	Alaska ‡	California	Delaware ‡
Michigan	Connecticut	Hawaii ‡	District of Columbia
Mississippi ‡	Georgia	Idaho ‡	Florida
New Hampshire ‡	Indiana	Illinois	Louisiana ‡
New Jersey	Kansas ‡	Iowa	Nevada ‡
New York	Kentucky ‡	Minnesota	North Carolina
Ohio	Maryland	Missouri	North Dakota ‡
Rhode Island ‡	Massachusetts	Nebraska ‡	South Dakota ‡
South Carolina ‡	Montana ‡	Oklahoma ‡	Tennessee
Vermont ‡	New Mexico ‡	Oregon	Utah
West Virginia ‡	Pennsylvania	Texas	Washington
Wisconsin	Wyoming ‡	Virginia	

‡ EPSCoR state

SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, National Public Education Financial Survey; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-10.

Findings

- The 2007 national average for spending on elementary and secondary education was 3.48% of the GDP, a slight increase from 3.28% in 1997. Among individual states, the value for this indicator ranged from 2.34% to 5.28% of the state's GDP in 2007, indicating that some states were directing a much higher percentage of their resources toward elementary and secondary education.
- Spending for elementary and secondary public education as a share of the state's GDP decreased in 16 states and the District of Columbia during the 1997–2007 period.
- States that spent the highest percentage of their GDP on elementary and secondary education are located in the eastern region of the United States. A number of EPSCoR states were included in this group.

This indicator measures the relative amount of resources that local, state, and federal governments direct toward public education in prekindergarten through grade 12. It is calculated by dividing the current expenditures of elementary and secondary public schools by the state's gross domestic product (GDP). Current expenditures include instruction and instruction-related costs, student support service, administration, and operations and exclude funds for school construction and other capital outlays, debt service, and programs outside of public elementary and secondary education. State and local support represent the largest sources of funding for elementary and secondary education.

Financial data on public elementary and secondary education are reported by the National Center for Education Statistics, Department of Education. These data are part of the National Public Education Financial Survey and are included in the 2007 Common Core of Data, a comprehensive annual national statistical database that covers approximately 97,000 public elementary and secondary schools and 18,000 school districts in the United States. Current expenditures are expressed in actual dollars and their data year is the end date of the academic year. For example, current expenditure data for 2007 represent expenditures for the 2006–07 academic year. GDP data refer to the 2007 calendar year.

Table 8-10
Elementary and secondary public school current expenditures as share of gross domestic product, by state: 1997, 2002, and 2007

	Public school expenditures (current $thousands)			State GDP (current $millions)			School expenditures/ GDP (%)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	270,151,583	368,499,139	476,825,866	8,237,996	10,398,403	13,715,741	3.28	3.54	3.48
Alabama	3,436,406	4,444,390	6,245,031	102,433	123,805	164,524	3.35	3.59	3.80
Alaska	1,069,379	1,284,854	1,634,316	25,028	29,186	44,887	4.27	4.40	3.64
Arizona	3,527,473	5,499,645	7,815,720	127,370	171,942	245,952	2.77	3.20	3.18
Arkansas	2,074,113	2,822,877	3,997,701	59,182	72,203	95,116	3.50	3.91	4.20
California	29,909,168	46,265,544	57,352,599	1,019,150	1,340,446	1,801,762	2.93	3.45	3.18
Colorado	3,577,211	5,151,003	6,579,053	132,881	182,154	235,848	2.69	2.83	2.79
Connecticut	4,522,716	6,031,062	7,855,459	137,698	166,073	212,252	3.28	3.63	3.70
Delaware	788,715	1,072,875	1,437,707	35,488	45,324	61,545	2.22	2.37	2.34
District of Columbia	632,952	912,432	1,130,006	50,368	67,717	92,516	1.26	1.35	1.22
Florida	12,018,676	15,535,864	22,887,024	391,451	522,719	741,861	3.07	2.97	3.09
Georgia	7,230,405	10,853,496	14,828,715	237,468	306,680	391,241	3.04	3.54	3.79
Hawaii	1,057,069	1,348,381	1,998,913	37,546	43,476	62,019	2.82	3.10	3.22
Idaho	1,090,597	1,481,803	1,777,491	28,510	36,651	52,110	3.83	4.04	3.41
Illinois	11,720,249	16,480,787	20,326,591	403,982	487,129	617,409	2.90	3.38	3.29
Indiana	6,055,055	7,704,547	9,497,077	168,115	205,015	249,229	3.60	3.76	3.81
Iowa	2,885,943	3,565,796	4,231,932	81,923	97,356	129,911	3.52	3.66	3.26
Kansas	2,568,525	3,450,923	4,339,477	72,071	89,573	116,986	3.56	3.85	3.71
Kentucky	3,382,062	4,268,608	5,424,621	105,725	120,726	152,099	3.20	3.54	3.57
Louisiana	3,747,507	4,802,565	6,040,368	113,261	134,308	207,407	3.31	3.58	2.91
Maine	1,351,500	1,812,798	2,258,764	30,873	38,625	48,021	4.38	4.69	4.70
Maryland	5,529,309	7,480,723	10,198,084	154,139	204,120	264,426	3.59	3.66	3.86
Massachusetts	6,846,610	9,957,292	12,453,611	221,827	284,386	352,178	3.09	3.50	3.54
Michigan	11,686,124	14,975,150	17,013,259	298,994	349,837	379,934	3.91	4.28	4.48
Minnesota	5,087,353	6,586,559	8,060,410	155,938	198,558	252,472	3.26	3.32	3.19
Mississippi	2,035,675	2,642,116	3,692,358	57,954	68,144	87,652	3.51	3.88	4.21
Missouri	4,775,931	6,491,603	7,957,705	158,203	188,351	229,027	3.02	3.45	3.47
Montana	902,252	1,073,005	1,320,112	19,142	23,560	34,266	4.71	4.55	3.85
Nebraska	1,707,455	2,206,946	2,825,608	50,542	59,934	80,360	3.38	3.68	3.52
Nevada	1,434,395	2,169,000	3,311,471	59,917	81,274	129,314	2.39	2.67	2.56
New Hampshire	1,173,958	1,641,378	2,246,692	36,569	46,188	57,820	3.21	3.55	3.89
New Jersey	11,771,941	15,822,609	22,448,262	300,910	372,754	461,295	3.91	4.24	4.87
New Mexico	1,557,376	2,204,165	2,904,474	47,442	52,510	75,192	3.28	4.20	3.86
New York	24,237,291	32,218,975	43,679,908	654,750	821,577	1,105,020	3.70	3.92	3.95
North Carolina	5,964,939	8,550,546	11,248,336	228,864	296,435	390,467	2.61	2.88	2.88
North Dakota	577,498	711,437	838,221	16,316	19,880	28,518	3.54	3.58	2.94
Ohio	10,948,074	14,774,065	18,251,361	332,124	389,773	462,506	3.30	3.79	3.95
Oklahoma	2,990,044	3,875,547	4,750,536	78,019	97,170	136,374	3.83	3.99	3.48
Oregon	3,184,100	4,214,512	5,039,632	96,591	117,131	158,268	3.30	3.60	3.18
Pennsylvania	12,820,704	15,550,975	20,404,304	343,368	423,110	533,212	3.73	3.68	3.83
Rhode Island	1,151,888	1,533,455	2,039,633	28,506	36,909	46,699	4.04	4.15	4.37
South Carolina	3,296,661	4,744,809	6,023,043	97,397	121,582	151,703	3.38	3.90	3.97
South Dakota	627,109	819,296	977,006	19,804	26,416	35,211	3.17	3.10	2.77
Tennessee	4,145,380	5,511,452	6,975,099	153,405	191,525	245,162	2.70	2.88	2.85
Texas	20,167,238	28,191,128	36,105,784	599,492	783,480	1,148,531	3.36	3.60	3.14
Utah	1,822,725	2,374,702	2,987,810	56,590	72,665	105,574	3.22	3.27	2.83
Vermont	718,092	992,149	1,300,149	15,167	19,553	24,627	4.73	5.07	5.28
Virginia	6,343,766	8,718,554	12,465,858	211,921	285,759	384,132	2.99	3.05	3.25
Washington	5,587,808	7,103,721	8,752,007	178,334	231,463	310,279	3.13	3.07	2.82
West Virginia	1,847,560	2,219,013	2,742,344	38,795	45,032	57,877	4.76	4.93	4.74
Wisconsin	5,975,122	7,592,176	9,029,660	151,549	188,600	233,406	3.94	4.03	3.87
Wyoming	591,488	761,830	1,124,564	14,904	19,619	31,544	3.97	3.88	3.57
Puerto Rico	1,796,077	2,152,724	3,268,200	48,187	71,624	NA	3.73	3.01	NA

NA = not available

GDP = gross domestic product

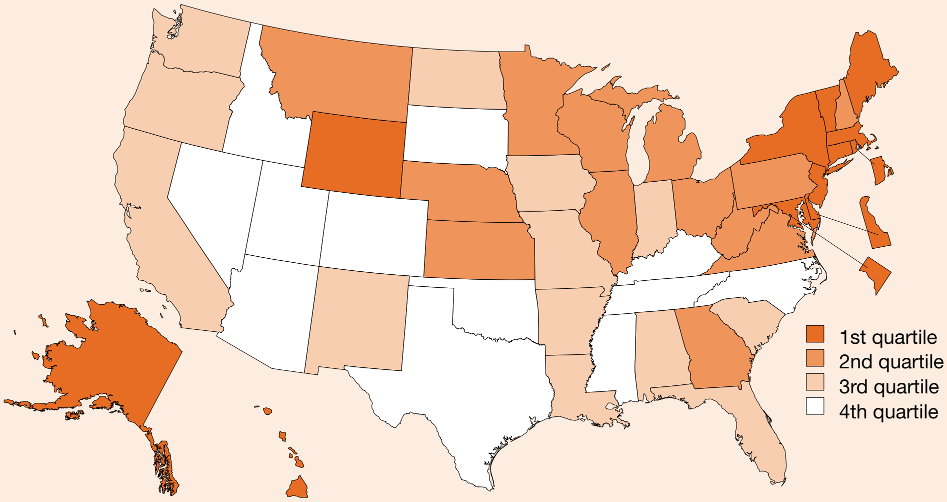
SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, National Public Education Financial Survey (various years); Bureau of Economic Analysis, Gross Domestic Product data (various years); and Government of Puerto Rico, Office of the Governor (various years).

Science and Engineering Indicators 2010

Current Expenditures per Pupil for Elementary and Secondary Public Schools

Figure 8-11

Current expenditures per pupil for elementary and secondary public schools: 2007



1st quartile ($16,163–$11,060)	2nd quartile ($11,037–$9,102)	3rd quartile ($9,080–$8,391)	4th quartile ($8,286–$5,706)
Alaska ‡	Georgia	Alabama ‡	Arizona
Connecticut	Illinois	Arkansas ‡	Colorado
Delaware ‡	Kansas ‡	California	Idaho ‡
District of Columbia	Michigan	Florida	Kentucky ‡
Hawaii ‡	Minnesota	Indiana	Mississippi ‡
Maine ‡	Montana ‡	Iowa	Nevada ‡
Maryland	Nebraska ‡	Louisiana ‡	North Carolina
Massachusetts	New Hampshire ‡	Missouri	Oklahoma ‡
New Jersey	Ohio	New Mexico ‡	South Dakota ‡
New York	Pennsylvania	North Dakota ‡	Tennessee
Rhode Island ‡	Virginia	Oregon	Texas
Vermont ‡	West Virginia ‡	South Carolina ‡	Utah
Wyoming ‡	Wisconsin	Washington	

‡ EPSCoR state

SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, State Nonfiscal Survey of Public Elementary/Secondary Education; and National Public Education Financial Survey. See table 8-11.

Findings

- Per-pupil spending on day-to-day operations grew nationwide from $5,923 in 1997 to $9,683 in 2007, an increase of 63% in unadjusted dollars. This was equivalent to an increase of approximately 30% after adjusting for inflation.
- In 2007, all states showed substantial increases in per-pupil spending relative to 1997, and only 1 state did not exceed the 1997 national average, compared with 31 states in 1997.
- Per-pupil spending in individual states varied widely, ranging from a high of $16,163 to a low of $5,706 in 2007.
- No direct correlation can be made between spending and academic performance. Several states that ranked in the lower two quartiles of this indicator ranked in the upper quartiles of the National Assessment of Educational Progress indicators

This indicator measures the amount that local, state, and federal governments spend on elementary and secondary education, adjusted for the size of the student body. It is calculated by dividing the current expenditures over the entire academic year for prekindergarten through grade 12 by the number of students in those grades in public schools. Current expenditures represent amounts spent on the day-to-day operations of schools and school districts. They include expenditures for instruction and instruction-related costs, student support services, administration, and operations and exclude funds for school construction and other capital outlays, debt service, and programs outside of public elementary and secondary education.

During the 2006–07 school year, 65.8% of current expenses were used for instructional costs, 5.3% for student support services, 10.8% for administrative costs, and 18.0% for operational costs.

The number of pupils enrolled in prekindergarten through grade 12 is determined during the fall of the academic year. All figures represent actual spending and have not been adjusted for inflation. The year is the end date of the academic year. For example, data for 2007 represent costs for the 2006–07 academic year.

Current expenditures per pupil do not take into account the cost of living in a state, which could affect the amount of goods and services that can be purchased.

Table 8-11

Current expenditures per pupil for elementary and secondary public schools, by state: 1997, 2002, and 2007

	Public school expenditures ($thousands)			Student enrollment			Per-pupil expenditures ($)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	270,151,583	368,499,139	476,825,866	45,611,046	47,647,972	49,245,840	5,923	7,734	9,683
Alabama	3,436,406	4,444,390	6,245,031	747,932	737,190	743,632	4,595	6,029	8,398
Alaska	1,069,379	1,284,854	1,634,316	129,919	134,358	132,608	8,231	9,563	12,324
Arizona	3,527,473	5,499,645	7,815,720	799,250	922,180	1,065,082	4,413	5,964	7,338
Arkansas	2,074,113	2,822,877	3,997,701	457,349	449,805	476,409	4,535	6,276	8,391
California	29,909,168	46,265,544	57,352,599	5,686,198	6,223,821	6,406,821	5,260	7,434	8,952
Colorado	3,577,211	5,151,003	6,579,053	673,438	742,145	794,026	5,312	6,941	8,286
Connecticut	4,522,716	6,031,062	7,855,459	527,129	570,228	575,100	8,580	10,577	13,659
Delaware	788,715	1,072,875	1,437,707	110,549	115,560	122,254	7,135	9,284	11,760
District of Columbia	632,952	912,432	1,130,006	78,648	75,392	72,850	8,048	12,103	15,511
Florida	12,018,676	15,535,864	22,887,024	2,242,212	2,500,478	2,671,513	5,360	6,213	8,567
Georgia	7,230,405	10,853,496	14,828,715	1,346,761	1,470,634	1,629,157	5,369	7,380	9,102
Hawaii	1,057,069	1,348,381	1,998,913	187,653	184,546	180,728	5,633	7,306	11,060
Idaho	1,090,597	1,481,803	1,777,491	245,252	246,521	267,380	4,447	6,011	6,648
Illinois	11,720,249	16,480,787	20,326,591	1,973,040	2,071,391	2,118,276	5,940	7,956	9,596
Indiana	6,055,055	7,704,547	9,497,077	982,876	996,133	1,045,940	6,161	7,734	9,080
Iowa	2,885,943	3,565,796	4,231,932	502,941	485,932	481,368	5,738	7,338	8,791
Kansas	2,568,525	3,450,923	4,339,477	466,293	470,205	469,506	5,508	7,339	9,243
Kentucky	3,382,062	4,268,608	5,424,621	656,089	654,363	683,173	5,155	6,523	7,940
Louisiana	3,747,507	4,802,565	6,040,368	793,296	731,328	675,851	4,724	6,567	8,937
Maine	1,351,500	1,812,798	2,258,764	213,593	205,586	193,986	6,327	8,818	11,644
Maryland	5,529,309	7,480,723	10,198,084	818,583	860,640	851,640	6,755	8,692	11,975
Massachusetts	6,846,610	9,957,292	12,453,611	933,898	973,140	968,661	7,331	10,232	12,857
Michigan	11,686,124	14,975,150	17,013,259	1,685,714	1,730,668	1,714,709	6,932	8,653	9,922
Minnesota	5,087,353	6,586,559	8,060,410	847,204	851,384	840,565	6,005	7,736	9,589
Mississippi	2,035,675	2,642,116	3,692,358	503,967	493,507	495,026	4,039	5,354	7,459
Missouri	4,775,931	6,491,603	7,957,705	900,517	909,792	899,426	5,304	7,135	8,848
Montana	902,252	1,073,005	1,320,112	164,627	151,947	143,624	5,481	7,062	9,191
Nebraska	1,707,455	2,206,946	2,825,608	291,967	285,095	280,647	5,848	7,741	10,068
Nevada	1,434,395	2,169,000	3,311,471	282,131	356,814	424,240	5,084	6,079	7,806
New Hampshire	1,173,958	1,641,378	2,246,692	198,308	206,847	203,551	5,920	7,935	11,037
New Jersey	11,771,941	15,822,609	22,448,262	1,227,832	1,341,656	1,388,850	9,588	11,793	16,163
New Mexico	1,557,376	2,204,165	2,904,474	332,632	320,260	328,220	4,682	6,882	8,849
New York	24,237,291	32,218,975	43,679,908	2,843,131	2,872,132	2,809,649	8,525	11,218	15,546
North Carolina	5,964,939	8,550,546	11,248,336	1,210,108	1,315,363	1,427,880	4,929	6,501	7,878
North Dakota	577,498	711,437	838,221	120,123	106,047	96,670	4,808	6,709	8,671
Ohio	10,948,074	14,774,065	18,251,361	1,844,698	1,830,985	1,836,096	5,935	8,069	9,940
Oklahoma	2,990,044	3,875,547	4,750,536	620,695	622,139	639,391	4,817	6,229	7,430
Oregon	3,184,100	4,214,512	5,039,632	537,854	551,480	562,574	5,920	7,642	8,958
Pennsylvania	12,820,704	15,550,975	20,404,304	1,804,256	1,821,627	1,871,060	7,106	8,537	10,905
Rhode Island	1,151,888	1,533,455	2,039,633	151,324	158,046	151,612	7,612	9,703	13,453
South Carolina	3,296,661	4,744,809	6,023,043	652,816	676,198	703,119	5,050	7,017	8,566
South Dakota	627,109	819,296	977,006	143,331	127,542	121,158	4,375	6,424	8,064
Tennessee	4,145,380	5,511,452	6,975,099	904,818	924,899	978,368	4,581	5,959	7,129
Texas	20,167,238	28,191,128	36,105,784	3,828,975	4,163,447	4,599,509	5,267	6,771	7,850
Utah	1,822,725	2,374,702	2,987,810	481,812	484,677	523,586	3,783	4,900	5,706
Vermont	718,092	992,149	1,300,149	106,341	101,179	95,399	6,753	9,806	13,629
Virginia	6,343,766	8,718,554	12,465,858	1,096,093	1,163,091	1,220,440	5,788	7,496	10,214
Washington	5,587,808	7,103,721	8,752,007	974,504	1,009,200	1,026,774	5,734	7,039	8,524
West Virginia	1,847,560	2,219,013	2,742,344	304,052	282,885	281,939	6,076	7,844	9,727
Wisconsin	5,975,122	7,592,176	9,029,660	879,259	879,361	871,027	6,796	8,634	10,367
Wyoming	591,488	761,830	1,124,564	99,058	88,128	84,770	5,971	8,645	13,266
Puerto Rico	1,796,077	2,152,724	3,268,200	618,861	604,177	544,138	2,902	3,563	6,006

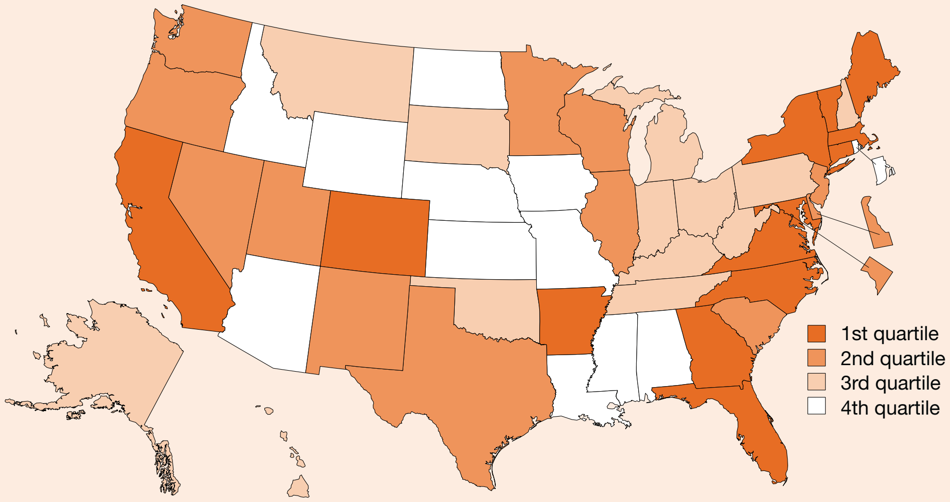
SOURCES: National Center for Education Statistics (NCES), NCES Common Core of Data, State Nonfiscal Survey of Public Elementary/Secondary Education (various years); and National Public Education Financial Survey (various years).

Science and Engineering Indicators 2010

Share of Public High School Students Taking Advanced Placement Exams

Figure 8-12

Share of public high school students taking Advanced Placement Exams: 2008



1st quartile (37.2%–28.4%)	2nd quartile (27.6%–21.2%)	3rd quartile (21.1%–15.3%)	4th quartile (15.0%–8.4%)
Arkansas ‡	Delaware ‡	Alaska ‡	Alabama ‡
California	District of Columbia	Hawaii ‡	Arizona
Colorado	Illinois	Indiana	Idaho ‡
Connecticut	Minnesota	Kentucky ‡	Iowa
Florida	Nevada ‡	Michigan	Kansas ‡
Georgia	New Jersey	Montana ‡	Louisiana ‡
Maine ‡	New Mexico ‡	New Hampshire ‡	Mississippi ‡
Maryland	Oregon	Ohio	Missouri
Massachusetts	South Carolina ‡	Oklahoma ‡	Nebraska ‡
New York	Texas	Pennsylvania	North Dakota ‡
North Carolina	Utah	South Dakota ‡	Rhode Island ‡
Vermont ‡	Washington	Tennessee	Wyoming ‡
Virginia	Wisconsin	West Virginia ‡	

‡ EPSCoR state

SOURCE: College Board, Advanced Placement Report to the Nation. See table 8-12.

Findings

- Nationwide, the percentage of public school students who took an AP Exam rose from 15.9% of the class of 2000 to 25.0% of the class of 2008.
- The percentage of public school students taking an AP Exam varied greatly among states and ranged from 8.4% to 37.2% of the class of 2008. Thirty-six states and the District of Columbia exceeded the 2000 national average in 2008, compared with 15 states and the District of Columbia that exceeded the national average in 2000.
- AP participation levels were higher for all jurisdictions in 2008 than in 2000. Arkansas showed the largest increase, with the class of 2008 exceeding the participation of the class of 2000 by more than 25 percentage points. Many of the EPSCoR states had the lowest AP Exam participation rates.

Participation in the Advanced Placement (AP) program provides a measure of the extent to which a rigorous curriculum is available to and used by high school students. This indicator measures the percentage of students in the graduating class who have taken one or more AP Exams. This percentage is calculated by dividing the number of students in the graduating class who have taken at least one AP Exam by the total number of students in the graduating class.

Throughout the United States, nearly 758,000 public school students from the class of 2008 took nearly 2.2 million AP Exams during their high school careers. Generally, students who take AP Exams have completed a rigorous course of study in a specific subject area in high school with the expectation of obtaining college credit or advanced placement. AP Exams were taken most frequently in U.S. history, English literature and composition, English language and composition, calculus AB, and U.S. government and politics.

In the 50 states and the District of Columbia, students from the class of 2008 attended 12,323 U.S. public schools that participated in the AP program. This represented 79% of the public high schools in the United States. These schools make an average of 10 different AP courses available to their students.

Table 8-12

Share of public high school students taking Advanced Placement Exams, by state: 2000, 2004, and 2008

(Percent)

State	2000	2004	2008
United States	15.9	20.9	25.0
Alabama	7.2	8.8	13.5
Alaska	15.4	16.7	20.3
Arizona	11.3	12.9	14.0
Arkansas	8.1	13.0	33.3
California	22.2	28.5	30.8
Colorado	18.6	25.3	30.5
Connecticut	19.1	24.6	29.0
Delaware	13.3	19.6	26.8
District of Columbia	17.3	23.1	26.3
Florida	22.7	33.5	34.0
Georgia	17.2	21.5	30.3
Hawaii	10.6	14.8	16.6
Idaho	9.6	12.5	14.5
Illinois	13.4	18.6	22.8
Indiana	11.9	15.5	19.8
Iowa	6.9	10.0	12.6
Kansas	7.0	9.2	13.7
Kentucky	10.6	15.5	19.8
Louisiana	3.2	5.0	8.4
Maine	14.8	19.9	31.9
Maryland	20.2	29.2	37.2
Massachusetts	19.6	25.3	29.2
Michigan	13.9	16.8	20.2
Minnesota	13.4	16.4	22.5
Mississippi	5.6	7.0	12.6
Missouri	5.5	8.1	10.8
Montana	10.1	13.0	15.9
Nebraska	5.0	6.3	10.7
Nevada	15.1	19.8	24.6
New Hampshire	13.3	16.0	21.1
New Jersey	17.9	21.3	24.2
New Mexico	11.1	17.0	21.5
New York	27.3	32.4	35.4
North Carolina	19.7	26.9	28.4
North Dakota	5.9	8.4	10.4
Ohio	11.3	15.2	17.6
Oklahoma	9.5	17.0	20.2
Oregon	10.5	13.6	21.2
Pennsylvania	12.4	14.9	17.9
Rhode Island	10.7	12.1	14.9
South Carolina	17.7	19.2	23.1
South Dakota	9.6	13.5	16.0
Tennessee	10.4	13.6	16.5
Texas	16.6	23.2	27.5
Utah	24.5	27.6	27.6
Vermont	16.6	21.2	29.0
Virginia	25.0	28.1	34.1
Washington	11.5	18.5	25.0
West Virginia	8.4	13.0	15.3
Wisconsin	15.2	20.0	24.2
Wyoming	6.1	11.2	15.0
Puerto Rico	NA	NA	NA

NA = not available

NOTE: National average for United States is reported value in Advanced Placement Report to the Nation.

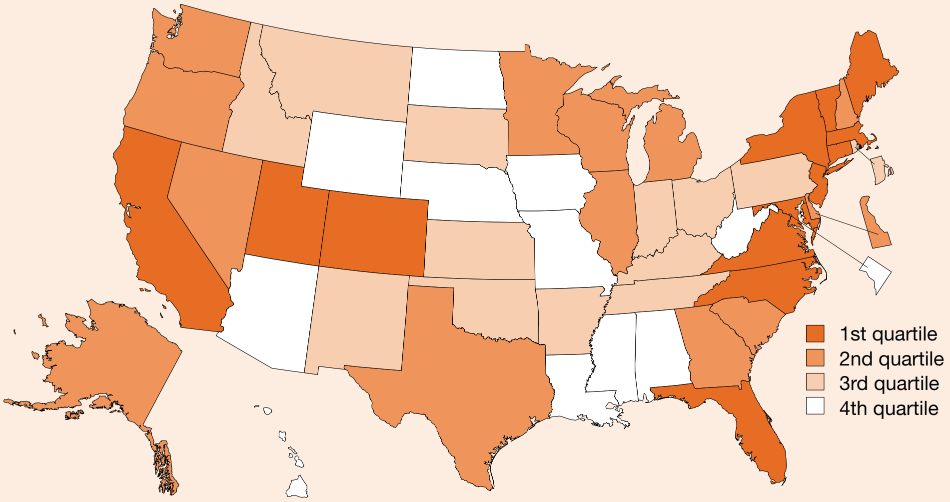
SOURCE: College Board, Advanced Placement Report to the Nation (various years).

Science and Engineering Indicators 2010

Share of Public High School Students Scoring 3 or Higher on at Least One Advanced Placement Exam

Figure 8-13

Share of public high school students scoring 3 or higher on at least one Advanced Placement Exam: 2008



1st quartile (23.4%–17.3%)	2nd quartile (16.6%–13.0%)	3rd quartile (11.9%–8.6%)	4th quartile (8.3%–3.7%)
California	Alaska ‡	Arkansas ‡	Alabama ‡
Colorado	Delaware ‡	Idaho ‡	Arizona
Connecticut	Georgia	Indiana	District of Columbia
Florida	Illinois	Kansas ‡	Hawaii ‡
Maine ‡	Michigan	Kentucky ‡	Iowa
Maryland	Minnesota	Montana ‡	Louisiana ‡
Massachusetts	Nevada ‡	New Mexico ‡	Mississippi ‡
New Jersey	New Hampshire ‡	Ohio	Missouri
New York	Oregon	Oklahoma ‡	Nebraska ‡
North Carolina	South Carolina ‡	Pennsylvania	North Dakota ‡
Utah	Texas	Rhode Island ‡	West Virginia ‡
Vermont ‡	Washington	South Dakota ‡	Wyoming ‡
Virginia	Wisconsin	Tennessee	

‡ EPSCoR state

SOURCE: College Board, Advanced Placement Report to the Nation. See table 8-13.

Findings

- Nationally, 15.2% of public school students in the class of 2008 demonstrated the ability to do college-level work by obtaining a score of 3 or higher on at least one AP Exam, a substantial increase over the 10.2% achieved by the class of 2000.
- Students from all states demonstrated greater success on AP Exams in 2008 than in 2000, but this success was not evenly distributed. In 2008, 20 states and the District of Columbia had percentages below the 2000 national average of 10.2% compared with 38 jurisdictions in 2000.
- The percentage of students who are successful on AP Exams varies widely among states. For the class of 2008, this percentage ranged from a high of 23.4% to a low of 3.7% across states. Some of this variation occurs because opportunities for advanced work are more readily available to students in certain states.
- Values of this indicator were higher for all jurisdictions in 2008 than in 2000. Although two of the three states with the largest increase in performance for the class of 2008 were EPSCoR states, most of the EPSCoR states ranked in the lower quartiles.

This indicator provides a measure of the extent to which high school students are successfully demonstrating mastery of college-level material. It is defined as the percentage of U.S. public high school graduates who have scored 3 or higher on at least one Advanced Placement (AP) Exam. Many colleges and universities grant college credit or advanced placement for AP Exam grades of 3 or higher. A high value on this indicator shows the extent to which students have been offered access to rigorous coursework and successfully mastered its requirements.

A total of 37 different AP Exams are offered each spring by the College Board. The exams are scored on a scale of 1 to 5, with 3 representing work equivalent to college-level performance ranging from midlevel B to midlevel C. To prepare for the AP Exam in a subject area, most students enroll in an AP class that employs a curriculum of high academic intensity. Performance on AP Exams is considered one of the best predictors of success in college by many colleges and universities.

Table 8-13

Share of public high school students scoring 3 or higher on at least one Advanced Placement Exam, by state: 2000, 2004, and 2008

(Percent)

State	2000	2004	2008
United States	10.2	13.2	15.2
Alabama	3.9	5.0	6.8
Alaska	10.1	10.8	13.3
Arizona	7.2	8.0	7.9
Arkansas	4.3	6.1	10.6
California	15.0	18.7	20.2
Colorado	12.2	16.2	19.0
Connecticut	13.6	17.6	21.0
Delaware	7.6	11.1	13.8
District of Columbia	6.6	8.2	6.9
Florida	13.5	19.2	18.2
Georgia	9.7	12.0	16.3
Hawaii	5.8	7.7	8.0
Idaho	6.5	8.1	9.5
Illinois	9.9	13.3	15.2
Indiana	6.0	7.7	10.0
Iowa	4.9	6.6	8.3
Kansas	4.4	6.3	8.6
Kentucky	5.5	7.7	10.0
Louisiana	1.9	2.5	3.7
Maine	10.1	12.8	19.3
Maryland	14.1	19.4	23.4
Massachusetts	14.5	18.1	20.8
Michigan	8.8	10.9	13.0
Minnesota	8.1	10.6	14.2
Mississippi	2.3	2.9	3.9
Missouri	3.7	5.3	6.5
Montana	6.8	8.8	10.6
Nebraska	3.2	4.0	6.5
Nevada	9.1	12.4	13.5
New Hampshire	9.2	10.9	15.5
New Jersey	12.9	15.5	17.3
New Mexico	6.1	8.1	9.9
New York	17.9	21.2	23.3
North Carolina	11.3	15.8	17.3
North Dakota	4.4	5.7	6.9
Ohio	7.1	9.4	10.8
Oklahoma	5.4	8.3	9.8
Oregon	7.1	8.8	13.1
Pennsylvania	8.3	10.1	11.9
Rhode Island	6.9	7.8	9.5
South Carolina	10.0	11.2	13.8
South Dakota	5.9	8.3	9.7
Tennessee	6.2	7.9	9.2
Texas	9.9	13.1	14.5
Utah	17.4	19.3	18.9
Vermont	11.5	14.0	19.8
Virginia	15.9	17.7	21.3
Washington	7.6	11.6	15.5
West Virginia	4.6	6.4	6.9
Wisconsin	10.5	13.7	16.6
Wyoming	3.8	6.7	7.5
Puerto Rico	NA	NA	NA

NA = not available

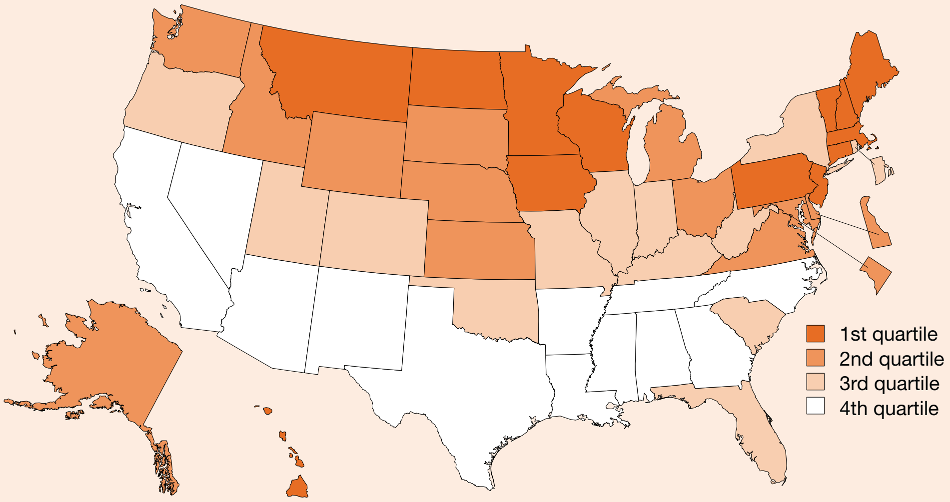
NOTE: National average for United States is reported value in Advanced Placement Report to the Nation.

SOURCE: College Board, Advanced Placement Report to the Nation (various years).

Science and Engineering Indicators 2010

High School Graduates or Higher Among Individuals 25–44 Years Old

Figure 8-14
High school graduates or higher among individuals 25–44 years old: 2007



1st quartile (95.8%–91.0%)	2nd quartile (90.7%–89.3%)	3rd quartile (89.2%–86.2%)	4th quartile (85.8%–80.8%)
Connecticut	Alaska ‡	Colorado	Alabama ‡
Hawaii ‡	Delaware ‡	Florida	Arizona
Iowa	District of Columbia	Illinois	Arkansas ‡
Maine ‡	Idaho ‡	Indiana	California
Massachusetts	Kansas ‡	Kentucky ‡	Georgia
Minnesota	Maryland	Missouri	Louisiana ‡
Montana ‡	Michigan	New York	Mississippi ‡
New Hampshire ‡	Nebraska ‡	Oklahoma ‡	Nevada ‡
New Jersey	Ohio	Oregon	New Mexico ‡
North Dakota ‡	South Dakota ‡	Rhode Island ‡	North Carolina
Pennsylvania	Virginia	South Carolina ‡	Tennessee
Vermont ‡	Washington	Utah	Texas
Wisconsin	Wyoming ‡	West Virginia ‡	

‡ EPSCoR state

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program; and American Community Survey. See table 8-14.

Findings

- Nationwide, 86.7% of the early–mid-career population had at least a high school credential in 2007, an increase from the 85.0% who held such a credential in 2000.
- Forty-six states and the District of Columbia showed an increase in the percentage of their early–mid-career population with at least a high school credential between 2000 and 2007. Ten states had 2007 values below the 2000 national average of 85.0%, compared with 17 states and the District of Columbia in 2000.
- In 2007, the early–mid-career population with at least a high school credential varied greatly among states, ranging from 80.8% to 95.8%. States in close proximity to the southern border of the United States tended to rank lowest on this indicator.

This indicator represents the percentage of the early–mid-career population that has earned at least a high school credential. The indicator displays results based on where high school graduates live rather than where they were educated. High values indicate a resident population and potential workforce with widespread basic education credentials.

Estimates of educational attainment have been developed by the Census Bureau, which bases them on the 2000 Decennial Census and the American Community Survey (ACS). The census is conducted every 10 years, but ACS provides annual data on the characteristics of the population and where they live.

In 2005, ACS became the largest household survey in the United States, with an annual sample size of about 3 million addresses. Estimates of population are developed by the Census Bureau through the Population Estimates Program, which is also based on the 2000 Decennial Census. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations.

Table 8-14

High school graduates or higher among individuals 25–44 years old, by state: 2000, 2003, and 2007

	Graduates 25–44 years old			Population 25–44 years old			Graduates/population 25–44 years old (%)		
State	2000	2003	2007	2000	2003	2007	2000	2003	2007
United States	72,241,876	71,684,426	72,358,114	85,040,251	84,216,990	83,483,659	85.0	85.1	86.7
Alabama	1,064,945	1,027,964	1,036,147	1,288,527	1,241,184	1,234,350	82.6	82.8	83.9
Alaska	186,160	167,805	176,847	203,522	194,823	197,222	91.5	86.1	89.7
Arizona	1,232,818	1,286,915	1,462,672	1,511,469	1,599,029	1,781,045	81.6	80.5	82.1
Arkansas	622,698	608,116	637,072	750,972	738,579	755,981	82.9	82.3	84.3
California	8,286,071	8,529,909	8,581,683	10,714,403	10,832,873	10,581,536	77.3	78.7	81.1
Colorado	1,242,919	1,239,272	1,283,903	1,400,850	1,417,501	1,448,632	88.7	87.4	88.6
Connecticut	926,614	903,677	847,351	1,032,689	999,800	925,266	89.7	90.4	91.6
Delaware	207,799	204,842	207,161	236,441	233,356	230,359	87.9	87.8	89.9
District of Columbia	157,077	160,782	173,875	189,439	188,758	192,511	82.9	85.2	90.3
Florida	3,840,710	3,924,625	4,166,135	4,569,347	4,676,558	4,812,179	84.1	83.9	86.6
Georgia	2,238,995	2,280,061	2,404,616	2,652,764	2,723,720	2,834,749	84.4	83.7	84.8
Hawaii	333,762	316,491	334,898	362,336	352,806	353,251	92.1	89.7	94.8
Idaho	316,815	323,260	362,468	362,401	370,690	401,380	87.4	87.2	90.3
Illinois	3,265,416	3,267,787	3,188,986	3,795,544	3,727,314	3,600,910	86.0	87.7	88.6
Indiana	1,567,100	1,494,212	1,528,485	1,791,828	1,748,331	1,734,016	87.5	85.5	88.1
Iowa	740,397	709,299	697,233	808,259	775,320	753,784	91.6	91.5	92.5
Kansas	687,268	675,316	656,852	769,204	743,961	727,170	89.3	90.8	90.3
Kentucky	1,009,246	1,013,026	1,023,568	1,210,773	1,182,970	1,188,087	83.4	85.6	86.2
Louisiana	1,044,255	1,014,054	949,440	1,293,128	1,230,819	1,159,582	80.8	82.4	81.9
Maine	339,227	325,208	312,986	370,597	358,691	337,652	91.5	90.7	92.7
Maryland	1,487,216	1,454,663	1,409,457	1,664,677	1,641,907	1,568,230	89.3	88.6	89.9
Massachusetts	1,795,438	1,763,262	1,651,537	1,989,783	1,922,446	1,794,769	90.2	91.7	92.0
Michigan	2,630,713	2,551,652	2,421,941	2,960,544	2,840,435	2,683,585	88.9	89.8	90.3
Minnesota	1,395,170	1,374,938	1,330,265	1,497,320	1,465,370	1,423,704	93.2	93.8	93.4
Mississippi	650,242	645,671	629,509	807,170	782,327	766,714	80.6	82.5	82.1
Missouri	1,426,806	1,399,485	1,397,472	1,626,302	1,587,931	1,579,645	87.7	88.1	88.5
Montana	225,105	213,382	216,166	245,220	232,735	235,309	91.8	91.7	91.9
Nebraska	441,527	432,446	415,179	487,107	471,024	457,810	90.6	91.8	90.7
Nevada	508,173	538,622	624,384	628,572	679,392	761,550	80.8	79.3	82.0
New Hampshire	350,744	340,140	326,094	381,240	373,644	351,263	92.0	91.0	92.8
New Jersey	2,313,820	2,254,281	2,184,317	2,624,146	2,578,072	2,400,533	88.2	87.4	91.0
New Mexico	425,745	400,847	433,949	516,100	506,956	516,167	82.5	79.1	84.1
New York	4,926,064	4,912,059	4,698,849	5,831,622	5,667,484	5,383,101	84.5	86.7	87.3
North Carolina	2,117,289	2,096,022	2,187,835	2,500,535	2,507,025	2,552,793	84.7	83.6	85.7
North Dakota	164,893	157,062	148,753	174,891	160,522	155,217	94.3	97.8	95.8
Ohio	2,965,744	2,840,789	2,754,008	3,325,210	3,172,294	3,054,756	89.2	89.5	90.2
Oklahoma	836,030	796,708	827,697	975,169	946,358	955,471	85.7	84.2	86.6
Oregon	861,602	880,905	907,879	997,269	1,003,698	1,034,933	86.4	87.8	87.7
Pennsylvania	3,136,195	2,966,827	2,895,587	3,508,562	3,343,434	3,182,590	89.4	88.7	91.0
Rhode Island	265,033	262,340	248,540	310,636	306,459	281,590	85.3	85.6	88.3
South Carolina	990,207	1,002,730	1,026,577	1,185,955	1,167,347	1,185,520	83.5	85.9	86.6
South Dakota	188,052	182,643	177,251	206,399	197,386	197,197	91.1	92.5	89.9
Tennessee	1,439,729	1,446,735	1,480,790	1,718,428	1,684,796	1,725,854	83.8	85.9	85.8
Texas	5,115,457	5,136,496	5,598,948	6,484,321	6,644,003	6,926,932	78.9	77.3	80.8
Utah	555,513	602,199	672,439	626,600	648,111	753,898	88.7	92.9	89.2
Vermont	162,109	153,679	147,144	176,456	168,392	157,657	91.9	91.3	93.3
Virginia	1,962,040	1,911,347	1,971,608	2,237,655	2,227,978	2,204,242	87.7	85.8	89.4
Washington	1,617,766	1,607,576	1,637,950	1,816,217	1,803,610	1,834,696	89.1	89.1	89.3
West Virginia	420,900	400,998	411,722	501,343	479,781	473,410	84.0	83.6	87.0
Wisconsin	1,429,331	1,369,084	1,369,475	1,581,690	1,537,180	1,499,802	90.4	89.1	91.3
Wyoming	126,931	116,217	122,414	138,619	131,810	135,059	91.6	88.2	90.6
Puerto Rico	794,579	NA	874,101	1,049,995	1,069,617	NA	75.7	NA	NA

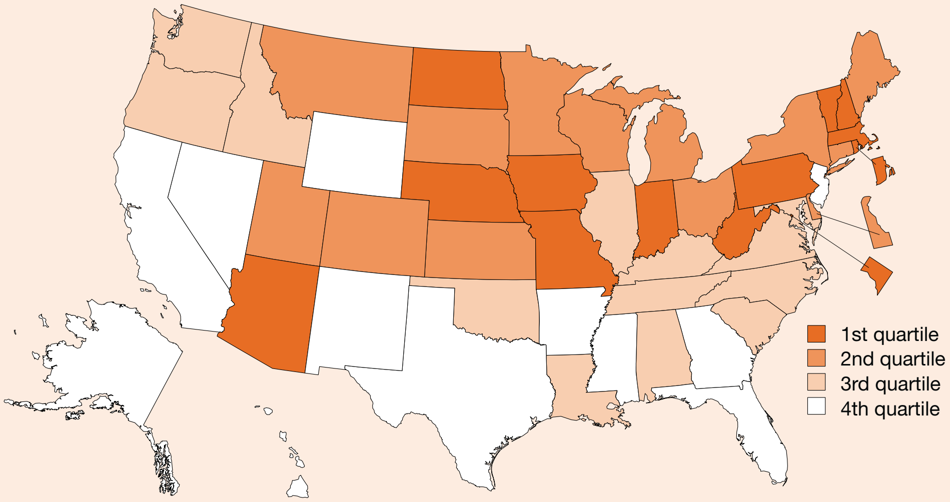
NA = not available

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years).

Science and Engineering Indicators 2010

Bachelor’s Degrees Conferred per 1,000 Individuals 18–24 Years Old

Figure 8-15
Bachelor’s degrees conferred per 1,000 individuals 18–24 years old: 2007



1st quartile (139.6–63.2)	2nd quartile (62.2–54.4)	3rd quartile (54.0–45.6)	4th quartile (44.1–20.7)
Arizona	Colorado	Alabama ‡	Alaska ‡
District of Columbia	Connecticut	Idaho ‡	Arkansas ‡
Indiana	Delaware ‡	Illinois	California
Iowa	Kansas ‡	Kentucky ‡	Florida
Massachusetts	Maine ‡	Louisiana ‡	Georgia
Missouri	Michigan	Maryland	Hawaii ‡
Nebraska ‡	Minnesota	North Carolina	Mississippi ‡
New Hampshire ‡	Montana ‡	Oklahoma ‡	Nevada ‡
North Dakota ‡	New York	Oregon	New Jersey
Pennsylvania	Ohio	South Carolina ‡	New Mexico ‡
Rhode Island ‡	South Dakota ‡	Tennessee	Texas
Vermont ‡	Utah	Virginia	Wyoming ‡
West Virginia ‡	Wisconsin	Washington	

‡ EPSCoR state

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System; Census Bureau, 2000 Decennial Census; and Census Bureau, Population Estimates Program. See table 8-15.

Findings

- In 2007, 1.5 million bachelor’s degrees were conferred nationally in all fields, which is up from 1.2 million in 1997 and represents an increase of 27%. Between 1997 and 2007, the number of bachelor’s degrees conferred per 1,000 individuals 18–24 years old in the population has increased by 8% nationwide.
- In 2007, state values on this indicator varied greatly. They ranged from 89.9 to 20.7 bachelor’s degrees conferred per 1,000 individuals 18–24 years old.
- In 12 states and the District of Columbia, fewer bachelor’s degrees were conferred per 1,000 individuals 18–24 years old in 2007 than in 1997.

Earning a bachelor’s degree gives people greater opportunities to work in higher-paying jobs than are generally available to those with less education. It also prepares them for advanced education. In addition, the presence of higher education institutions that produce such degrees may generate resources for the state. The cohort 18–24 years old was chosen to approximate the age range of most students who are pursuing an undergraduate degree.

Although the number of bachelor’s degrees awarded is based on an actual count, the population ages 18–24 years is an estimate developed by the Census Bureau in the Population Estimates Program, which relies on the Decennial Census. Small differences in the indicator value between states or across time generally are not meaningful.

A high value for this indicator may suggest the successful provision of educational opportunity at this level. Student mobility after graduation, however, may make this indicator less meaningful in predicting the qualifications of a state’s future workforce. A state’s value for this indicator may also be high when its higher education system draws a large percentage of out-of-state students, a situation that sometimes occurs in states with small resident populations and the District of Columbia.

Table 8-15
Bachelor's degrees conferred per 1,000 individuals 18–24 years old, by state: 1997, 2002, and 2007

	Bachelor's degrees			Population 18–24 years old			Degrees/1,000 individuals 18–24 years old		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	1,171,891	1,288,674	1,490,321	24,980,036	28,419,861	29,407,260	46.9	45.3	50.7
Alabama	20,638	20,223	21,762	433,513	448,685	446,162	47.6	45.1	48.8
Alaska	1,473	1,377	1,512	66,729	64,031	72,877	22.1	21.5	20.7
Arizona	20,029	26,553	41,640	430,444	548,385	589,973	46.5	48.4	70.6
Arkansas	9,214	10,078	11,421	248,415	270,578	262,261	37.1	37.2	43.5
California	108,255	126,507	145,083	3,050,146	3,564,996	3,797,718	35.5	35.5	38.2
Colorado	20,213	22,577	25,677	362,705	458,430	457,831	55.7	49.2	56.1
Connecticut	13,684	14,820	18,524	258,320	290,083	319,957	53.0	51.1	57.9
Delaware	4,295	4,894	5,093	65,110	80,006	83,909	66.0	61.2	60.7
District of Columbia	7,869	8,564	10,261	43,082	71,859	73,516	182.7	119.2	139.6
Florida	47,428	53,542	65,682	1,183,286	1,439,912	1,588,214	40.1	37.2	41.4
Georgia	27,396	29,820	36,564	736,994	876,433	900,438	37.2	34.0	40.6
Hawaii	4,702	4,757	5,486	117,605	122,728	124,276	40.0	38.8	44.1
Idaho	4,509	4,913	7,894	134,718	145,770	146,117	33.5	33.7	54.0
Illinois	51,742	57,862	63,214	1,108,589	1,246,753	1,303,052	46.7	46.4	48.5
Indiana	30,477	33,918	38,369	566,940	625,957	600,127	53.8	54.2	63.9
Iowa	17,939	19,255	20,538	270,541	304,469	304,047	66.3	63.2	67.5
Kansas	14,739	15,135	17,372	254,180	286,702	288,019	58.0	52.8	60.3
Kentucky	14,705	16,419	19,125	394,870	409,809	381,413	37.2	40.1	50.1
Louisiana	17,506	20,216	21,428	463,579	491,999	469,512	37.8	41.1	45.6
Maine	5,565	5,787	6,859	110,057	109,039	111,798	50.6	53.1	61.4
Maryland	21,391	23,161	26,513	427,282	486,971	539,344	50.1	47.6	49.2
Massachusetts	40,378	43,069	47,567	501,116	600,205	656,481	80.6	71.8	72.5
Michigan	44,427	47,538	52,625	916,990	971,354	967,733	48.4	48.9	54.4
Minnesota	22,594	24,475	29,044	426,154	492,940	503,943	53.0	49.7	57.6
Mississippi	10,252	11,899	12,052	296,825	315,700	303,351	34.5	37.7	39.7
Missouri	27,994	31,990	35,127	498,637	557,922	555,959	56.1	57.3	63.2
Montana	4,752	5,277	5,217	86,917	90,990	93,761	54.7	58.0	55.6
Nebraska	9,871	10,646	12,065	163,298	181,923	185,182	60.4	58.5	65.2
Nevada	3,669	4,244	5,568	140,784	191,087	207,957	26.1	22.2	26.8
New Hampshire	7,581	7,260	8,274	93,994	110,493	117,693	80.7	65.7	70.3
New Jersey	24,845	28,376	32,695	667,162	702,715	759,003	37.2	40.4	43.1
New Mexico	6,088	5,823	6,815	171,641	193,224	203,225	35.5	30.1	33.5
New York	96,193	101,741	117,274	1,588,411	1,836,834	1,977,437	60.6	55.4	59.3
North Carolina	34,202	36,132	40,920	694,894	821,050	857,552	49.2	44.0	47.7
North Dakota	4,627	4,810	5,543	66,864	77,340	82,096	69.2	62.2	67.5
Ohio	49,163	52,934	58,813	1,046,134	1,092,489	1,074,846	47.0	48.5	54.7
Oklahoma	15,116	16,005	18,553	330,430	376,524	368,779	45.7	42.5	50.3
Oregon	13,194	13,955	17,270	295,027	342,012	332,599	44.7	40.8	51.9
Pennsylvania	62,482	69,542	81,168	1,021,108	1,133,927	1,192,303	61.2	61.3	68.1
Rhode Island	8,409	9,038	10,215	82,236	112,316	113,670	102.3	80.5	89.9
South Carolina	15,177	17,294	20,092	379,854	419,038	430,733	40.0	41.3	46.6
South Dakota	4,390	4,477	5,104	74,361	80,949	82,097	59.0	55.3	62.2
Tennessee	21,147	23,330	26,877	509,421	564,930	548,165	41.5	41.3	49.0
Texas	71,409	79,556	94,601	1,979,779	2,335,170	2,421,150	36.1	34.1	39.1
Utah	15,606	17,876	19,655	277,479	340,031	328,226	56.2	52.6	59.9
Vermont	4,299	4,642	5,060	51,147	59,065	61,388	84.1	78.6	82.4
Virginia	30,207	32,819	39,151	648,469	711,752	762,960	46.6	46.1	51.3
Washington	22,846	24,172	28,500	521,036	594,975	596,815	43.8	40.6	47.8
West Virginia	8,172	9,022	10,543	183,414	173,637	157,857	44.6	52.0	66.8
Wisconsin	27,380	28,699	32,229	487,388	543,276	550,539	56.2	52.8	58.5
Wyoming	1,652	1,655	1,687	51,961	52,398	53,199	31.8	31.6	31.7
Puerto Rico	14,107	16,464	16,989	NA	NA	NA	NA	NA	NA

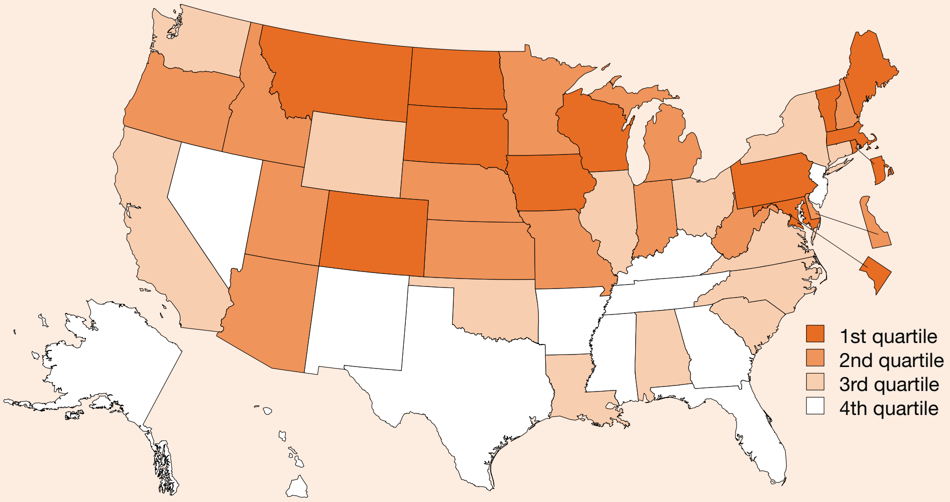
NA = not available

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); Census Bureau, 2000 Decennial Census; and Census Bureau, Population Estimates Program (various years).

Science and Engineering Indicators 2010

Bachelor's Degrees in Natural Sciences and Engineering Conferred per 1,000 Individuals 18–24 Years Old

Figure 8-16
Bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18–24 years old: 2007



1st quartile (19.8–10.4)	2nd quartile (10.2–8.7)	3rd quartile (8.6–6.9)	4th quartile (6.8–3.7)
Colorado	Arizona	Alabama ‡	Alaska ‡
District of Columbia	Delaware ‡	California	Arkansas ‡
Iowa	Idaho ‡	Connecticut	Florida
Maine ‡	Indiana	Illinois	Georgia
Maryland	Kansas ‡	Louisiana ‡	Hawaii ‡
Massachusetts	Michigan	New York	Kentucky ‡
Montana ‡	Minnesota	North Carolina	Mississippi ‡
North Dakota ‡	Missouri	Ohio	Nevada ‡
Pennsylvania	Nebraska ‡	Oklahoma ‡	New Jersey
Rhode Island ‡	New Hampshire ‡	South Carolina ‡	New Mexico ‡
South Dakota ‡	Oregon	Virginia	Tennessee
Vermont ‡	Utah	Washington	Texas
Wisconsin	West Virginia ‡	Wyoming ‡	

‡ EPSCoR state

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System; Census Bureau, 2000 Decennial Census; and Census Bureau, Population Estimates Program. See table 8-16.

Findings

- Between 1997 and 2007, the value of this indicator did not change appreciably.
- In 2007, the value of this indicator ranged from 15.4 to 3.7 bachelor's degrees conferred per 1,000 individuals 18–24 years old for individual states.
- States that ranked in the top two quartiles on this indicator were generally the same as those in the top two quartiles for the number of bachelor's degrees conferred per 1,000 individuals 18–24 years old.
- EPSCoR states were uniformly distributed throughout the four quartiles of the state ranking, indicating that in spite of the lack of a large, federally supported research structure, institutions in these states do provide college-level training in NS&E fields.

Natural sciences and engineering (NS&E) fields include the physical, earth, ocean, atmospheric, biological, agricultural, and computer sciences; mathematics; and engineering. NS&E fields exclude social sciences and psychology. The ratio of new NS&E bachelor's degrees to the population ages18–24 years indicates the extent to which a state prepares young people to enter the types of technology-intensive occupations that are fundamental to a knowledge-based, technology-driven economy. In addition, the presence of higher education institutions that produce such degrees may generate resources for the state. The cohort 18–24 years old was chosen to approximate the age range of most students who are pursing an undergraduate degree.

Although the number of NS&E bachelor's degrees awarded is based on an actual count, the population ages 18–24 years is an estimate developed by the Census Bureau in the Population Estimates Program, which relies on the Decennial Census. Small differences in the value of the indicator between states or across time generally are not meaningful.

Because students often relocate after graduation, this measure does not necessarily indicate the qualifications of a state's future workforce. A state's value for this indicator may also be high when its higher education system draws a large percentage of out-of-state students to study in NS&E fields, a situation that sometimes occurs in states with small resident populations and the District of Columbia.

Table 8-16

Bachelor's degrees in natural sciences and engineering conferred per 1,000 individuals 18–24 years old, by state: 1997, 2002, and 2007

State	NS&E bachelor's degrees			Population 18–24 years old			Degrees/1,000 individuals 18–24 years old		
	1997	2002	2007	1997	2002	2007	1997	2002	2007
EPSCoR states	33,748	35,339	37,632	4,462,502	4,864,031	4,847,332	7.6	7.3	7.8
Non-EPSCoR states	164,878	178,965	197,718	20,474,452	23,483,971	24,486,412	8.1	7.6	8.1
Average EPSCoR state value	na	na	na	na	na	na	8.6	8.1	8.6
Average non-EPSCoR state value	na	na	na	na	na	na	8.6	8.2	8.7
United States	199,868	216,028	236,802	24,980,036	28,419,861	29,407,260	8.0	7.6	8.1
Alabama	3,460	3,333	3,728	433,513	448,685	446,162	8.0	7.4	8.4
Alaska	301	229	267	66,729	64,031	72,877	4.5	3.6	3.7
Arizona	2,773	3,715	6,034	430,444	548,385	589,973	6.4	6.8	10.2
Arkansas	1,462	1,656	1,525	248,415	270,578	262,261	5.9	6.1	5.8
California	21,476	23,435	26,086	3,050,146	3,564,996	3,797,718	7.0	6.6	6.9
Colorado	4,477	4,993	5,046	362,705	458,430	457,831	12.3	10.9	11.0
Connecticut	1,954	1,904	2,333	258,320	290,083	319,957	7.6	6.6	7.3
Delaware	693	717	734	65,110	80,006	83,909	10.6	9.0	8.7
District of Columbia	1,242	1,724	1,452	43,082	71,859	73,516	28.8	24.0	19.8
Florida	6,642	7,808	9,226	1,183,286	1,439,912	1,588,214	5.6	5.4	5.8
Georgia	4,546	5,509	5,984	736,994	876,433	900,438	6.2	6.3	6.6
Hawaii	582	686	683	117,605	122,728	124,276	4.9	5.6	5.5
Idaho	871	1,008	1,324	134,718	145,770	146,117	6.5	6.9	9.1
Illinois	8,428	9,559	9,441	1,108,589	1,246,753	1,303,052	7.6	7.7	7.2
Indiana	5,170	5,378	5,860	566,940	625,957	600,127	9.1	8.6	9.8
Iowa	2,956	3,140	3,237	270,541	304,469	304,047	10.9	10.3	10.6
Kansas	2,312	2,482	2,506	254,180	286,702	288,019	9.1	8.7	8.7
Kentucky	2,177	2,312	2,419	394,870	409,809	381,413	5.5	5.6	6.3
Louisiana	3,061	3,594	3,381	463,579	491,999	469,512	6.6	7.3	7.2
Maine	991	1,110	1,185	110,057	109,039	111,798	9.0	10.2	10.6
Maryland	4,389	4,862	5,585	427,282	486,971	539,344	10.3	10.0	10.4
Massachusetts	7,115	7,394	7,564	501,116	600,205	656,481	14.2	12.3	11.5
Michigan	8,324	8,609	9,240	916,990	971,354	967,733	9.1	8.9	9.5
Minnesota	3,717	4,205	4,722	426,154	492,940	503,943	8.7	8.5	9.4
Mississippi	1,707	1,753	1,767	296,825	315,700	303,351	5.8	5.6	5.8
Missouri	4,525	5,310	5,054	498,637	557,922	555,959	9.1	9.5	9.1
Montana	1,135	1,197	1,133	86,917	90,990	93,761	13.1	13.2	12.1
Nebraska	1,477	1,412	1,733	163,298	181,923	185,182	9.0	7.8	9.4
Nevada	503	556	785	140,784	191,087	207,957	3.6	2.9	3.8
New Hampshire	1,265	1,133	1,127	93,994	110,493	117,693	13.5	10.3	9.6
New Jersey	4,654	5,392	5,147	667,162	702,715	759,003	7.0	7.7	6.8
New Mexico	1,124	1,129	1,251	171,641	193,224	203,225	6.5	5.8	6.2
New York	14,300	15,173	16,436	1,588,411	1,836,834	1,977,437	9.0	8.3	8.3
North Carolina	6,541	6,313	6,754	694,894	821,050	857,552	9.4	7.7	7.9
North Dakota	843	876	898	66,864	77,340	82,096	12.6	11.3	10.9
Ohio	7,980	8,002	8,432	1,046,134	1,092,489	1,074,846	7.6	7.3	7.8
Oklahoma	2,473	2,514	2,583	330,430	376,524	368,779	7.5	6.7	7.0
Oregon	2,073	2,483	2,984	295,027	342,012	332,599	7.0	7.3	9.0
Pennsylvania	11,287	12,425	13,953	1,021,108	1,133,927	1,192,303	11.1	11.0	11.7
Rhode Island	1,134	1,287	1,571	82,236	112,316	113,670	13.8	11.5	13.8
South Carolina	2,821	2,798	3,073	379,854	419,038	430,733	7.4	6.7	7.1
South Dakota	991	1,009	1,056	74,361	80,949	82,097	13.3	12.5	12.9
Tennessee	3,455	3,380	3,617	509,421	564,930	548,165	6.8	6.0	6.6
Texas	11,292	12,014	14,487	1,979,779	2,335,170	2,421,150	5.7	5.1	6.0
Utah	2,714	3,037	3,338	277,479	340,031	328,226	9.8	8.9	10.2
Vermont	754	809	944	51,147	59,065	61,388	14.7	13.7	15.4
Virginia	5,529	5,875	6,562	648,469	711,752	762,960	8.5	8.3	8.6
Washington	3,860	4,053	4,614	521,036	594,975	596,815	7.4	6.8	7.7
West Virginia	1,141	1,296	1,562	183,414	173,637	157,857	6.2	7.5	9.9
Wisconsin	4,701	4,997	5,982	487,388	543,276	550,539	9.6	9.2	10.9
Wyoming	470	443	397	51,961	52,398	53,199	9.0	8.5	7.5
Puerto Rico	2,771	3,074	2,787	NA	NA	NA	NA	NA	NA

na = not applicable; NA = not available

EPSCoR = Experimental Program to Stimulate Competitive Research; NS&E = natural sciences and engineering

NOTE: For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

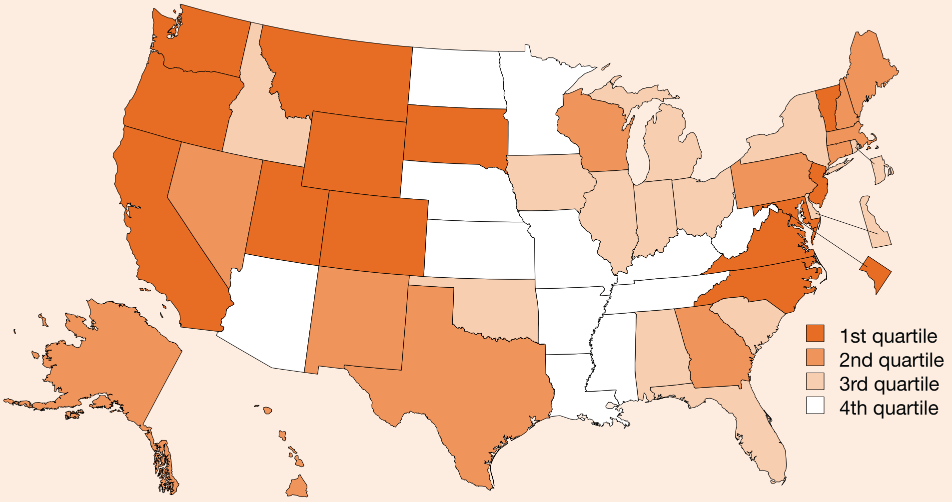
SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); Census Bureau, 2000 Decennial Census; and Census Bureau, Population Estimates Program (various years).

Science and Engineering Indicators 2010

S&E Degrees as Share of Higher Education Degrees Conferred

Figure 8-17

S&E degrees as share of higher education degrees conferred: 2007



1st quartile (53.3%–34.5%)	**2nd quartile (34.3%–30.9%)**	**3rd quartile (30.8%–28.0%)**	**4th quartile (27.9%–18.0%)**
California	Alaska ‡	Alabama ‡	Arizona
Colorado	Connecticut	Delaware ‡	Arkansas ‡
District of Columbia	Georgia	Florida	Kansas ‡
Maryland	Hawaii ‡	Idaho ‡	Kentucky ‡
Montana ‡	Maine ‡	Illinois	Louisiana ‡
New Jersey	Massachusetts	Indiana	Minnesota
North Carolina	Nevada ‡	Iowa	Mississippi ‡
Oregon	New Hampshire ‡	Michigan	Missouri
South Dakota ‡	New Mexico ‡	New York	Nebraska ‡
Utah	Pennsylvania	Ohio	North Dakota ‡
Vermont ‡	Texas	Oklahoma ‡	Tennessee
Virginia	Wisconsin	Rhode Island ‡	West Virginia ‡
Washington		South Carolina ‡	
Wyoming ‡			

‡ EPSCoR state

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-17.

Findings

- In 2007, nearly 686,000 S&E bachelor's, master's, and doctoral degrees were conferred nationwide, an increase of nearly 27% during the past decade.
- The proportion of S&E degrees as a share of total degrees conferred did not show any substantial changes between 1997 and 2007.
- There are noteworthy differences in the proportions of technical higher education degrees conferred in different states. In some states, more than 40% of higher education degrees were awarded in technical fields. In others, only about 20% of higher education degrees were awarded in technical fields.
- States in which the highest percentages of higher education degrees were conferred in technical fields tended to be located in the western United States.
- The District of Columbia has a high value because of the large number of programs in political science and public administration at several of its academic institutions.

This indicator is a measure of the extent to which a state's higher education programs are concentrated in S&E fields. The indicator is expressed as the percentage of higher education degrees that were conferred in S&E fields.

S&E fields include the physical, earth, ocean, atmospheric, biological, agricultural, computer, and social sciences; mathematics; engineering; and psychology. Counts of both S&E degrees and higher education degrees conferred include bachelor's, master's, and doctoral degrees; associate's degrees are excluded.

Degree data reflect the location of the degree-granting institution, not the state where degree-earning students permanently reside. The year indicates the end date of the academic year. For example, data for 2007 represent degrees conferred during the 2006–07 academic year.

Table 8-17

S&E degrees as share of higher education degrees conferred, by state: 1997, 2002, and 2007

	S&E degrees			All higher education degrees			S&E/higher education degrees (%)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	538,702	597,517	685,914	1,636,726	1,811,202	2,138,003	32.9	33.0	32.1
Alabama	7,801	7,747	9,920	28,678	29,034	32,207	27.2	26.7	30.8
Alaska	684	561	750	2,009	1,828	2,261	34.0	30.7	33.2
Arizona	7,244	8,667	13,463	30,255	42,697	74,778	23.9	20.3	18.0
Arkansas	2,930	3,385	3,440	11,577	12,740	14,835	25.3	26.6	23.2
California	66,347	77,904	89,947	151,485	176,513	204,838	43.8	44.1	43.9
Colorado	11,427	13,308	13,729	28,304	31,388	35,981	40.4	42.4	38.2
Connecticut	7,153	7,294	9,052	21,300	22,939	27,781	33.6	31.8	32.6
Delaware	2,005	2,084	2,325	5,660	6,583	7,642	35.4	31.7	30.4
District of Columbia	7,068	7,555	8,287	15,872	16,468	20,489	44.5	45.9	40.4
Florida	17,551	20,934	27,510	65,429	73,988	91,561	26.8	28.3	30.0
Georgia	10,725	13,605	16,566	37,793	42,480	49,495	28.4	32.0	33.5
Hawaii	2,128	2,129	2,511	6,533	6,211	7,330	32.6	34.3	34.3
Idaho	2,038	2,305	2,859	5,656	6,245	9,614	36.0	36.9	29.7
Illinois	22,100	25,141	30,055	80,243	89,307	101,537	27.5	28.2	29.6
Indiana	12,127	12,833	14,442	39,188	44,005	51,564	30.9	29.2	28.0
Iowa	6,704	6,879	7,893	21,926	23,706	25,698	30.6	29.0	30.7
Kansas	6,065	6,388	6,552	20,074	20,728	23,943	30.2	30.8	27.4
Kentucky	5,299	6,154	7,218	19,669	21,825	27,152	26.9	28.2	26.6
Louisiana	6,843	7,322	7,767	23,565	26,491	28,224	29.0	27.6	27.5
Maine	2,236	2,408	2,733	6,686	7,145	8,532	33.4	33.7	32.0
Maryland	12,177	13,859	16,932	32,362	35,601	41,936	37.6	38.9	40.4
Massachusetts	22,537	24,538	26,363	66,594	71,260	78,421	33.8	34.4	33.6
Michigan	19,809	20,938	23,006	62,669	70,717	75,304	31.6	29.6	30.6
Minnesota	9,619	11,243	12,571	29,990	33,450	45,085	32.1	33.6	27.9
Mississippi	3,602	3,887	4,294	13,823	15,619	16,438	26.1	24.9	26.1
Missouri	10,841	12,813	13,515	39,902	46,834	53,828	27.2	27.4	25.1
Montana	2,240	2,327	2,450	5,706	6,340	6,509	39.3	36.7	37.6
Nebraska	3,420	3,663	4,115	12,629	14,190	15,765	27.1	25.8	26.1
Nevada	1,266	1,503	2,267	4,726	5,489	7,279	26.8	27.4	31.1
New Hampshire	3,212	3,626	3,725	9,772	9,486	11,207	32.9	38.2	33.2
New Jersey	13,725	16,083	16,851	34,345	39,686	46,676	40.0	40.5	36.1
New Mexico	2,981	2,724	3,302	8,835	8,402	9,748	33.7	32.4	33.9
New York	48,004	50,423	55,360	146,034	155,906	185,736	32.9	32.3	29.8
North Carolina	15,028	16,470	19,022	43,477	46,754	55,071	34.6	35.2	34.5
North Dakota	1,587	1,570	1,731	5,417	5,777	7,042	29.3	27.2	24.6
Ohio	20,918	21,879	24,410	69,154	73,784	82,584	30.2	29.7	29.6
Oklahoma	6,541	6,808	7,442	20,001	21,531	24,244	32.7	31.6	30.7
Oregon	6,359	6,828	8,387	17,733	19,139	23,655	35.9	35.7	35.5
Pennsylvania	27,575	30,717	35,314	84,854	95,111	113,396	32.5	32.3	31.1
Rhode Island	3,132	3,430	3,875	10,558	11,359	12,724	29.7	30.2	30.5
South Carolina	6,550	7,255	7,649	20,179	22,023	25,841	32.5	32.9	29.6
South Dakota	2,128	1,962	2,204	5,512	5,493	6,386	38.6	35.7	34.5
Tennessee	8,172	8,425	9,272	28,733	32,004	36,576	28.4	26.3	25.3
Texas	29,744	33,844	40,387	97,090	108,049	130,830	30.6	31.3	30.9
Utah	6,984	7,793	8,787	18,920	21,496	23,993	36.9	36.3	36.6
Vermont	2,183	2,264	2,880	5,517	6,003	7,042	39.6	37.7	40.9
Virginia	16,270	17,956	20,679	42,316	44,555	53,981	38.4	40.3	38.3
Washington	10,761	12,292	14,026	30,499	31,971	37,541	35.3	38.4	37.4
West Virginia	2,629	2,927	3,239	10,548	11,413	13,707	24.9	25.6	23.6
Wisconsin	10,986	11,684	13,691	34,805	37,284	41,842	31.6	31.3	32.7
Wyoming	1,247	1,183	1,149	2,124	2,155	2,154	58.7	54.9	53.3
Puerto Rico	4,896	5,715	5,620	15,811	19,433	22,734	31.0	29.4	24.7

NOTES: S&E degrees include bachelor's, master's, and doctorate. S&E degrees include physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering. "All higher education degrees" includes bachelor's, master's, and doctorate.

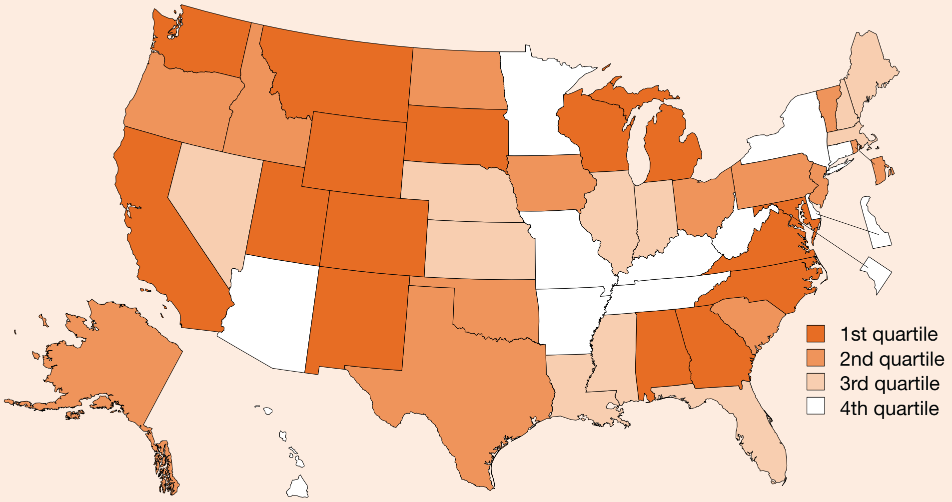
SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science and Engineering Indicators 2010

Natural Sciences and Engineering Degrees as Share of Higher Education Degrees Conferred

Figure 8-18

Natural sciences and engineering degrees as share of higher education degrees conferred: 2007



1st quartile (34.7%–19.6%)	2nd quartile (19.4%–17.2%)	3rd quartile (17.0%–15.2%)	4th quartile (15.1%–11.5%)
Alabama ‡	Alaska ‡	Florida	Arizona
California	Idaho ‡	Illinois	Arkansas ‡
Colorado	Iowa	Indiana	Connecticut
Georgia	New Jersey	Kansas ‡	Delaware ‡
Maryland	North Dakota ‡	Louisiana ‡	District of Columbia
Michigan	Ohio	Maine ‡	Hawaii ‡
Montana ‡	Oklahoma ‡	Massachusetts	Kentucky ‡
New Mexico ‡	Oregon	Mississippi ‡	Minnesota
North Carolina	Pennsylvania	Nebraska ‡	Missouri
South Dakota ‡	Rhode Island ‡	Nevada ‡	New York
Utah	South Carolina ‡	New Hampshire ‡	Tennessee
Virginia	Texas		West Virginia ‡
Washington	Vermont ‡		
Wisconsin			
Wyoming ‡			

‡ EPSCoR state

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-18.

Findings

- In 2007, nearly 376,000 NS&E bachelor's, master's, and doctoral degrees were conferred nationwide, an increase of nearly 25% during the past decade.
- The proportion of NS&E degrees as a share of total degrees conferred showed an 8% decline between 2002 and 2007.
- There are noteworthy differences in the proportions of natural science or engineering higher education degrees conferred in different states. In 2007, the proportions ranged between 35% and 11%.
- States with the highest percentage of higher education degrees in natural science or engineering fields tended to be located in the western United States, and four of the top five are EPSCoR states.

This indicator is a measure of the extent to which a state's higher education programs are concentrated in natural sciences and engineering (NS&E) fields. The indicator is expressed as the percentage of higher education degrees that were conferred in NS&E fields.

NS&E fields include the physical, earth, ocean, atmospheric, biological, agricultural, and computer sciences; mathematics; and engineering. Social sciences such as anthropology, economics, political science and public administration, psychology, and sociology are not included. Counts of both NS&E degrees and higher education degrees conferred include bachelor's, master's, and doctoral degrees; associate's degrees are excluded.

Degree data reflect the location of the degree-granting institution, not the state in which degree-earning students permanently reside. The year reflects the end date of the academic year. For example, data for 2007 represent degrees conferred during the 2006–07 academic year.

Table 8-18

Natural sciences and engineering degrees as share of higher education degrees conferred, by state: 1997, 2002, and 2007

	NS&E degrees			All higher education degrees			NS&E/higher education degrees (%)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	300,380	346,643	375,931	1,636,726	1,811,202	2,138,003	18.4	19.1	17.6
Alabama	4,971	4,842	6,550	28,678	29,034	32,207	17.3	16.7	20.3
Alaska	440	338	438	2,009	1,828	2,261	21.9	18.5	19.4
Arizona	4,379	5,713	8,569	30,255	42,697	74,778	14.5	13.4	11.5
Arkansas	1,751	2,276	2,112	11,577	12,740	14,835	15.1	17.9	14.2
California	35,241	40,070	42,934	151,485	176,513	204,838	23.3	22.7	21.0
Colorado	6,625	8,100	7,506	28,304	31,388	35,981	23.4	25.8	20.9
Connecticut	3,196	3,296	4,206	21,300	22,939	27,781	15.0	14.4	15.1
Delaware	1,006	996	1,126	5,660	6,583	7,642	17.8	15.1	14.7
District of Columbia	2,963	3,701	3,061	15,872	16,468	20,489	18.7	22.5	14.9
Florida	9,334	11,944	14,494	65,429	73,988	91,561	14.3	16.1	15.8
Georgia	6,366	8,673	10,230	37,793	42,480	49,495	16.8	20.4	20.7
Hawaii	899	976	1,027	6,533	6,211	7,330	13.8	15.7	14.0
Idaho	1,298	1,564	1,846	5,656	6,245	9,614	22.9	25.0	19.2
Illinois	12,308	15,361	17,106	80,243	89,307	101,537	15.3	17.2	16.8
Indiana	7,219	7,967	8,546	39,188	44,005	51,564	18.4	18.1	16.6
Iowa	3,966	4,209	4,739	21,926	23,706	25,698	18.1	17.8	18.4
Kansas	3,572	3,875	3,638	20,074	20,728	23,943	17.8	18.7	15.2
Kentucky	2,960	3,694	4,039	19,669	21,825	27,152	15.0	16.9	14.9
Louisiana	4,249	4,828	4,730	23,565	26,491	28,224	18.0	18.2	16.8
Maine	1,220	1,331	1,403	6,686	7,145	8,532	18.2	18.6	16.4
Maryland	6,869	8,144	9,891	32,362	35,601	41,936	21.2	22.9	23.6
Massachusetts	11,411	12,634	12,988	66,594	71,260	78,421	17.1	17.7	16.6
Michigan	12,698	13,977	14,726	62,669	70,717	75,304	20.3	19.8	19.6
Minnesota	4,997	6,909	6,773	29,990	33,450	45,085	16.7	20.7	15.0
Mississippi	2,342	2,528	2,773	13,823	15,619	16,438	16.9	16.2	16.9
Missouri	6,020	7,367	7,301	39,902	46,834	53,828	15.1	15.7	13.6
Montana	1,504	1,669	1,571	5,706	6,340	6,509	26.4	26.3	24.1
Nebraska	2,178	2,350	2,533	12,629	14,190	15,765	17.2	16.6	16.1
Nevada	740	887	1,234	4,726	5,489	7,279	15.7	16.2	17.0
New Hampshire	1,833	2,167	1,726	9,772	9,486	11,207	18.8	22.8	15.4
New Jersey	7,441	9,098	8,513	34,345	39,686	46,676	21.7	22.9	18.2
New Mexico	1,877	1,886	2,201	8,835	8,402	9,748	21.2	22.4	22.6
New York	23,908	26,586	27,486	146,034	155,906	185,736	16.4	17.1	14.8
North Carolina	8,388	9,629	10,947	43,477	46,754	55,071	19.3	20.6	19.9
North Dakota	1,053	1,115	1,208	5,417	5,777	7,042	19.4	19.3	17.2
Ohio	12,290	13,512	14,240	69,154	73,784	82,584	17.8	18.3	17.2
Oklahoma	3,688	3,862	4,170	20,001	21,531	24,244	18.4	17.9	17.2
Oregon	3,014	3,470	4,220	17,733	19,139	23,655	17.0	18.1	17.8
Pennsylvania	15,787	18,537	20,083	84,854	95,111	113,396	18.6	19.5	17.7
Rhode Island	1,691	2,017	2,231	10,558	11,359	12,724	16.0	17.8	17.5
South Carolina	4,121	4,598	4,486	20,179	22,023	25,841	20.4	20.9	17.4
South Dakota	1,336	1,371	1,405	5,512	5,493	6,386	24.2	25.0	22.0
Tennessee	4,638	4,651	5,157	28,733	32,004	36,576	16.1	14.5	14.1
Texas	18,346	21,547	24,382	97,090	108,049	130,830	18.9	19.9	18.6
Utah	3,749	4,380	4,707	18,920	21,496	23,993	19.8	20.4	19.6
Vermont	964	1,045	1,320	5,517	6,003	7,042	17.5	17.4	18.7
Virginia	8,669	9,768	10,747	42,316	44,555	53,981	20.5	21.9	19.9
Washington	5,897	7,277	7,364	30,499	31,971	37,541	19.3	22.8	19.6
West Virginia	1,516	1,817	2,067	10,548	11,413	13,707	14.4	15.9	15.1
Wisconsin	6,634	7,232	8,433	34,805	37,284	41,842	19.1	19.4	20.2
Wyoming	818	859	748	2,124	2,155	2,154	38.5	39.9	34.7
Puerto Rico	3,439	4,082	3,636	15,811	19,433	22,734	21.8	21.0	16.0

NS&E = natural sciences and engineering

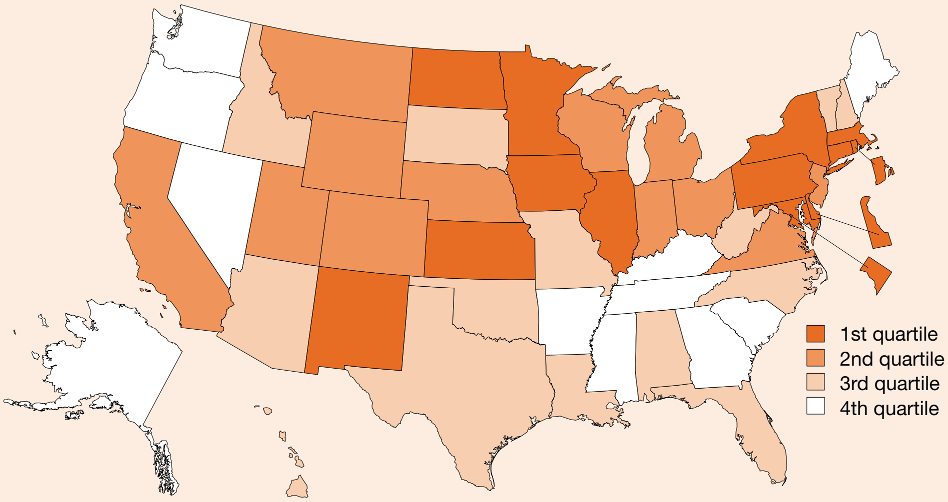
NOTES: NS&E degrees include bachelor's, master's, and doctorate. NS&E degrees include physical, computer, agricultural, biological, earth, atmospheric, and ocean sciences; mathematics; and engineering. "All higher education degrees" includes bachelor's, master's, and doctorate.

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science and Engineering Indicators 2010

S&E Graduate Students per 1,000 Individuals 25–34 Years Old

Figure 8-19
S&E graduate students per 1,000 individuals 25–34 years old: 2007



1st quartile (88.9–14.2)	2nd quartile (13.4–11.2)	3rd quartile (10.8–8.9)	4th quartile (8.3–5.1)
Connecticut	California	Alabama ‡	Alaska ‡
Delaware ‡	Colorado	Arizona	Arkansas ‡
District of Columbia	Indiana	Florida	Georgia
Illinois	Michigan	Hawaii ‡	Kentucky ‡
Iowa	Montana ‡	Idaho ‡	Maine ‡
Kansas ‡	Nebraska ‡	Louisiana ‡	Mississippi ‡
Maryland	New Jersey	Missouri	Nevada ‡
Massachusetts	Ohio	New Hampshire ‡	Oregon
Minnesota	Utah	North Carolina	South Carolina ‡
New Mexico ‡	Virginia	Oklahoma ‡	Tennessee
New York	Wisconsin	South Dakota ‡	Washington
North Dakota ‡	Wyoming ‡	Texas	
Pennsylvania		Vermont ‡	
Rhode Island ‡		West Virginia ‡	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and Census Bureau, Population Estimates Program. See table 8-19.

Findings

- The number of S&E graduate students in the United States grew from approximately 405,000 in 1997 to 499,000 in 2007, a 23% increase.
- Individual states provided graduate level S&E training to varying proportions of the population, with 2.9% to 0.5% of individuals 25–34 years old pursuing S&E graduate studies in 2007.
- Changes in the value of this indicator between 1997 and 2007 may reflect shifts in population, significant changes in S&E graduate education, or a combination of both.
- Growth in the number of S&E graduate students was most significant in California during this period. Other states with sizeable increases included Texas, New York, Florida, and Minnesota.

Graduate students in S&E fields may become the technical leaders of the future. The ratio of S&E graduate students to a state's population ages 25–34 years old is a relative measure of a state's population with graduate training in S&E. Graduate students are counted on the basis of their university enrollment and include state residents, residents of other states, and noncitizens. The cohort 25–34 years old was chosen to approximate the age of most graduate students. This population cohort includes all state residents ages 25–34 and does not distinguish between citizens and noncitizens.

Data on S&E graduate students were collected by surveying all academic institutions in the United States that offer doctoral or master's degree programs in any S&E field, including the physical, earth, ocean, atmospheric, biological, agricultural, computer, and social sciences; mathematics; engineering; and psychology. Graduate students enrolled in schools of nursing, public health, dentistry, veterinary medicine, and other health-related disciplines are not included.

Table 8-19

S&E graduate students per 1,000 individuals 25–34 years old, by state: 1997, 2002, and 2007

	S&E graduate students			Population 25–34 years old			S&E graduate students/1,000 individuals 25–34 years old		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	405,307	451,387	499,024	39,558,339	39,698,462	40,590,926	10.2	11.4	12.3
Alabama	5,288	5,704	6,162	625,515	587,727	603,903	8.5	9.7	10.2
Alaska	749	736	832	79,364	89,170	100,168	9.4	8.3	8.3
Arizona	6,468	7,153	8,157	654,684	781,407	915,523	9.9	9.2	8.9
Arkansas	1,853	1,932	2,649	335,763	351,068	378,494	5.5	5.5	7.0
California	51,176	58,469	66,792	5,279,694	5,271,205	5,179,032	9.7	11.1	12.9
Colorado	8,371	9,620	9,749	545,166	691,900	727,990	15.4	13.9	13.4
Connecticut	5,562	7,026	8,643	488,806	431,725	399,838	11.4	16.3	21.6
Delaware	1,413	1,564	1,777	119,512	105,900	106,957	11.8	14.8	16.6
District of Columbia	7,843	7,783	9,549	104,953	103,017	107,374	74.7	75.6	88.9
Florida	13,978	17,465	20,741	1,970,764	2,106,930	2,276,893	7.1	8.3	9.1
Georgia	8,481	10,092	11,435	1,217,255	1,315,540	1,374,703	7.0	7.7	8.3
Hawaii	1,598	1,657	1,858	160,985	171,531	177,096	9.9	9.7	10.5
Idaho	1,426	1,691	1,853	150,552	175,200	207,897	9.5	9.7	8.9
Illinois	21,857	24,813	25,281	1,783,545	1,800,397	1,766,903	12.3	13.8	14.3
Indiana	8,309	8,840	9,791	854,925	821,411	850,340	9.7	10.8	11.5
Iowa	4,617	4,928	5,146	374,757	356,050	363,669	12.3	13.8	14.2
Kansas	5,817	6,202	5,638	358,134	346,195	360,118	16.2	17.9	15.7
Kentucky	3,507	4,389	4,391	556,431	559,574	586,067	6.3	7.8	7.5
Louisiana	5,362	5,928	5,391	601,194	581,665	579,336	8.9	10.2	9.3
Maine	584	639	764	172,945	152,953	149,052	3.4	4.2	5.1
Maryland	9,163	10,164	11,357	814,881	731,189	719,905	11.2	13.9	15.8
Massachusetts	19,274	22,006	23,604	1,014,531	895,476	821,184	19.0	24.6	28.7
Michigan	14,708	16,706	15,595	1,423,309	1,321,563	1,256,377	10.3	12.6	12.4
Minnesota	6,435	7,248	12,733	669,827	667,582	683,505	9.6	10.9	18.6
Mississippi	2,686	2,776	3,142	382,623	374,687	382,061	7.0	7.4	8.2
Missouri	5,760	6,828	7,645	754,942	733,432	774,880	7.6	9.3	9.9
Montana	1,168	1,328	1,502	98,004	101,874	116,754	11.9	13.0	12.9
Nebraska	2,368	2,633	2,874	217,666	220,620	228,308	10.9	11.9	12.6
Nevada	1,466	1,662	2,262	253,645	323,849	381,263	5.8	5.1	5.9
New Hampshire	1,192	1,444	1,493	185,759	156,636	150,642	6.4	9.2	9.9
New Jersey	10,537	11,613	12,468	1,169,347	1,155,785	1,058,894	9.0	10.0	11.8
New Mexico	2,970	3,374	3,819	221,752	234,601	261,877	13.4	14.4	14.6
New York	38,481	40,114	45,887	2,780,058	2,675,696	2,522,113	13.8	15.0	18.2
North Carolina	9,810	11,271	13,170	1,143,569	1,212,062	1,215,863	8.6	9.3	10.8
North Dakota	847	1,108	1,485	84,358	73,534	78,531	10.0	15.1	18.9
Ohio	16,921	17,159	18,982	1,600,802	1,476,170	1,461,238	10.6	11.6	13.0
Oklahoma	3,763	4,484	4,604	433,901	451,368	489,871	8.7	9.9	9.4
Oregon	3,805	4,304	4,300	432,385	485,187	523,985	8.8	8.9	8.2
Pennsylvania	18,640	19,786	20,643	1,663,839	1,499,828	1,450,797	11.2	13.2	14.2
Rhode Island	1,554	1,768	1,961	155,539	137,322	128,693	10.0	12.9	15.2
South Carolina	3,562	3,313	3,303	570,554	555,147	572,462	6.2	6.0	5.8
South Dakota	851	1,028	891	90,549	90,023	98,407	9.4	11.4	9.1
Tennessee	6,151	6,136	6,200	797,574	804,714	843,811	7.7	7.6	7.3
Texas	26,779	31,264	35,100	2,857,237	3,248,635	3,505,689	9.4	9.6	10.0
Utah	3,908	4,321	4,850	292,936	343,479	432,390	13.3	12.6	11.2
Vermont	569	601	630	86,613	72,309	70,148	6.6	8.3	9.0
Virginia	11,380	12,805	14,000	1,097,057	1,028,882	1,048,130	10.4	12.4	13.4
Washington	5,841	6,129	6,414	817,042	849,669	900,709	7.1	7.2	7.1
West Virginia	1,974	2,320	2,276	229,861	224,782	231,369	8.6	10.3	9.8
Wisconsin	7,639	8,244	8,415	728,952	691,683	710,393	10.5	11.9	11.8
Wyoming	846	819	820	54,283	60,113	69,597	15.6	13.6	11.8
Puerto Rico	2,256	3,371	3,280	NA	NA	NA	NA	NA	NA

NA = not available

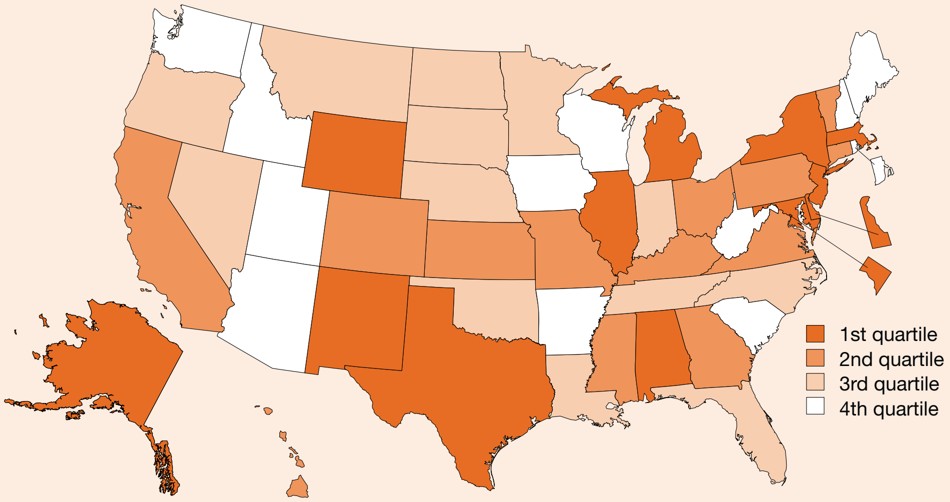
NOTE: S&E graduate students include students pursuing graduate degrees in physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and Census Bureau, Population Estimates Program (various years).

Science and Engineering Indicators 2010

Advanced S&E Degrees as Share of S&E Degrees Conferred

Figure 8-20
Advanced S&E degrees as share of S&E degrees conferred: 2007



1st quartile (45.1%–25.3%)	2nd quartile (25.0%–22.0%)	3rd quartile (21.9%–18.4%)	4th quartile (18.3%–8.0%)
Alabama ‡	California	Florida	Arizona
Alaska ‡	Colorado	Indiana	Arkansas ‡
Delaware ‡	Connecticut	Louisiana ‡	Idaho ‡
District of Columbia	Georgia	Minnesota	Iowa
Illinois	Hawaii ‡	Montana ‡	Maine ‡
Maryland	Kansas ‡	Nebraska ‡	New Hampshire ‡
Massachusetts	Kentucky ‡	Nevada ‡	Rhode Island ‡
Michigan	Mississippi ‡	North Carolina	South Carolina ‡
New Jersey	Missouri	North Dakota ‡	Utah
New Mexico ‡	Ohio	Oklahoma ‡	Washington
New York	Pennsylvania	Oregon	West Virginia ‡
Texas	Vermont ‡	South Dakota ‡	Wisconsin
Wyoming ‡	Virginia	Tennessee	

‡ EPSCoR state

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-20.

Findings

- In 2007, more than 150,000 advanced S&E degrees were awarded nationwide. This total represented approximately 26% more degrees than were awarded in 1997. However, the share of advanced degrees remained stable as a percentage of all S&E degrees conferred.
- In 2007, some states provided more extensive graduate-level technical training, with nearly 34% of their S&E graduates completing training at the master's or doctoral level; other states had much smaller graduate S&E programs, with values as low as 8%.
- The largest absolute increases in the production of advanced S&E degree holders between 1997 and 2007 occurred in California, Illinois, Texas, and New York.
- In states with few S&E graduate programs, the number of advanced S&E degrees conferred varies considerably from year to year. Readers should use caution when making annual comparisons for those states with small S&E graduate programs

This indicator shows the extent to which a state's higher education programs in S&E are concentrated at the graduate level. S&E fields include the physical, earth, ocean, atmospheric, biological, agricultural, computer, and social sciences; mathematics; engineering; and psychology. Advanced S&E degrees include master's and doctoral degrees. Total S&E degrees include bachelor's, master's, and doctoral degrees but exclude associate's degrees.

The indicator value is computed by dividing the number of advanced S&E degrees by the total number of S&E degrees awarded by the higher education institutions within the state.

Table 8-20

Advanced S&E degrees as share of S&E degrees conferred, by state: 1997, 2002, and 2007

	Advanced S&E degrees			All S&E degrees			Advanced S&E/ all S&E degrees (%)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	119,428	122,569	150,127	503,939	533,788	626,200	23.7	23.0	24.0
Alabama	1,863	1,991	2,282	7,199	7,160	8,271	25.9	27.8	27.6
Alaska	199	156	235	679	559	725	29.3	27.9	32.4
Arizona	1,787	1,612	1,930	6,743	7,538	11,915	26.5	21.4	16.2
Arkansas	414	476	552	2,917	3,096	3,226	14.2	15.4	17.1
California	12,988	14,942	19,027	56,483	65,685	78,329	23.0	22.7	24.3
Colorado	2,906	3,002	3,209	11,306	12,344	13,320	25.7	24.3	24.1
Connecticut	1,729	1,752	2,136	6,973	7,008	8,586	24.8	25.0	24.9
Delaware	432	389	547	1,929	2,003	2,154	22.4	19.4	25.4
District of Columbia	3,036	3,030	3,558	6,566	7,074	7,889	46.2	42.8	45.1
Florida	3,926	4,454	5,525	17,252	19,736	25,785	22.8	22.6	21.4
Georgia	2,279	2,767	3,272	10,415	12,278	14,646	21.9	22.5	22.3
Hawaii	536	443	552	2,046	2,032	2,385	26.2	21.8	23.1
Idaho	305	306	481	1,677	1,811	2,649	18.2	16.9	18.2
Illinois	6,466	6,786	9,205	21,877	23,368	27,328	29.6	29.0	33.7
Indiana	2,455	2,324	2,880	11,590	11,682	13,541	21.2	19.9	21.3
Iowa	1,137	1,089	1,256	6,560	6,604	7,364	17.3	16.5	17.1
Kansas	1,187	1,135	1,325	5,295	5,424	6,005	22.4	20.9	22.1
Kentucky	972	997	1,601	5,020	5,344	6,470	19.4	18.7	24.7
Louisiana	1,519	1,453	1,672	6,721	7,073	7,629	22.6	20.5	21.9
Maine	221	175	212	2,172	2,300	2,662	10.2	7.6	8.0
Maryland	3,483	3,927	4,886	11,867	13,135	15,800	29.4	29.9	30.9
Massachusetts	6,496	6,760	7,906	21,879	23,196	25,519	29.7	29.1	31.0
Michigan	4,621	4,977	5,557	18,631	19,139	21,374	24.8	26.0	26.0
Minnesota	1,665	1,813	2,252	9,265	9,642	11,534	18.0	18.8	19.5
Mississippi	730	727	838	3,447	3,558	3,817	21.2	20.4	22.0
Missouri	2,751	2,971	3,176	10,603	11,988	12,741	25.9	24.8	24.9
Montana	378	364	443	2,128	2,110	2,291	17.8	17.3	19.3
Nebraska	546	612	742	3,084	3,090	3,793	17.7	19.8	19.6
Nevada	284	278	393	1,218	1,335	2,021	23.3	20.8	19.4
New Hampshire	445	440	472	2,953	2,883	3,321	15.1	15.3	14.2
New Jersey	2,974	3,258	3,957	12,792	14,316	15,624	23.2	22.8	25.3
New Mexico	868	708	854	2,764	2,438	2,863	31.4	29.0	29.8
New York	11,419	11,511	13,543	44,186	44,595	51,276	25.8	25.8	26.4
North Carolina	2,477	2,694	3,421	14,878	15,132	17,325	16.6	17.8	19.7
North Dakota	238	210	312	1,556	1,487	1,644	15.3	14.1	19.0
Ohio	5,370	4,489	5,405	19,687	18,920	21,640	27.3	23.7	25.0
Oklahoma	1,557	1,698	1,357	5,625	5,861	6,185	27.7	29.0	21.9
Oregon	1,284	1,175	1,514	6,145	6,535	7,986	20.9	18.0	19.0
Pennsylvania	5,385	5,614	7,193	26,023	27,674	32,641	20.7	20.3	22.0
Rhode Island	549	566	648	2,914	3,067	3,597	18.8	18.5	18.0
South Carolina	1,004	981	1,079	5,999	6,170	6,981	16.7	15.9	15.5
South Dakota	382	314	416	2,012	1,779	2,029	19.0	17.7	20.5
Tennessee	1,633	1,386	1,620	8,048	8,013	8,802	20.3	17.3	18.4
Texas	7,072	7,164	9,413	27,060	28,592	36,053	26.1	25.1	26.1
Utah	1,077	1,006	1,308	6,434	6,739	7,999	16.7	14.9	16.4
Vermont	334	287	632	2,035	2,119	2,747	16.4	13.5	23.0
Virginia	3,423	3,156	4,126	15,366	15,694	18,369	22.3	20.1	22.5
Washington	2,032	1,903	2,310	10,014	10,350	12,632	20.3	18.4	18.3
West Virginia	472	492	573	2,559	2,732	3,142	18.4	18.0	18.2
Wisconsin	1,852	1,608	2,117	10,390	10,555	12,763	17.8	15.2	16.6
Wyoming	270	201	207	957	825	812	28.2	24.4	25.5
Puerto Rico	498	784	1,133	4,358	5,044	5,202	11.4	15.5	21.8

NOTES: "All S&E degrees" includes bachelor's, master's, and doctorate; "advanced S&E degrees" includes only master's and doctorate. S&E degrees include physical, computer, agricultural, biological, earth, atmospheric, ocean, and social sciences; psychology; mathematics; and engineering.

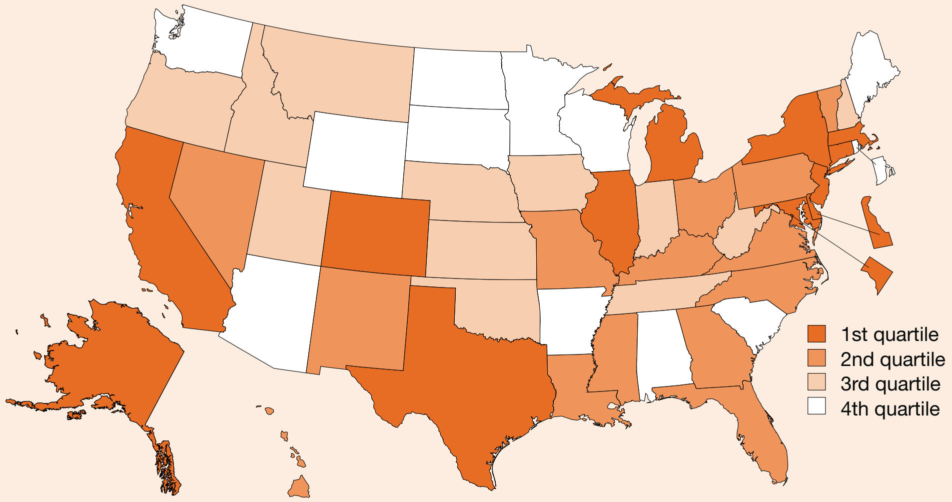
SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science and Engineering Indicators 2010

Advanced Natural Sciences and Engineering Degrees as Share of Natural Sciences and Engineering Degrees Conferred

Figure 8-21

Advanced natural sciences and engineering degrees as share of natural sciences and engineering degrees conferred: 2007



1st quartile (42.3%–26.8%)

Alaska ‡
California
Colorado
Connecticut
Delaware ‡
District of Columbia
Illinois
Maryland
Massachusetts
Michigan
New Jersey
New York
Texas

2nd quartile (25.9%–22.3%)

Florida
Georgia
Hawaii ‡
Kentucky ‡
Louisiana ‡
Mississippi ‡
Missouri
Nevada ‡
New Mexico ‡
North Carolina
Ohio
Pennsylvania
Vermont ‡
Virginia

3rd quartile (22.1%–19.8%)

Idaho ‡
Indiana
Iowa
Kansas ‡
Montana ‡
Nebraska ‡
New Hampshire ‡
Oklahoma ‡
Oregon
Tennessee
Utah
West Virginia ‡

4th quartile (19.5%–12.1%)

Alabama ‡
Arizona
Arkansas ‡
Maine ‡
Minnesota
North Dakota ‡
Rhode Island ‡
South Carolina ‡
South Dakota ‡
Washington
Wisconsin
Wyoming ‡

‡ EPSCoR state

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-21.

Findings

- In 2007, nearly 94,000 advanced NS&E degrees were awarded nationwide. This total represented approximately 26% more than were awarded in 1997, but the share of advanced degrees remained stable as a percentage of all NS&E degrees conferred.
- In 2007, some states provided more extensive graduate-level training in NS&E, with nearly 37% of their NS&E graduates completing training at the master's or doctoral level; other states had much smaller graduate NS&E programs, with values as low as 12%.
- The largest absolute increases in the production of advanced NS&E degree holders between 1997 and 2007 occurred in California and Texas.
- In states with few NS&E graduate programs, the number of advanced NS&E degrees conferred varies considerably from year to year. Readers should use caution when making annual comparisons for those states with small NS&E graduate programs.

This indicator shows the extent to which a state's higher education programs in natural sciences and engineering (NS&E) are concentrated at the graduate level. NS&E fields include the physical, earth, ocean, atmospheric, biological, agricultural, and computer sciences; mathematics; and engineering. Social sciences including anthropology, economics, political science and public administration, psychology, and sociology are not included. Advanced NS&E degrees include master's and doctoral degrees. Total NS&E degrees include bachelor's, master's, and doctoral degrees but exclude associate's degrees.

The indicator value is computed by dividing the number of advanced NS&E degrees by the total number of NS&E degrees awarded by the higher education institutions within the state.

Table 8-21

Advanced natural sciences and engineering degrees as share of natural sciences and engineering degrees conferred, by state: 1997, 2002, and 2007

	Advanced NS&E degrees			NS&E degrees conferred			Advanced NS&E degrees/ NS&E degrees conferred (%)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	74,427	77,551	93,952	300,380	346,643	375,931	24.8	22.4	25.0
Alabama	949	931	1,181	4,971	4,842	6,550	19.1	19.2	18.0
Alaska	134	107	146	440	338	438	30.5	31.7	33.3
Arizona	1,277	1,079	1,258	4,379	5,713	8,569	29.2	18.9	14.7
Arkansas	276	331	378	1,751	2,276	2,112	15.8	14.5	17.9
California	7,205	8,907	11,496	35,241	40,070	42,934	20.4	22.2	26.8
Colorado	2,028	2,147	2,090	6,625	8,100	7,506	30.6	26.5	27.8
Connecticut	1,140	1,182	1,535	3,196	3,296	4,206	35.7	35.9	36.5
Delaware	237	198	323	1,006	996	1,126	23.6	19.9	28.7
District of Columbia	1,243	1,514	1,296	2,963	3,701	3,061	42.0	40.9	42.3
Florida	2,412	2,944	3,562	9,334	11,944	14,494	25.8	24.6	24.6
Georgia	1,544	1,907	2,348	6,366	8,673	10,230	24.3	22.0	23.0
Hawaii	293	242	261	899	976	1,027	32.6	24.8	25.4
Idaho	235	243	380	1,298	1,564	1,846	18.1	15.5	20.6
Illinois	3,817	4,108	4,988	12,308	15,361	17,106	31.0	26.7	29.2
Indiana	1,568	1,471	1,892	7,219	7,967	8,546	21.7	18.5	22.1
Iowa	876	798	977	3,966	4,209	4,739	22.1	19.0	20.6
Kansas	717	691	789	3,572	3,875	3,638	20.1	17.8	21.7
Kentucky	540	612	901	2,960	3,694	4,039	18.2	16.6	22.3
Louisiana	1,069	992	1,216	4,249	4,828	4,730	25.2	20.5	25.7
Maine	165	116	170	1,220	1,331	1,403	13.5	8.7	12.1
Maryland	2,241	2,618	3,312	6,869	8,144	9,891	32.6	32.1	33.5
Massachusetts	3,792	4,050	4,814	11,411	12,634	12,988	33.2	32.1	37.1
Michigan	3,343	3,748	4,073	12,698	13,977	14,726	26.3	26.8	27.7
Minnesota	942	1,121	1,206	4,997	6,909	6,773	18.9	16.2	17.8
Mississippi	510	515	645	2,342	2,528	2,773	21.8	20.4	23.3
Missouri	1,300	1,283	1,637	6,020	7,367	7,301	21.6	17.4	22.4
Montana	283	273	324	1,504	1,669	1,571	18.8	16.4	20.6
Nebraska	372	388	529	2,178	2,350	2,533	17.1	16.5	20.9
Nevada	192	185	283	740	887	1,234	25.9	20.9	22.9
New Hampshire	322	336	349	1,833	2,167	1,726	17.6	15.5	20.2
New Jersey	2,120	2,262	2,543	7,441	9,098	8,513	28.5	24.9	29.9
New Mexico	573	499	571	1,877	1,886	2,201	30.5	26.5	25.9
New York	6,801	6,546	7,685	23,908	26,586	27,486	28.4	24.6	28.0
North Carolina	1,736	1,997	2,513	8,388	9,629	10,947	20.7	20.7	23.0
North Dakota	179	156	236	1,053	1,115	1,208	17.0	14.0	19.5
Ohio	3,369	2,789	3,361	12,290	13,512	14,240	27.4	20.6	23.6
Oklahoma	728	798	894	3,688	3,862	4,170	19.7	20.7	21.4
Oregon	808	777	925	3,014	3,470	4,220	26.8	22.4	21.9
Pennsylvania	3,409	3,649	4,586	15,787	18,537	20,083	21.6	19.7	22.8
Rhode Island	339	374	408	1,691	2,017	2,231	20.0	18.5	18.3
South Carolina	774	741	771	4,121	4,598	4,486	18.8	16.1	17.2
South Dakota	256	198	243	1,336	1,371	1,405	19.2	14.4	17.3
Tennessee	1,059	864	1,079	4,638	4,651	5,157	22.8	18.6	20.9
Texas	4,925	5,089	6,545	18,346	21,547	24,382	26.8	23.6	26.8
Utah	719	666	956	3,749	4,380	4,707	19.2	15.2	20.3
Vermont	106	121	294	964	1,045	1,320	11.0	11.6	22.3
Virginia	2,309	2,041	2,530	8,669	9,768	10,747	26.6	20.9	23.5
Washington	1,313	1,299	1,381	5,897	7,277	7,364	22.3	17.9	18.8
West Virginia	319	332	409	1,516	1,817	2,067	21.0	18.3	19.8
Wisconsin	1,392	1,180	1,527	6,634	7,232	8,433	21.0	16.3	18.1
Wyoming	171	136	136	818	859	748	20.9	15.8	18.2
Puerto Rico	204	354	462	3,439	4,082	3,636	5.9	8.7	12.7

NS&E = natural sciences and engineering

NOTES: “NS&E degrees conferred” includes bachelor’s, master’s, and doctorate; “advanced NS&E degrees” includes only master’s and doctorate. NS&E degrees include physical, computer, agricultural, biological, earth, atmospheric, and ocean sciences; mathematics; and engineering.

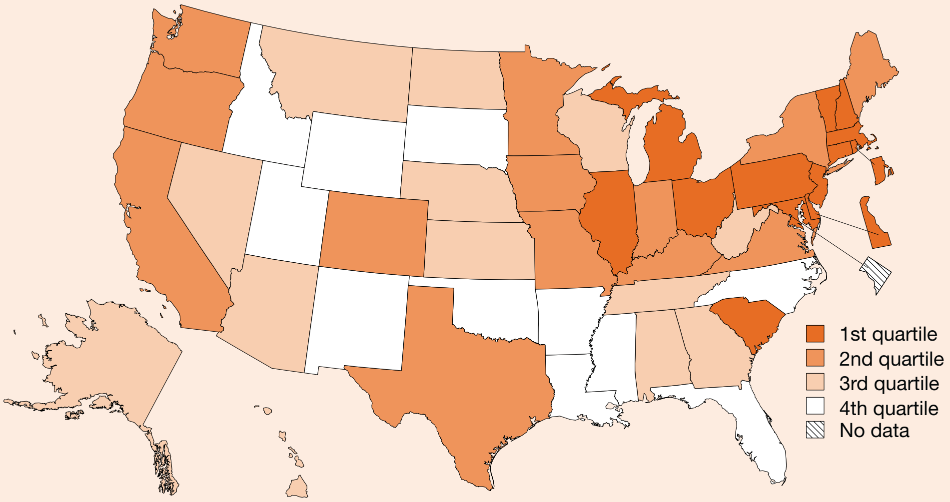
SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science and Engineering Indicators 2010

Average Undergraduate Charge at Public 4-Year Institutions

Figure 8-22

Average undergraduate charge at public 4-year institutions: 2008



1st quartile ($19,548–$15,089)	2nd quartile ($14,893–$12,367)	3rd quartile ($12,289–$10,984)	4th quartile ($10,889–$9,479)	No data
Connecticut	California	Alabama ‡	Arkansas ‡	District of Columbia
Delaware ‡	Colorado	Alaska ‡	Florida	
Illinois	Indiana	Arizona	Idaho ‡	
Maryland	Iowa	Georgia	Louisiana ‡	
Massachusetts	Kentucky ‡	Hawaii ‡	Mississippi ‡	
Michigan	Maine ‡	Kansas ‡	New Mexico ‡	
New Hampshire ‡	Minnesota	Montana ‡	North Carolina	
New Jersey	Missouri	Nebraska ‡	Oklahoma ‡	
Ohio	New York	Nevada ‡	South Dakota ‡	
Pennsylvania	Oregon	North Dakota ‡	Utah	
Rhode Island ‡	Texas	Tennessee	Wyoming ‡	
South Carolina ‡	Virginia	West Virginia ‡		
Vermont ‡	Washington	Wisconsin		

‡ EPSCoR state

SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-22.

Findings

- During 2008, the total annual nominal charge for a full-time undergraduate student to attend a public 4-year institution averaged $13,424 nationally, an increase of 76% during the past decade in current dollars. This was equivalent to an increase of approximately 40% after adjusting for inflation.
- All states showed major increases in undergraduate charges at public institutions in 2008, as compared with 1998. In several states, undergraduate charges more than doubled during this period.
- In 2008, the state average for a year of undergraduate education at a public 4-year institution ranged from a low of $9,479 to a high of $19,548.
- Tuition and required fees averaged 44% of the total charges at public 4-year institutions in 2008, but individual states had different cost structures.

The average annual charge for an undergraduate student to attend a public 4-year academic institution is one indicator of how accessible higher education is to a state's students. The annual charge includes standard in-state charges for tuition, required fees, room, and board for a full-time undergraduate student who is a resident of that state. These charges were weighted by the number of full-time undergraduates attending each public institution within the state. The total charge for all public 4-year institutions in the state was divided by the total number of full-time undergraduates attending all public 4-year institutions in the state. The year is the end date of the academic year. For example, data for 2008 represent costs for the 2007–08 academic year.

To improve educational attainment, the federal government, state governments, and academic institutions provide various kinds of financial aid that reduce the charge to students. The data in this indicator do not include any adjustments for such financial aid.

Table 8-22

Average undergraduate charge at public 4-year institutions, by state: 1998, 2003, and 2008

(Dollars)

State	1998	2003	2008
United States	7,628	9,828	13,424
Alabama	6,354	7,931	11,035
Alaska	7,131	9,457	11,719
Arizona	6,669	8,797	12,289
Arkansas	5,890	7,791	10,598
California	8,491	10,849	14,893
Colorado	7,552	9,179	13,314
Connecticut	9,652	11,805	16,263
Delaware	9,165	11,523	16,165
District of Columbia	NA	NA	NA
Florida	6,890	8,762	10,709
Georgia	6,924	8,749	10,984
Hawaii	NA	8,242	12,202
Idaho	6,074	7,585	9,871
Illinois	8,537	11,027	16,795
Indiana	8,494	10,655	14,096
Iowa	6,426	9,185	13,191
Kansas	6,098	7,791	11,338
Kentucky	5,662	7,691	12,641
Louisiana	5,710	6,922	9,479
Maine	8,576	10,329	14,791
Maryland	9,717	12,332	15,644
Massachusetts	8,894	10,818	16,159
Michigan	8,947	11,408	16,003
Minnesota	7,617	9,983	14,188
Mississippi	5,534	8,039	10,776
Missouri	7,520	9,395	13,385
Montana	6,855	8,966	11,609
Nebraska	6,100	8,408	11,852
Nevada	7,295	9,001	12,168
New Hampshire	9,846	9,415	18,293
New Jersey	10,235	13,937	19,548
New Mexico	5,459	7,979	10,610
New York	9,460	10,984	14,140
North Carolina	5,919	8,350	10,889
North Dakota	6,264	7,388	11,134
Ohio	9,022	12,260	16,354
Oklahoma	5,301	6,832	10,600
Oregon	8,394	10,548	13,868
Pennsylvania	9,769	12,944	17,187
Rhode Island	9,962	12,266	15,775
South Carolina	7,160	11,139	15,089
South Dakota	5,993	7,724	10,522
Tennessee	5,788	8,349	11,340
Texas	6,313	8,661	12,367
Utah	5,953	7,410	9,706
Vermont	11,469	14,016	18,245
Virginia	8,627	9,538	13,928
Washington	7,704	10,816	13,478
West Virginia	6,558	8,175	11,426
Wisconsin	6,409	8,204	11,747
Wyoming	6,450	7,977	10,068
Puerto Rico	NA	NA	NA

NA = not available

NOTES: National average for United States from Digest of Education Statistics data tables. Average charges for entire academic year (reported in current dollars). Tuition and fees weighted by number of full-time-equivalent undergraduates but not adjusted to reflect student residency. Room and board based on full-time students.

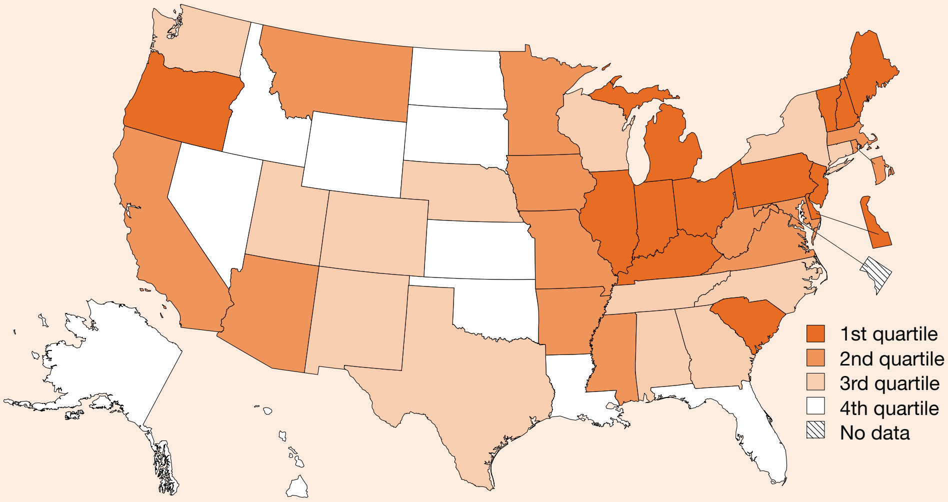
SOURCE: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science and Engineering Indicators 2010

Average Undergraduate Charge at Public 4-Year Institutions as Share of Disposable Personal Income

Figure 8-23

Average undergraduate charge at public 4-year institutions as share of disposable personal income: 2008



1st quartile (52.8%–43.8%)	2nd quartile (43.4%–37.4%)	3rd quartile (36.7%–34.8%)	4th quartile (34.5%–23.1%)	No data
Delaware ‡	Arizona	Alabama ‡	Alaska ‡	District of Columbia
Illinois	Arkansas ‡	Colorado	Florida	
Indiana	California	Connecticut	Hawaii ‡	
Kentucky ‡	Iowa	Georgia	Idaho ‡	
Maine ‡	Maryland	Nebraska ‡	Kansas ‡	
Michigan	Massachusetts	New Mexico ‡	Louisiana ‡	
New Hampshire ‡	Minnesota	New York	Nevada ‡	
New Jersey	Mississippi ‡	North Carolina	North Dakota ‡	
Ohio	Missouri	Tennessee	Oklahoma ‡	
Oregon	Montana ‡	Texas	South Dakota ‡	
Pennsylvania	Rhode Island ‡	Utah	Wyoming ‡	
South Carolina ‡	Virginia	Washington		
Vermont ‡	West Virginia ‡	Wisconsin		

‡ EPSCoR state

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System; and Bureau of Economic Analysis, State and Local Personal Income data. See table 8-23.

Findings

- In 2008, a year of undergraduate education at a state institution would have consumed, on average, 38.4% of a resident's disposable income, an increase from the 32.9% it would have consumed a decade earlier.
- The cost of a year of undergraduate education at a public institution was equivalent to one-quarter to one-half of the per capita disposable income for residents of most states in 2008.
- Although a year of undergraduate education at a public institution became more expensive for residents in most states within the past decade, affordability improved in one state during the past decade as its per capita disposable personal income rose appreciably.
- Residents in six states experienced major increases in the cost of a year of undergraduate education relative to their purchasing power (in excess of 10% of their per capita disposable income) between 1998 and 2008.

This indicator provides a broad measure of how affordable higher education at a public institution is for the average resident. It is calculated by dividing the average undergraduate charge at all public 4-year institutions in the state by the per capita disposable personal income of state residents. The average undergraduate charge includes standard in-state tuition, room, board, and required fees for a student who is a resident of the state. The year is the end date of the academic year. For example, data for 2008 represent costs for the 2007–08 academic year.

Disposable personal income is the income available to state residents for spending or saving. It is calculated as personal income minus personal current taxes paid to federal, state, and local governments.

High values indicate that a year of undergraduate education consumes a high percentage of the disposable personal income of state residents. However, the data in this indicator do not include any adjustment for financial aid that a student might receive.

Table 8-23

Average undergraduate charge at public 4-year institutions as share of disposable personal income, by state: 1998, 2003, and 2008

	Average undergraduate charge ($)			Per capita disposable personal income ($)			Undergraduate charge/disposable personal income (%)		
State	1998	2003	2008	1998	2003	2008	1998	2003	2008
United States	7,628	9,828	13,424	23,163	28,028	34,949	32.9	35.1	38.4
Alabama	6,354	7,931	11,035	19,500	23,969	30,297	32.6	33.1	36.4
Alaska	7,131	9,457	11,719	24,401	29,748	39,458	29.2	31.8	29.7
Arizona	6,669	8,797	12,289	20,250	24,368	29,391	32.9	36.1	41.8
Arkansas	5,890	7,791	10,598	18,146	22,214	28,270	32.5	35.1	37.5
California	8,491	10,849	14,893	24,258	29,457	37,041	35.0	36.8	40.2
Colorado	7,552	9,179	13,314	24,565	30,331	37,039	30.7	30.3	35.9
Connecticut	9,652	11,805	16,263	30,068	36,379	46,775	32.1	32.5	34.8
Delaware	9,165	11,523	16,165	23,933	29,605	35,880	38.3	38.9	45.1
District of Columbia	NA	NA	NA	30,608	40,583	56,245	NA	NA	NA
Florida	6,890	8,762	10,709	22,728	27,495	34,880	30.3	31.9	30.7
Georgia	6,924	8,749	10,984	21,792	25,581	30,082	31.8	34.2	36.5
Hawaii	NA	8,242	12,202	22,967	27,168	35,939	NA	30.3	34.0
Idaho	6,074	7,585	9,871	19,192	23,111	28,638	31.6	32.8	34.5
Illinois	8,537	11,027	16,795	25,103	30,025	37,298	34.0	36.7	45.0
Indiana	8,494	10,655	14,096	21,572	25,950	30,437	39.4	41.1	46.3
Iowa	6,426	9,185	13,191	21,725	25,866	32,919	29.6	35.5	40.1
Kansas	6,098	7,791	11,338	22,171	26,803	33,642	27.5	29.1	33.7
Kentucky	5,662	7,691	12,641	19,218	23,137	28,424	29.5	33.2	44.5
Louisiana	5,710	6,922	9,479	19,385	23,647	32,651	29.5	29.3	29.0
Maine	8,576	10,329	14,791	20,576	25,791	31,593	41.7	40.0	46.8
Maryland	9,717	12,332	15,644	25,610	32,470	41,325	37.9	38.0	37.9
Massachusetts	8,894	10,818	16,159	26,916	34,112	43,134	33.0	31.7	37.5
Michigan	8,947	11,408	16,003	23,077	27,936	31,719	38.8	40.8	50.5
Minnesota	7,617	9,983	14,188	24,649	30,169	37,300	30.9	33.1	38.0
Mississippi	5,534	8,039	10,776	17,593	21,281	27,077	31.5	37.8	39.8
Missouri	7,520	9,395	13,385	21,683	26,159	31,339	34.7	35.9	42.7
Montana	6,855	8,966	11,609	18,738	23,965	30,627	36.6	37.4	37.9
Nebraska	6,100	8,408	11,852	22,392	27,866	33,678	27.2	30.2	35.2
Nevada	7,295	9,001	12,168	24,576	28,473	35,768	29.7	31.6	34.0
New Hampshire	9,846	9,415	18,293	25,403	31,090	38,304	38.8	30.3	47.8
New Jersey	10,235	13,937	19,548	28,914	34,714	43,921	35.4	40.1	44.5
New Mexico	5,459	7,979	10,610	18,382	22,631	28,922	29.7	35.3	36.7
New York	9,460	10,984	14,140	26,461	31,053	40,254	35.8	35.4	35.1
North Carolina	5,919	8,350	10,889	21,400	24,935	30,311	27.7	33.5	35.9
North Dakota	6,264	7,388	11,134	20,620	26,469	35,824	30.4	27.9	31.1
Ohio	9,022	12,260	16,354	22,405	26,477	31,370	40.3	46.3	52.1
Oklahoma	5,301	6,832	10,600	19,161	23,950	33,143	27.7	28.5	32.0
Oregon	8,394	10,548	13,868	21,951	26,218	31,643	38.2	40.2	43.8
Pennsylvania	9,769	12,944	17,187	23,301	28,433	35,413	41.9	45.5	48.5
Rhode Island	9,962	12,266	15,775	23,111	29,022	36,336	43.1	42.3	43.4
South Carolina	7,160	11,139	15,089	19,440	23,449	28,556	36.8	47.5	52.8
South Dakota	5,993	7,724	10,522	21,251	27,253	34,216	28.2	28.3	30.8
Tennessee	5,788	8,349	11,340	21,452	26,133	31,327	27.0	31.9	36.2
Texas	6,313	8,661	12,367	22,282	26,865	34,850	28.3	32.2	35.5
Utah	5,953	7,410	9,706	18,937	22,742	26,641	31.4	32.6	36.4
Vermont	11,469	14,016	18,245	21,515	27,250	34,634	53.3	51.4	52.7
Virginia	8,627	9,538	13,928	23,662	29,787	37,194	36.5	32.0	37.4
Washington	7,704	10,816	13,478	24,615	29,992	38,009	31.3	36.1	35.5
West Virginia	6,558	8,175	11,426	18,068	22,117	27,926	36.3	37.0	40.9
Wisconsin	6,409	8,204	11,747	22,382	27,318	32,835	28.6	30.0	35.8
Wyoming	6,450	7,977	10,068	21,613	29,691	43,607	29.8	26.9	23.1
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not available

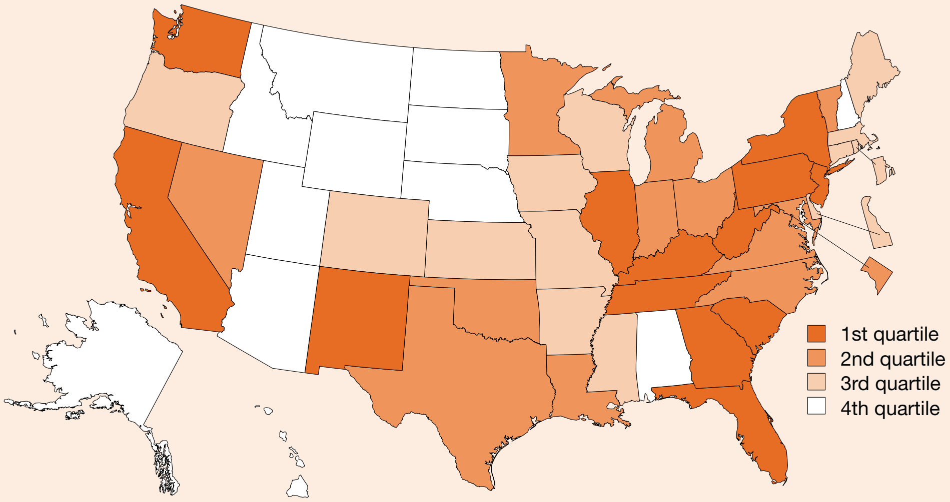
NOTES: National average undergraduate charge for United States from Digest of Education Statistics data tables. Average charges for entire academic year (reported in current dollars). Tuition and fees weighted by number of full-time-equivalent undergraduates but not adjusted to reflect student residency. Room and board based on full-time students. National value for disposable personal income is value reported by Bureau of Economic Analysis.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System (various years); and Bureau of Economic Analysis, State and Local Personal Income data.

Science and Engineering Indicators 2010

State Expenditures on Student Aid per Full-Time Undergraduate Student

Figure 8-24
State expenditures on student aid per full-time undergraduate student: 2007



1st quartile ($2,821–$1,222)	2nd quartile ($1,192–$660)	3rd quartile ($586–$226)	4th quartile ($189–$17)
California	District of Columbia	Arkansas ‡	Alabama ‡
Florida	Indiana	Colorado	Alaska ‡
Georgia	Louisiana ‡	Connecticut	Arizona
Illinois	Maryland	Delaware ‡	Hawaii ‡
Kentucky ‡	Michigan	Iowa	Idaho ‡
New Jersey	Minnesota	Kansas ‡	Montana ‡
New Mexico ‡	Nevada ‡	Maine ‡	Nebraska ‡
New York	North Carolina	Massachusetts	New Hampshire ‡
Pennsylvania	Ohio	Mississippi ‡	North Dakota ‡
South Carolina ‡	Oklahoma ‡	Missouri	South Dakota ‡
Tennessee	Texas	Oregon	Utah
Washington	Vermont ‡	Rhode Island ‡	Wyoming ‡
West Virginia ‡	Virginia	Wisconsin	

‡ EPSCoR state

SOURCES: National Association of State Student Grant and Aid Programs, Annual Survey Report; and National Center for Education Statistics, Integrated Postsecondary Education Data System. See table 8-24.

Findings

- The total amount of state financial aid from grants provided to undergraduates rose nationwide from $3.0 billion in 1997 to $7.3 billion in 2007.
- On a per-student basis, state funding for student grants across the United States increased from $568 per undergraduate in 1997 to $1,029 per undergraduate in 2007 (in current dollars).
- The amount of financial assistance provided by states and the District of Columbia varied greatly in 2007. Nine jurisdictions averaged less than $100 per undergraduate student, while 16 provided more than $1,000 per student. Four states reported spending less, in current dollars, per student for student financial aid in 2007 than in 1997, even though the cost of undergraduate education rose rapidly during this period. Three of these four states provided less than $100 per student.

The cost of an undergraduate education can be reduced with financial assistance from the state or federal government or from an academic institution. This indicator is calculated by dividing the amount of financial support from state grants by the number of full-time undergraduate students who attend both public and private institutions in the state. A high value is one indicator of state efforts to provide access to higher education at a time of escalating undergraduate costs. The actual distribution of state grants to individual students may be affected by the percentage of undergraduates who are state residents.

This indicator should be viewed relative to the tuition charged to undergraduates in a state, as some states have chosen to subsidize tuition for all students at public institutions rather than provide grants. Other differences between states (such as the amount of scholarship aid available from other sources, the percentage of students attending out-of-state institutions, and their eligibility for state funding) mean that readers should exercise caution when making comparisons between states and examining changes over time.

Total state grant expenditures for financial aid include need-based and non-need-based grants. State assistance through subsidized or unsubsidized loans and awards to students at the graduate and first professional degree levels is not included. The year is the end date of the academic year. For example, data for 2007 represent costs for the 2006–07 academic year.

Table 8-24
State expenditures on student aid per full-time undergraduate student, by state: 1997, 2002, and 2007

	State expenditures on student aid (current $thousands)			Undergraduate enrollment at 4-year institutions			State expenditures on student aid/ undergraduate ($)		
State	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	3,014,185	4,999,047	7,339,605	5,302,145	6,156,202	7,133,213	568	812	1,029
Alabama	8,163	7,335	8,772	94,855	103,215	115,282	86	71	76
Alaska	213	NA	587	10,411	10,899	11,617	20	NA	51
Arizona	2,748	2,812	13,231	75,904	118,138	284,069	36	24	47
Arkansas	13,725	37,897	30,212	51,954	60,282	67,132	264	629	450
California	257,544	514,348	763,008	454,713	551,489	620,961	566	933	1,229
Colorado	39,446	60,013	67,300	96,815	108,137	137,785	407	555	488
Connecticut	20,299	45,175	41,717	58,564	70,650	79,591	347	639	524
Delaware	1,183	1,626	13,489	18,892	22,309	23,026	63	73	586
District of Columbia	939	1,321	33,666	30,793	36,261	39,588	30	36	850
Florida	109,048	321,447	484,227	177,504	247,696	347,718	614	1,298	1,393
Georgia	185,867	362,201	480,730	142,198	162,595	198,074	1,307	2,228	2,427
Hawaii	379	531	408	19,770	22,630	24,216	19	23	17
Idaho	977	4,810	5,750	26,751	40,276	43,060	37	119	134
Illinois	298,993	407,622	444,348	208,464	237,251	285,235	1,434	1,718	1,558
Indiana	79,149	126,390	200,237	157,992	178,153	202,564	501	709	989
Iowa	42,411	51,668	55,535	77,563	87,498	102,432	547	591	542
Kansas	10,235	13,099	16,498	63,212	70,546	72,929	162	186	226
Kentucky	28,902	86,325	184,399	84,044	91,423	103,830	344	944	1,776
Louisiana	16,705	104,117	120,305	116,082	122,627	113,090	144	849	1,064
Maine	6,636	12,021	15,556	24,556	28,255	31,378	270	425	496
Maryland	42,188	51,910	95,089	80,058	94,159	104,236	527	551	912
Massachusetts	57,477	114,600	83,649	182,142	194,274	217,010	316	590	385
Michigan	85,872	106,244	206,242	194,897	228,848	245,394	441	464	840
Minnesota	92,746	130,408	162,919	103,063	125,283	136,720	900	1,041	1,192
Mississippi	590	21,481	22,588	50,169	54,737	58,369	12	392	387
Missouri	26,654	43,488	59,768	115,631	133,642	148,534	231	325	402
Montana	314	2,810	4,563	27,175	27,882	27,665	12	101	165
Nebraska	3,211	7,380	10,388	48,119	49,914	55,104	67	148	189
Nevada	3,707	19,899	38,353	16,920	25,774	42,335	219	772	906
New Hampshire	679	3,075	3,727	31,568	34,996	38,418	22	88	97
New Jersey	161,033	212,195	279,219	104,728	124,387	135,340	1,538	1,706	2,063
New Mexico	19,565	39,395	70,518	30,975	35,763	39,322	632	1,102	1,793
New York	633,902	699,481	861,448	421,585	484,218	525,797	1,504	1,445	1,638
North Carolina	46,248	134,196	221,632	157,278	175,306	206,979	294	765	1,071
North Dakota	2,454	1,776	2,238	23,553	27,535	27,994	104	64	80
Ohio	128,652	194,039	255,593	235,206	261,671	285,339	547	742	896
Oklahoma	22,046	31,464	66,075	71,838	86,968	92,355	307	362	715
Oregon	16,241	19,866	33,383	55,434	68,061	72,865	293	292	458
Pennsylvania	241,296	337,014	457,980	298,877	339,385	374,628	807	993	1,222
Rhode Island	5,699	6,077	13,021	37,890	43,202	48,036	150	141	271
South Carolina	21,540	102,039	271,239	74,790	86,528	96,153	288	1,179	2,821
South Dakota	346	NA	2,140	23,204	25,328	25,849	15	NA	83
Tennessee	19,364	37,915	231,287	112,152	124,302	143,843	173	305	1,608
Texas	42,761	199,523	374,730	306,560	361,336	411,776	139	552	910
Utah	2,170	4,069	8,566	73,490	89,795	98,342	30	45	87
Vermont	11,318	15,636	17,189	21,890	22,208	26,048	517	704	660
Virginia	80,064	110,467	149,296	142,237	158,773	195,135	563	696	765
Washington	59,631	102,458	184,942	84,623	97,843	121,059	705	1,047	1,528
West Virginia	10,527	21,054	77,883	51,761	56,387	56,805	203	373	1,371
Wisconsin	52,168	68,167	93,802	133,295	147,367	164,355	391	463	571
Wyoming	160	163	163	NA	NA	7,831	NA	NA	21
Puerto Rico	23,824	35,602	33,444	112,666	127,677	134,046	211	279	249

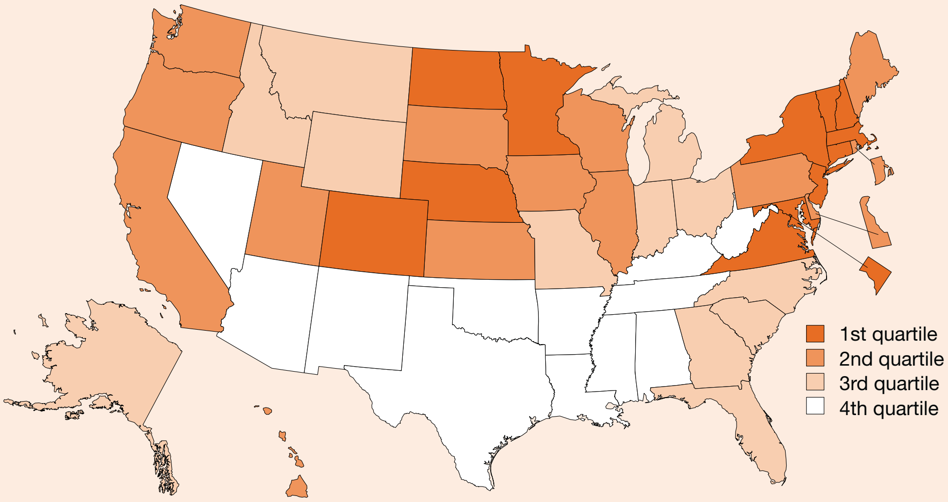
NA = not available

SOURCES: National Association of State Student Grant and Aid Programs, Annual Survey Report (various years); and National Center for Education Statistics, Integrated Postsecondary Education Data System (various years).

Science and Engineering Indicators 2010

Associate's Degree Holders or Higher Among Individuals 25–44 Years Old

Figure 8-25
Associate's degree holders or higher among individuals 25–44 years old: 2007



1st quartile (59.1%–43.2%)	2nd quartile (43.0%–37.4%)	3rd quartile (37.2%–33.3%)	4th quartile (32.8%–26.9%)
Colorado	California	Alaska ‡	Alabama ‡
Connecticut	Delaware ‡	Florida	Arizona
District of Columbia	Hawaii ‡	Georgia	Arkansas ‡
Maryland	Illinois	Idaho ‡	Kentucky ‡
Massachusetts	Iowa	Indiana	Louisiana ‡
Minnesota	Kansas ‡	Michigan	Mississippi ‡
Nebraska ‡	Maine ‡	Missouri	Nevada ‡
New Hampshire ‡	Oregon	Montana ‡	New Mexico ‡
New Jersey	Pennsylvania	North Carolina	Oklahoma ‡
New York	Rhode Island ‡	Ohio	Tennessee
North Dakota ‡	South Dakota ‡	South Carolina ‡	Texas
Vermont ‡	Utah	Wyoming ‡	West Virginia ‡
Virginia	Washington		
	Wisconsin		

‡ EPSCoR state

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program; and American Community Survey. See table 8-25.

Findings

- The early- to mid-career population with at least an associate's degree was 38.3% nationwide in 2007, which represents an increase from 34.7% in 2000.
- Between 2000 and 2007, all states showed an increase in the percentage of their early- to mid-career population with at least an associate's degree.
- In 2007, the percentage of this cohort with at least an associate's degree varied greatly among states, ranging from 51.8% to 26.9%.
- States that ranked highest on this indicator tended to be located in the northern United States.
- States with the lowest cost of living tended to rank lowest on this indicator.

This indicator represents the percentage of the early- to mid-career population that has earned at least a college degree. That degree may be an associate's, bachelor's, master's, or doctoral degree. The indicator represents where college degree holders live rather than where they were educated. The age cohort of 25–44 years represents the group most likely to have completed a college program.

Estimates of educational attainment are developed by the Census Bureau based on the 2000 Decennial Census and the American Community Survey (ACS). The census is conducted every 10 years, but ACS provides annual data on the characteristics of population and housing. In 2005, ACS became the largest household survey in the United States, with an annual sample size of about 3 million addresses. Estimates of population are taken from the Census Bureau's Population Estimates Program, which is also based on the 2000 Decennial Census.

Table 8-25
Associate's degree holders or higher among individuals 25–44 years old, by state: 2000, 2003, and 2007

	Associate's degree holders or higher 25–44 years old			Population 25–44 years old			Associate's degree holders/individuals 25–44 years old (%)		
State	2000	2003	2007	2000	2003	2007	2000	2003	2007
United States	29,471,612	30,738,684	31,935,182	85,040,251	84,216,990	83,483,659	34.7	36.5	38.3
Alabama	370,196	381,050	388,036	1,288,527	1,241,184	1,234,350	28.7	30.7	31.4
Alaska	61,646	58,059	65,635	203,522	194,823	197,222	30.3	29.8	33.3
Arizona	472,901	498,703	583,947	1,511,469	1,599,029	1,781,045	31.3	31.2	32.8
Arkansas	177,657	187,589	207,170	750,972	738,579	755,981	23.7	25.4	27.4
California	3,670,622	3,918,228	3,958,150	10,714,403	10,832,873	10,581,536	34.3	36.2	37.4
Colorado	596,036	623,279	635,206	1,400,850	1,417,501	1,448,632	42.5	44.0	43.8
Connecticut	443,608	447,818	431,258	1,032,689	999,800	925,266	43.0	44.8	46.6
Delaware	84,170	90,649	86,106	236,441	233,356	230,359	35.6	38.8	37.4
District of Columbia	90,097	100,283	113,684	189,439	188,758	192,511	47.6	53.1	59.1
Florida	1,513,345	1,616,842	1,781,351	4,569,347	4,676,558	4,812,179	33.1	34.6	37.0
Georgia	884,108	929,979	1,016,236	2,652,764	2,723,720	2,834,749	33.3	34.1	35.8
Hawaii	136,758	132,630	149,667	362,336	352,806	353,251	37.7	37.6	42.4
Idaho	112,690	121,592	142,792	362,401	370,690	401,380	31.1	32.8	35.6
Illinois	1,444,942	1,487,189	1,522,302	3,795,544	3,727,314	3,600,910	38.1	39.9	42.3
Indiana	537,644	543,808	590,086	1,791,828	1,748,331	1,734,016	30.0	31.1	34.0
Iowa	289,740	294,559	324,136	808,259	775,320	753,784	35.8	38.0	43.0
Kansas	282,475	307,608	294,750	769,204	743,961	727,170	36.7	41.3	40.5
Kentucky	317,109	335,263	359,918	1,210,773	1,182,970	1,188,087	26.2	28.3	30.3
Louisiana	316,348	346,949	312,253	1,293,128	1,230,819	1,159,582	24.5	28.2	26.9
Maine	122,958	128,525	131,939	370,597	358,691	337,652	33.2	35.8	39.1
Maryland	672,460	714,825	701,070	1,664,677	1,641,907	1,568,230	40.4	43.5	44.7
Massachusetts	942,748	970,834	929,041	1,989,783	1,922,446	1,794,769	47.4	50.5	51.8
Michigan	982,169	1,026,212	992,470	2,960,544	2,840,435	2,683,585	33.2	36.1	37.0
Minnesota	631,677	668,668	680,415	1,497,320	1,465,370	1,423,704	42.2	45.6	47.8
Mississippi	208,866	214,703	227,816	807,170	782,327	766,714	25.9	27.4	29.7
Missouri	517,750	541,597	567,002	1,626,302	1,587,931	1,579,645	31.8	34.1	35.9
Montana	81,428	85,047	86,169	245,220	232,735	235,309	33.2	36.5	36.6
Nebraska	185,090	187,939	203,440	487,107	471,024	457,810	38.0	39.9	44.4
Nevada	152,536	167,370	214,807	628,572	679,392	761,550	24.3	24.6	28.2
New Hampshire	156,434	163,231	159,905	381,240	373,644	351,263	41.0	43.7	45.5
New Jersey	1,076,450	1,105,776	1,090,780	2,624,146	2,578,072	2,400,533	41.0	42.9	45.4
New Mexico	149,398	142,448	157,903	516,100	506,956	516,167	28.9	28.1	30.6
New York	2,359,507	2,432,498	2,465,176	5,831,622	5,667,484	5,383,101	40.5	42.9	45.8
North Carolina	844,019	892,169	949,768	2,500,535	2,507,025	2,552,793	33.8	35.6	37.2
North Dakota	71,509	70,144	75,163	174,891	160,522	155,217	40.9	43.7	48.4
Ohio	1,075,353	1,107,195	1,115,946	3,325,210	3,172,294	3,054,756	32.3	34.9	36.5
Oklahoma	276,525	275,638	294,617	975,169	946,358	955,471	28.4	29.1	30.8
Oregon	333,963	355,143	393,990	997,269	1,003,698	1,034,933	33.5	35.4	38.1
Pennsylvania	1,230,548	1,243,379	1,291,414	3,508,562	3,343,434	3,182,590	35.1	37.2	40.6
Rhode Island	117,758	128,487	118,325	310,636	306,459	281,590	37.9	41.9	42.0
South Carolina	357,570	370,577	411,754	1,185,955	1,167,347	1,185,520	30.2	31.7	34.7
South Dakota	73,128	76,724	81,602	206,399	197,386	197,197	35.4	38.9	41.4
Tennessee	489,940	511,871	529,569	1,718,428	1,684,796	1,725,854	28.5	30.4	30.7
Texas	1,973,279	2,059,427	2,244,095	6,484,321	6,644,003	6,926,932	30.4	31.0	32.4
Utah	222,534	247,337	289,026	626,600	648,111	753,898	35.5	38.2	38.3
Vermont	70,277	68,018	69,117	176,456	168,392	157,657	39.8	40.4	43.8
Virginia	874,239	904,354	951,423	2,237,655	2,227,978	2,204,242	39.1	40.6	43.2
Washington	693,591	721,329	772,894	1,816,217	1,803,610	1,834,696	38.2	40.0	42.1
West Virginia	115,337	123,752	130,375	501,343	479,781	473,410	23.0	25.8	27.5
Wisconsin	566,244	566,942	596,698	1,581,690	1,537,180	1,499,802	35.8	36.9	39.8
Wyoming	44,235	44,448	48,790	138,619	131,810	135,059	31.9	33.7	36.1
Puerto Rico	358,595	NA	417,208	1,049,995	1,069,617	NA	34.2	NA	NA

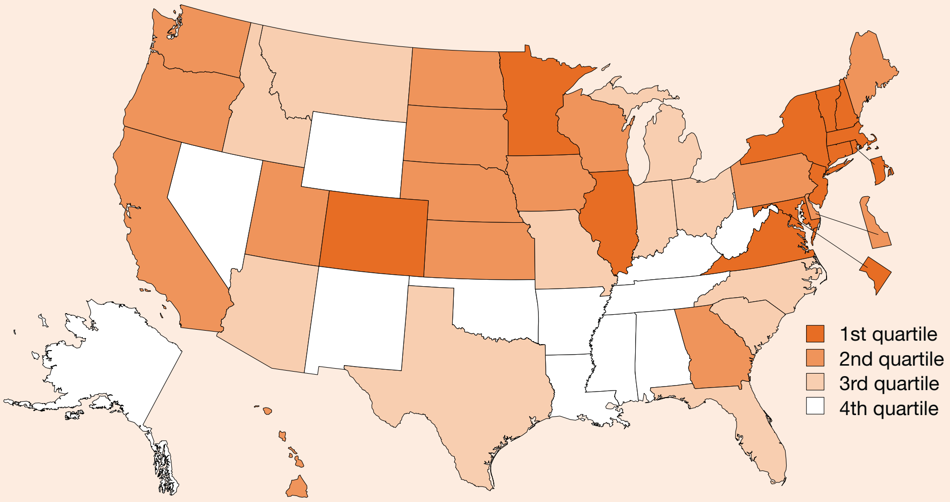
NA = not available

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years).

Science and Engineering Indicators 2010

Bachelor's Degree Holders or Higher Among Individuals 25–44 Years Old

Figure 8-26
Bachelor's degree holders or higher among individuals 25–44 years old: 2007



1st quartile (56.4%–33.5%)

Colorado
Connecticut
District of Columbia
Illinois
Maryland
Massachusetts
Minnesota
New Hampshire ‡
New Jersey
New York
Rhode Island ‡
Vermont ‡
Virginia

2nd quartile (32.3%–28.3%)

California
Delaware ‡
Georgia
Hawaii ‡
Iowa
Kansas ‡
Maine ‡
Nebraska ‡
North Dakota ‡
Oregon
Pennsylvania
South Dakota ‡
Utah
Washington
Wisconsin

3rd quartile (28.1%–24.5%)

Arizona
Florida
Idaho ‡
Indiana
Michigan
Missouri
Montana ‡
North Carolina
Ohio
South Carolina ‡
Texas

4th quartile (24.4%–19.4%)

Alabama ‡
Alaska ‡
Arkansas ‡
Kentucky ‡
Louisiana ‡
Mississippi ‡
Nevada ‡
New Mexico ‡
Oklahoma ‡
Tennessee
West Virginia ‡
Wyoming ‡

‡ EPSCoR state

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program; and American Community Survey. See table 8-26.

Findings

- The early- to mid-career population with at least a bachelor's degree was 29.8% nationwide in 2007, which represents an increase from 26.8% in 2000.
- All states showed an increase in the percentage of their early-career population with at least a bachelor's degree between 2000 and 2007.
- In 2007, the percentage of the early-career population with at least a bachelor's degree varied among states, ranging from 44.2% to 19.4%. The highest percentages tended to be found in the New England and Middle Atlantic states.
- States with the lowest cost of living tended to rank lowest on this indicator.
- EPSCoR states tended to be clustered in the lower quartiles for this indicator. However, several northern EPSCoR states showed high values.

This indicator represents the percentage of the early- to mid-career population that has earned at least a 4-year undergraduate degree. That degree may be at the bachelor's, master's, or doctoral level. The indicator represents where college degree holders live rather than where they were educated. The age cohort of 25–44 years represents a group of individuals who are potential long-term participants in a state's workforce.

Estimates of educational attainment are developed by the Census Bureau based on the 2000 Decennial Census and the American Community Survey (ACS). The census is conducted every 10 years, but ACS provides annual data on the characteristics of population and housing. In 2005, ACS became the largest household survey in the United States, with an annual sample size of about 3 million addresses. Estimates of population are taken from the Census Bureau's Population Estimates Program, which is also based on the 2000 Decennial Census.

Table 8-26
Bachelor's degree holders or higher among individuals 25–44 years old, by state: 2000, 2003, and 2007

	Bachelor's degree holders 25–44 years old			Population 25–44 years old			Bachelor's degree holders/individuals 25–44 years old (%)		
State	2000	2003	2007	2000	2003	2007	2000	2003	2007
EPSCoR states	3,004,954	3,180,725	3,264,082	13,582,778	13,252,012	13,214,968	22.1	24.0	24.7
Non-EPSCoR states	19,692,206	20,707,252	21,483,835	71,268,034	70,776,220	70,076,180	27.6	29.3	30.7
Average EPSCoR state value	na	na	na	na	na	na	23.4	25.4	26.3
Average non-EPSCoR state value	na	na	na	na	na	na	28.0	29.7	31.2
United States	22,781,996	23,984,096	24,856,576	85,040,251	84,216,990	83,483,659	26.8	28.5	29.8
Alabama	275,759	282,805	290,288	1,288,527	1,241,184	1,234,350	21.4	22.8	23.5
Alaska	45,560	44,868	48,098	203,522	194,823	197,222	22.4	23.0	24.4
Arizona	355,836	374,059	435,697	1,511,469	1,599,029	1,781,045	23.5	23.4	24.5
Arkansas	136,883	149,619	151,406	750,972	738,579	755,981	18.2	20.3	20.0
California	2,882,717	3,134,086	3,171,265	10,714,403	10,832,873	10,581,536	26.9	28.9	30.0
Colorado	480,984	513,973	518,478	1,400,850	1,417,501	1,448,632	34.3	36.3	35.8
Connecticut	362,272	380,576	356,702	1,032,689	999,800	925,266	35.1	38.1	38.6
Delaware	65,811	73,052	65,103	236,441	233,356	230,359	27.8	31.3	28.3
District of Columbia	84,836	96,119	108,659	189,439	188,758	192,511	44.8	50.9	56.4
Florida	1,081,551	1,159,165	1,285,284	4,569,347	4,676,558	4,812,179	23.7	24.8	26.7
Georgia	718,591	766,181	815,246	2,652,764	2,723,720	2,834,749	27.1	28.1	28.8
Hawaii	99,378	97,202	104,925	362,336	352,806	353,251	27.4	27.6	29.7
Idaho	80,235	88,937	102,126	362,401	370,690	401,380	22.1	24.0	25.4
Illinois	1,149,688	1,191,554	1,225,024	3,795,544	3,727,314	3,600,910	30.3	32.0	34.0
Indiana	397,050	404,241	431,559	1,791,828	1,748,331	1,734,016	22.2	23.1	24.9
Iowa	202,004	200,579	225,941	808,259	775,320	753,784	25.0	25.9	30.0
Kansas	223,467	243,308	230,048	769,204	743,961	727,170	29.1	32.7	31.6
Kentucky	234,921	247,142	268,167	1,210,773	1,182,970	1,188,087	19.4	20.9	22.6
Louisiana	256,363	283,161	242,865	1,293,128	1,230,819	1,159,582	19.8	23.0	20.9
Maine	86,989	92,827	95,436	370,597	358,691	337,652	23.5	25.9	28.3
Maryland	566,294	600,135	587,903	1,664,677	1,641,907	1,568,230	34.0	36.6	37.5
Massachusetts	773,569	820,821	793,674	1,989,783	1,922,446	1,794,769	38.9	42.7	44.2
Michigan	719,607	764,082	753,761	2,960,544	2,840,435	2,683,585	24.3	26.9	28.1
Minnesota	476,707	506,833	512,435	1,497,320	1,465,370	1,423,704	31.8	34.6	36.0
Mississippi	144,488	149,176	156,955	807,170	782,327	766,714	17.9	19.1	20.5
Missouri	407,449	424,660	443,268	1,626,302	1,587,931	1,579,645	25.1	26.7	28.1
Montana	62,682	63,186	64,466	245,220	232,735	235,309	25.6	27.1	27.4
Nebraska	134,516	138,152	147,777	487,107	471,024	457,810	27.6	29.3	32.3
Nevada	111,517	128,178	160,041	628,572	679,392	761,550	17.7	18.9	21.0
New Hampshire	114,745	121,639	123,284	381,240	373,644	351,263	30.1	32.6	35.1
New Jersey	899,016	932,505	922,809	2,624,146	2,578,072	2,400,533	34.3	36.2	38.4
New Mexico	110,360	106,530	116,114	516,100	506,956	516,167	21.4	21.0	22.5
New York	1,817,661	1,885,493	1,967,978	5,831,622	5,667,484	5,383,101	31.2	33.3	36.6
North Carolina	636,799	682,432	712,815	2,500,535	2,507,025	2,552,793	25.5	27.2	27.9
North Dakota	46,291	49,712	49,433	174,891	160,522	155,217	26.5	31.0	31.8
Ohio	806,803	835,693	840,228	3,325,210	3,172,294	3,054,756	24.3	26.3	27.5
Oklahoma	209,025	211,507	223,073	975,169	946,358	955,471	21.4	22.3	23.3
Oregon	257,875	278,460	307,422	997,269	1,003,698	1,034,933	25.9	27.7	29.7
Pennsylvania	938,930	959,366	989,049	3,508,562	3,343,434	3,182,590	26.8	28.7	31.1
Rhode Island	88,647	101,468	94,366	310,636	306,459	281,590	28.5	33.1	33.5
South Carolina	259,773	279,322	297,357	1,185,955	1,167,347	1,185,520	21.9	23.9	25.1
South Dakota	51,213	52,989	56,132	206,399	197,386	197,197	24.8	26.8	28.5
Tennessee	380,929	393,328	411,337	1,718,428	1,684,796	1,725,854	22.2	23.3	23.8
Texas	1,571,951	1,623,020	1,761,431	6,484,321	6,644,003	6,926,932	24.2	24.4	25.4
Utah	162,495	174,787	213,575	626,600	648,111	753,898	25.9	27.0	28.3
Vermont	52,787	53,121	53,807	176,456	168,392	157,657	29.9	31.5	34.1
Virginia	722,081	750,953	788,015	2,237,655	2,227,978	2,204,242	32.3	33.7	35.7
Washington	520,382	553,669	577,393	1,816,217	1,803,610	1,834,696	28.7	30.7	31.5
West Virginia	83,441	92,148	91,998	501,343	479,781	473,410	16.6	19.2	19.4
Wisconsin	402,965	396,601	435,546	1,581,690	1,537,180	1,499,802	25.5	25.8	29.0
Wyoming	30,103	30,676	30,817	138,619	131,810	135,059	21.7	23.3	22.8
Puerto Rico	245,975	NA	291,498	1,049,995	1,069,617	NA	23.4	NA	NA

na = not applicable; NA = not available

EPSCoR = Experimental Program to Stimulate Competitive Research

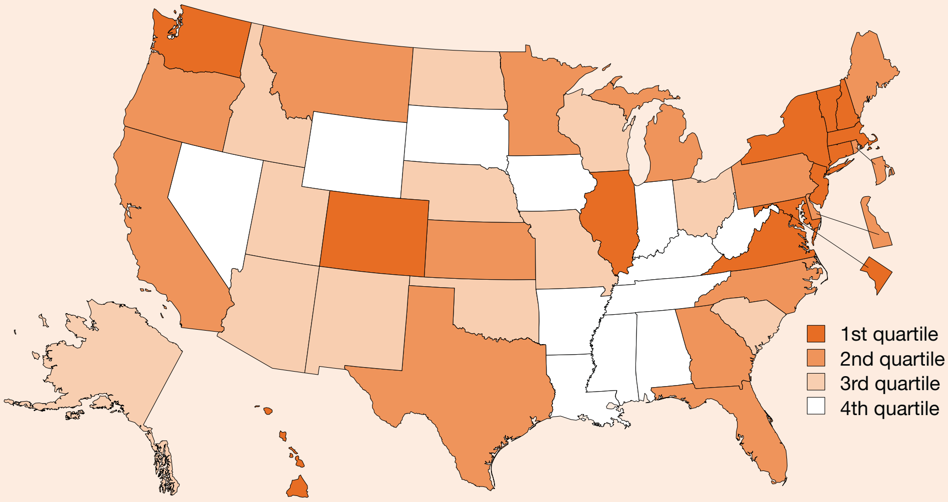
NOTE: For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

SOURCES: Census Bureau, 2000 Decennial Census; Population Estimates Program (various years); and American Community Survey (various years).

Science and Engineering Indicators 2010

Bachelor's Degree Holders Potentially in the Workforce

Figure 8-27
Bachelor's degree holders potentially in the workforce: 2007



1st quartile (51.1%–32.7%)	2nd quartile (32.6%–28.4%)	3rd quartile (28.3%–26.0%)	4th quartile (25.8%–22.2%)
Colorado	California	Alaska ‡	Alabama ‡
Connecticut	Delaware ‡	Arizona	Arkansas ‡
District of Columbia	Florida	Idaho ‡	Indiana
Hawaii ‡	Georgia	Missouri	Iowa
Illinois	Kansas ‡	Nebraska ‡	Kentucky ‡
Maryland	Maine ‡	New Mexico ‡	Louisiana ‡
Massachusetts	Michigan	North Dakota ‡	Mississippi ‡
New Hampshire ‡	Minnesota	Ohio	Nevada ‡
New Jersey	Montana ‡	Oklahoma ‡	South Dakota ‡
New York	North Carolina	South Carolina ‡	Tennessee
Vermont ‡	Oregon	Utah	West Virginia ‡
Virginia	Pennsylvania	Wisconsin	Wyoming ‡
Washington	Rhode Island ‡		
	Texas		

‡ EPSCoR state

SOURCES: Census Bureau, 2000 Decennial Census and American Community Survey; and Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-27.

Findings

- In 2007, 47 million individuals between ages 25 and 64 held bachelor's degrees in the United States, up from 39 million in 2000. Nationwide, the ratio of bachelor's degree holders to the size of the workforce rose from 28.5% in 2000 to 30.8% in 2007. This ratio varied considerably among the states, ranging from 22.2% to 42.6% in 2007.
- The value of this indicator increased in most jurisdictions between 2000 and 2007. This increase may reflect a replacement of older cohorts of workers with younger, more educated ones. It may also indicate the restructuring of state economies to emphasize work that requires a higher level of education or credentials.
- The geographic distribution of bachelor's degree holders bears little resemblance to any of the degree production indicators, which may be indicative of the considerable mobility of the college-educated population in the United States.

The ratio of degree holders (bachelor's, graduate, or professional) to the population potentially available for work is an indicator of the concentration of individuals with higher education qualifications in a jurisdiction. This indicator does not imply that all degree holders are currently employed; rather, it indicates the educational level of the workforce if all degree holders were employed. Knowledge-intensive businesses seeking to relocate may be attracted to states with high values on this indicator. Workers with at least a bachelor's degree have a clear advantage over less-educated workers in expected lifetime earnings.

Degree data are based on the U.S. Census Bureau's 2000 Decennial Census and American Community Survey and are limited to individuals 25–64 years old, the age range most representative of a jurisdiction's workforce. Individuals younger than age 25 are considered to be in the process of completing their education. Individuals older than 64 are considered to be largely retired, so their educational attainment would have limited applicability to the quality of the workforce. Civilian workforce data are Bureau of Labor Statistics estimates of employed persons based on Local Area Unemployment Statistics. Estimates for jurisdictions with smaller populations are generally less precise than estimates for jurisdictions with larger populations.

Table 8-27

Bachelor's degree holders potentially in the workforce, by state: 2000, 2003, and 2007

State	Bachelor's degree holders 25–64 years old			Employed workforce			Bachelor's degree holders/workforce (%)		
	2000	2003	2007	2000	2003	2007	2000	2003	2007
United States	39,078,598	43,038,717	47,027,346	136,940,378	137,418,377	152,650,836	28.5	31.3	30.8
Alabama	479,734	532,098	557,588	2,067,147	2,000,039	2,182,779	23.2	26.6	25.5
Alaska	87,739	91,931	99,542	299,324	308,523	352,304	29.3	29.8	28.3
Arizona	638,515	689,950	847,406	2,404,916	2,565,030	3,029,090	26.6	26.9	28.0
Arkansas	247,079	276,084	303,203	1,207,352	1,199,379	1,367,801	20.5	23.0	22.2
California	4,960,210	5,611,074	5,925,276	16,024,341	16,226,987	18,188,055	31.0	34.6	32.6
Colorado	819,906	901,534	988,923	2,300,192	2,323,554	2,705,557	35.6	38.8	36.6
Connecticut	633,867	695,356	706,405	1,697,670	1,704,693	1,865,483	37.3	40.8	37.9
Delaware	111,260	126,828	125,749	402,777	403,504	442,692	27.6	31.4	28.4
District of Columbia	133,155	148,230	166,334	291,916	283,736	325,562	45.6	52.2	51.1
Florida	1,968,126	2,266,930	2,596,402	7,569,406	7,811,887	9,147,797	26.0	29.0	28.4
Georgia	1,148,814	1,266,705	1,486,341	4,095,362	4,180,568	4,814,831	28.1	30.3	30.9
Hawaii	184,130	196,970	215,385	584,858	588,880	649,080	31.5	33.4	33.2
Idaho	149,622	172,807	199,003	632,451	652,627	754,136	23.7	26.5	26.4
Illinois	1,876,455	2,032,846	2,190,396	6,176,837	5,942,720	6,697,382	30.4	34.2	32.7
Indiana	672,835	707,713	801,095	3,052,719	3,011,436	3,211,461	22.0	23.5	24.9
Iowa	351,922	366,596	415,765	1,557,081	1,543,507	1,660,979	22.6	23.8	25.0
Kansas	385,924	434,766	445,743	1,351,988	1,364,410	1,478,781	28.5	31.9	30.1
Kentucky	402,094	435,777	498,060	1,866,348	1,851,017	2,043,770	21.5	23.5	24.4
Louisiana	453,353	512,319	480,089	1,930,662	1,899,642	1,997,873	23.5	27.0	24.0
Maine	170,334	193,729	207,589	650,385	655,561	704,693	26.2	29.6	29.5
Maryland	979,588	1,083,343	1,141,741	2,711,382	2,750,040	2,980,353	36.1	39.4	38.3
Massachusetts	1,266,113	1,370,101	1,450,619	3,273,281	3,211,853	3,408,197	38.7	42.7	42.6
Michigan	1,242,388	1,378,696	1,435,481	4,953,421	4,681,180	5,019,984	25.1	29.5	28.6
Minnesota	783,613	891,852	938,351	2,720,492	2,765,997	2,930,553	28.8	32.2	32.0
Mississippi	256,581	279,111	297,806	1,239,859	1,228,526	1,314,811	20.7	22.7	22.7
Missouri	695,491	776,798	834,879	2,875,336	2,819,935	3,031,187	24.2	27.5	27.5
Montana	124,462	130,542	144,380	446,552	447,679	501,349	27.9	29.2	28.8
Nebraska	230,857	244,248	273,457	923,198	932,870	983,438	25.0	26.2	27.8
Nevada	206,361	241,719	309,343	1,015,221	1,092,651	1,335,852	20.3	22.1	23.2
New Hampshire	207,431	226,741	252,305	675,541	684,348	738,314	30.7	33.1	34.2
New Jersey	1,510,429	1,639,510	1,744,741	4,130,310	4,126,674	4,466,275	36.6	39.7	39.1
New Mexico	226,334	232,196	259,419	810,024	832,639	943,062	27.9	27.9	27.5
New York	3,031,927	3,275,249	3,561,887	8,751,441	8,713,529	9,519,301	34.6	37.6	37.4
North Carolina	1,044,025	1,155,486	1,324,014	3,969,235	3,965,695	4,519,186	26.3	29.1	29.3
North Dakota	80,545	91,105	96,019	335,780	335,453	365,598	24.0	27.2	26.3
Ohio	1,375,311	1,480,377	1,598,059	5,573,154	5,502,110	5,976,510	24.7	26.9	26.7
Oklahoma	383,381	414,535	451,047	1,609,522	1,597,338	1,732,703	23.8	26.0	26.0
Oregon	488,862	533,853	613,549	1,716,954	1,704,397	1,927,802	28.5	31.3	31.8
Pennsylvania	1,618,658	1,736,241	1,896,406	5,830,902	5,818,296	6,287,116	27.8	29.8	30.2
Rhode Island	156,862	185,148	184,117	520,758	535,458	576,987	30.1	34.6	31.9
South Carolina	454,656	521,905	575,269	1,902,029	1,868,309	2,136,516	23.9	27.9	26.9
South Dakota	89,855	95,907	108,977	397,678	405,840	442,555	22.6	23.6	24.6
Tennessee	649,844	719,592	784,298	2,756,498	2,720,676	3,036,736	23.6	26.4	25.8
Texas	2,646,909	2,892,917	3,278,378	9,896,002	10,260,318	11,492,422	26.7	28.2	28.5
Utah	276,360	292,932	374,739	1,097,915	1,132,948	1,361,768	25.2	25.9	27.5
Vermont	103,476	113,291	121,452	326,742	333,788	353,861	31.7	33.9	34.3
Virginia	1,232,454	1,361,804	1,505,597	3,502,524	3,646,114	4,054,199	35.2	37.3	37.1
Washington	932,352	1,037,358	1,131,129	2,898,677	2,916,045	3,408,191	32.2	35.6	33.2
West Virginia	157,883	179,117	186,093	764,649	742,990	808,840	20.6	24.1	23.0
Wisconsin	690,065	732,493	829,718	2,894,884	2,866,994	3,089,321	23.8	25.5	26.9
Wyoming	60,451	64,307	67,782	256,685	259,987	287,743	23.6	24.7	23.6
Puerto Rico	378,586	NA	485,235	1,162,153	1,200,322	1,393,808	32.6	NA	34.8

NA = not available

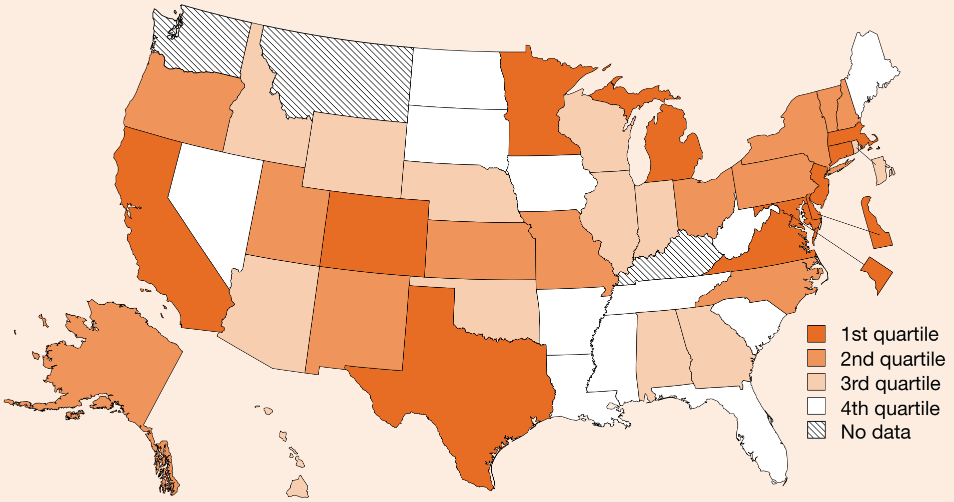
NOTES: Bachelor's degree holders include those who completed a bachelor's or higher degree. Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: Census Bureau, 2000 Decennial Census and American Community Survey (various years); and Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

Individuals in S&E Occupations as Share of Workforce

Figure 8-28
Individuals in S&E occupations as share of workforce: 2008



1st quartile (19.04%–3.96%)	2nd quartile (3.95%–3.37%)	3rd quartile (3.35%–2.80%)	4th quartile (2.76%–1.99%)	No data
California	Alaska ‡	Alabama ‡	Arkansas ‡	Kentucky ‡
Colorado	Kansas ‡	Arizona	Florida	Montana ‡
Connecticut	Missouri	Georgia	Iowa	Washington
Delaware ‡	New Hampshire ‡	Hawaii ‡	Louisiana ‡	
District of Columbia	New Mexico ‡	Idaho ‡	Maine ‡	
Maryland	New York	Illinois	Mississippi ‡	
Massachusetts	North Carolina	Indiana	Nevada ‡	
Michigan	Ohio	Nebraska ‡	North Dakota ‡	
Minnesota	Oregon	Oklahoma ‡	South Carolina ‡	
New Jersey	Pennsylvania	Rhode Island ‡	South Dakota ‡	
Texas	Utah	Wisconsin	Tennessee	
Virginia	Vermont ‡	Wyoming ‡	West Virginia ‡	

‡ EPSCoR state

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-28.

Findings

- In 2008, 3.8% of the U.S. workforce (about 5.8 million people) worked in occupations classified as S&E.
- In 2008, the percentage of the workforce engaged in S&E occupations ranged from 2.0% to 6.4% in individual states.
- The highest percentages of S&E occupations were found in the District of Columbia and the adjacent states of Maryland and Virginia as well as in Massachusetts and Colorado in 2008.
- EPSCoR states tended to cluster in the lower quartiles of this indicator, indicating that their workforces contained a smaller percentage of individuals in S&E occupations.

This indicator shows the extent to which a state's workforce is employed in S&E occupations. A high value for this indicator shows that a state's economy has a high percentage of technical jobs relative to other states.

S&E occupations are defined by standard occupational codes. They include engineers and computer, mathematical, life, physical, and social scientists. They exclude managers, technicians, elementary and secondary schoolteachers, and medical personnel.

State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work. The survey is conducted as part of a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. State data on the size of the civilian workforce are BLS estimates based on the Current Population Survey, which assigns workers to a state based on where they live.

Situations in which workers live in one state and work in another introduce some imprecision into the calculation of this indicator. The treatment of postsecondary teachers is another source of imprecision. Because OES data do not classify postsecondary teachers by field, in these data, faculty teaching in S&E fields are not counted as working in S&E occupations. Estimates for jurisdictions with smaller populations are generally less precise than estimates for jurisdictions with larger populations.

Table 8-28

Individuals in S&E occupations as share of workforce, by state: 2004, 2006, and 2008

	S&E occupations			Employed workforce			Workforce in S&E occupations (%)		
State	2004	2006	2008	2004	2006	2008	2004	2006	2008
United States	5,085,740	5,407,710	5,781,460	139,213,523	144,581,912	153,999,337	3.65	3.74	3.75
Alabama	57,560	66,100	68,580	2,014,678	2,120,573	2,162,479	2.86	3.12	3.17
Alaska	10,660	10,720	13,260	312,922	323,531	357,136	3.41	3.31	3.71
Arizona	95,380	98,110	102,100	2,649,243	2,854,381	3,132,667	3.60	3.44	3.26
Arkansas	22,150	24,860	29,310	1,228,163	1,292,886	1,370,259	1.80	1.92	2.14
California	693,670	730,010	791,750	16,444,457	17,029,307	18,391,844	4.22	4.29	4.30
Colorado	126,280	133,730	147,000	2,384,562	2,537,037	2,730,447	5.30	5.27	5.38
Connecticut	82,820	79,380	80,290	1,714,758	1,765,075	1,876,125	4.83	4.50	4.28
Delaware	17,980	21,550	22,330	408,022	424,506	442,902	4.41	5.08	5.04
District of Columbia	57,750	64,120	63,360	285,567	296,957	332,703	20.22	21.59	19.04
Florida	229,950	246,190	248,200	8,056,259	8,692,761	9,231,462	2.85	2.83	2.69
Georgia	141,710	136,470	147,380	4,257,465	4,522,025	4,847,650	3.33	3.02	3.04
Hawaii	16,360	18,940	18,830	597,147	628,277	654,261	2.74	3.01	2.88
Idaho	22,310	NA	23,310	670,746	723,621	754,879	3.33	NA	3.09
Illinois	219,530	222,470	224,370	6,012,320	6,315,715	6,697,335	3.65	3.52	3.35
Indiana	79,120	80,110	90,840	3,017,271	3,108,806	3,230,367	2.62	2.58	2.81
Iowa	39,280	43,670	46,180	1,542,342	1,602,849	1,675,981	2.55	2.72	2.76
Kansas	52,020	48,620	54,260	1,378,713	1,400,169	1,496,943	3.77	3.47	3.62
Kentucky	44,350	44,680	NA	1,859,902	1,922,163	2,042,915	2.38	2.32	NA
Louisiana	42,230	40,180	41,790	1,926,594	1,910,348	2,078,935	2.19	2.10	2.01
Maine	15,160	15,950	17,000	661,163	678,843	706,829	2.29	2.35	2.41
Maryland	154,310	159,470	167,070	2,766,653	2,892,620	2,997,709	5.58	5.51	5.57
Massachusetts	186,260	198,670	217,310	3,204,653	3,234,860	3,424,018	5.81	6.14	6.35
Michigan	183,140	208,520	204,290	4,694,981	4,730,291	4,935,584	3.90	4.41	4.14
Minnesota	119,380	125,930	134,440	2,781,744	2,822,297	2,932,961	4.29	4.46	4.58
Mississippi	23,190	24,910	27,270	1,234,167	1,218,664	1,314,444	1.88	2.04	2.07
Missouri	87,200	96,420	105,390	2,821,802	2,885,857	3,012,126	3.09	3.34	3.50
Montana	11,390	13,010	NA	456,624	478,162	506,159	2.49	2.72	NA
Nebraska	31,720	32,500	31,820	940,047	945,270	995,635	3.37	3.44	3.20
Nevada	23,980	26,930	27,300	1,134,550	1,240,868	1,373,462	2.11	2.17	1.99
New Hampshire	24,350	27,680	29,150	693,648	711,512	738,858	3.51	3.89	3.95
New Jersey	165,150	176,460	198,060	4,177,841	4,309,021	4,496,727	3.95	4.10	4.40
New Mexico	33,500	30,800	34,560	850,164	895,623	959,458	3.94	3.44	3.60
New York	272,930	306,810	326,510	8,810,155	9,072,733	9,679,617	3.10	3.38	3.37
North Carolina	135,380	138,790	153,680	4,028,598	4,250,619	4,543,754	3.36	3.27	3.38
North Dakota	8,420	9,360	9,450	338,221	346,359	369,671	2.49	2.70	2.56
Ohio	180,360	185,190	206,320	5,507,404	5,609,056	5,971,874	3.27	3.30	3.45
Oklahoma	NA	50,770	48,900	1,608,849	1,650,877	1,748,416	NA	3.08	2.80
Oregon	62,570	64,520	70,070	1,722,058	1,796,165	1,957,953	3.63	3.59	3.58
Pennsylvania	195,730	214,910	227,170	5,889,957	6,009,858	6,394,884	3.32	3.58	3.55
Rhode Island	19,660	18,060	18,090	531,121	547,618	567,597	3.70	3.30	3.19
South Carolina	51,030	53,230	57,770	1,900,122	1,988,378	2,152,965	2.69	2.68	2.68
South Dakota	9,420	10,120	11,870	409,263	417,100	444,890	2.30	2.43	2.67
Tennessee	65,120	67,040	72,760	2,733,793	2,835,530	3,041,276	2.38	2.36	2.39
Texas	383,180	408,710	463,850	10,456,224	10,921,673	11,701,585	3.66	3.74	3.96
Utah	43,030	49,690	52,570	1,169,163	1,272,801	1,383,743	3.68	3.90	3.80
Vermont	11,770	12,780	12,360	337,709	348,026	355,432	3.49	3.67	3.48
Virginia	220,180	251,720	259,280	3,704,593	3,878,988	4,124,766	5.94	6.49	6.29
Washington	154,610	171,780	NA	3,008,352	3,160,350	3,476,766	5.14	5.44	NA
West Virginia	16,100	17,150	17,000	744,034	767,134	806,152	2.16	2.24	2.11
Wisconsin	95,230	96,860	101,680	2,871,034	2,918,155	3,084,130	3.32	3.32	3.30
Wyoming	6,760	7,640	8,850	263,705	275,617	292,606	2.56	2.77	3.02
Puerto Rico	20,410	23,850	22,970	1,226,251	1,260,703	1,366,307	1.66	1.89	1.68

NA = not available

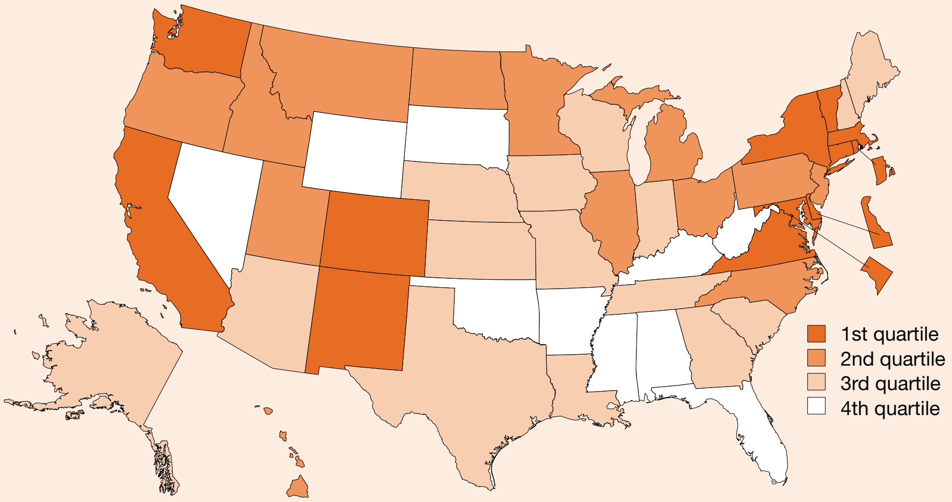
NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted. National total for S&E occupations in the United States provided by Occupational Employment Statistics (OES). OES estimates for 2004, 2006, and 2008 S&E occupations based on May data.

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

Employed S&E Doctorate Holders as Share of Workforce

Figure 8-29
Employed S&E doctorate holders as share of workforce: 2006



1st quartile (4.49%–0.49%)	2nd quartile (0.48%–0.37%)	3rd quartile (0.35%–0.29%)	4th quartile (0.28%–0.20%)
California	Hawaii[‡]	Alaska[‡]	Alabama[‡]
Colorado	Idaho[‡]	Arizona	Arkansas[‡]
Connecticut	Illinois	Georgia	Florida
Delaware[‡]	Michigan	Indiana	Kentucky[‡]
District of Columbia	Minnesota	Iowa	Mississippi[‡]
Maryland	Montana[‡]	Kansas[‡]	Nevada[‡]
Massachusetts	New Jersey	Louisiana[‡]	Oklahoma[‡]
New Mexico[‡]	North Carolina	Maine[‡]	South Dakota[‡]
New York	North Dakota[‡]	Missouri	West Virginia[‡]
Rhode Island[‡]	Ohio	Nebraska[‡]	Wyoming[‡]
Vermont[‡]	Oregon	New Hampshire[‡]	
Virginia	Pennsylvania	South Carolina[‡]	
Washington	Utah	Tennessee	
		Texas	
		Wisconsin	

[‡] EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-29.

Findings

- The number of employed S&E doctorate holders in the United States rose from 517,000 in 1997 to 618,000 in 2006, an increase of 20%.
- Overall, the value of this indicator rose from 0.39% in 1996 to 0.43% in 2006 because the number of employed S&E doctorate holders nationwide increased more rapidly than the size of the workforce.
- In 2006, the values for this indicator in individual states ranged from 0.20% to 1.00% of a state's workforce.
- States in the top quartile tended to be home to major research laboratories, research universities, or research-intensive industries.
- EPSCoR states tended to be clustered in the lower two quartiles for this indicator, reflecting the fact that lower levels of federal support reduce job opportunities for S&E doctorate holders.

This indicator shows a state's ability to attract and retain highly trained scientists and engineers. These individuals often conduct R&D, manage R&D activities, or are otherwise engaged in knowledge-intensive activities. A high value for this indicator in a state suggests employment opportunities for individuals with highly advanced training in S&E fields.

Data on employed S&E doctorate holders include those with doctoral degrees in computer and mathematical sciences; the biological, agricultural, or environmental life sciences; physical sciences; social sciences; psychology; engineering; and health fields. S&E doctorate data derive from the National Science Foundation's Survey of Doctorate Recipients, which excludes individuals with doctorates from foreign institutions and those above the age of 75. The Survey of Doctorate Recipients is a sample survey. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations. Data for S&E doctorate holders are presented by employment location regardless of residence.

Civilian workforce data are Bureau of Labor Statistics estimates from the Local Area Unemployment Statistics, which bases location on residence. Workforce data represent annual estimates of the employed civilian labor force; estimates are not seasonally adjusted.

Table 8-29

Employed S&E doctorate holders as share of workforce, by state: 1997, 2001, and 2006

	Employed S&E doctorate holders[a]			Employed workforce			S&E doctorate holders in workforce (%)		
State	1997	2001	2006	1997	2001	2006	1997	2001	2006
United States	516,560	572,800	618,370	130,988,267	137,115,199	144,581,912	0.39	0.42	0.43
Alabama	6,610	5,330	5,900	2,035,156	2,034,909	2,120,573	0.32	0.26	0.28
Alaska	1,110	1,200	1,110	289,963	301,694	323,531	0.38	0.40	0.34
Arizona	6,280	7,070	8,410	2,196,901	2,453,453	2,854,381	0.29	0.29	0.29
Arkansas	2,320	2,560	2,840	1,177,143	1,194,024	1,292,886	0.20	0.21	0.22
California	70,490	80,870	87,370	14,780,791	16,220,033	17,029,307	0.48	0.50	0.51
Colorado	10,740	11,780	13,150	2,154,294	2,303,494	2,537,037	0.50	0.51	0.52
Connecticut	8,770	9,490	10,330	1,674,937	1,700,046	1,765,075	0.52	0.56	0.59
Delaware	3,710	3,540	3,110	378,117	404,135	424,506	0.98	0.88	0.73
District of Columbia	11,800	14,200	13,330	262,789	286,649	296,957	4.49	4.95	4.49
Florida	13,330	15,740	17,630	7,040,660	7,624,718	8,692,761	0.19	0.21	0.20
Georgia	9,880	11,990	12,940	3,751,699	4,112,868	4,522,025	0.26	0.29	0.29
Hawaii	2,550	2,580	2,850	566,766	589,216	628,277	0.45	0.44	0.45
Idaho	2,030	2,230	2,840	598,004	644,816	723,621	0.34	0.35	0.39
Illinois	21,260	22,110	24,110	5,988,296	6,113,536	6,315,715	0.36	0.36	0.38
Indiana	7,570	9,580	9,870	3,014,499	3,020,985	3,108,806	0.25	0.32	0.32
Iowa	4,120	4,390	4,890	1,555,837	1,568,638	1,602,849	0.26	0.28	0.31
Kansas	3,770	3,970	4,250	1,329,797	1,347,715	1,400,169	0.28	0.29	0.30
Kentucky	4,110	4,590	4,990	1,809,785	1,852,056	1,922,163	0.23	0.25	0.26
Louisiana	5,360	5,290	5,470	1,890,102	1,922,110	1,910,348	0.28	0.28	0.29
Maine	2,150	1,990	2,350	624,410	650,699	678,843	0.34	0.31	0.35
Maryland	21,020	22,730	26,220	2,646,200	2,712,268	2,892,620	0.79	0.84	0.91
Massachusetts	23,330	29,100	32,360	3,158,851	3,275,343	3,234,860	0.74	0.89	1.00
Michigan	15,050	17,380	17,900	4,748,691	4,876,338	4,730,291	0.32	0.36	0.38
Minnesota	9,810	11,410	11,850	2,605,673	2,755,808	2,822,297	0.38	0.41	0.42
Mississippi	3,000	3,170	3,310	1,200,845	1,229,884	1,218,664	0.25	0.26	0.27
Missouri	9,490	9,280	9,230	2,780,185	2,867,853	2,885,857	0.34	0.32	0.32
Montana	1,690	1,440	1,990	427,504	447,827	478,162	0.40	0.32	0.42
Nebraska	3,010	2,890	2,970	904,492	925,783	945,270	0.33	0.31	0.31
Nevada	1,620	2,030	2,620	895,258	1,042,182	1,240,868	0.18	0.19	0.21
New Hampshire	2,230	2,470	2,440	635,469	680,706	711,512	0.35	0.36	0.34
New Jersey	20,440	22,740	20,840	4,031,022	4,117,543	4,309,021	0.51	0.55	0.48
New Mexico	7,480	7,750	8,330	768,596	821,003	895,623	0.97	0.94	0.93
New York	40,080	43,980	45,840	8,416,544	8,743,924	9,072,733	0.48	0.50	0.51
North Carolina	13,730	16,760	18,880	3,809,601	3,929,977	4,250,619	0.36	0.43	0.44
North Dakota	1,350	1,080	1,380	335,854	336,228	346,359	0.40	0.32	0.40
Ohio	18,700	20,070	20,540	5,448,161	5,566,735	5,609,056	0.34	0.36	0.37
Oklahoma	4,580	4,360	4,420	1,543,105	1,614,627	1,650,877	0.30	0.27	0.27
Oregon	6,210	7,040	8,280	1,652,997	1,711,041	1,796,165	0.38	0.41	0.46
Pennsylvania	23,940	26,140	29,090	5,775,178	5,874,153	6,009,858	0.41	0.45	0.48
Rhode Island	2,450	2,640	3,020	504,147	520,677	547,618	0.49	0.51	0.55
South Carolina	4,780	5,130	5,920	1,819,508	1,842,291	1,988,378	0.26	0.28	0.30
South Dakota	1,060	1,000	1,050	383,216	400,352	417,100	0.28	0.25	0.25
Tennessee	8,520	8,980	9,980	2,640,005	2,728,523	2,835,530	0.32	0.33	0.35
Texas	28,570	32,490	35,970	9,395,279	9,991,920	10,921,673	0.30	0.33	0.33
Utah	4,800	4,820	5,540	1,034,429	1,108,547	1,272,801	0.46	0.43	0.44
Vermont	1,750	1,750	1,700	315,806	330,099	348,026	0.55	0.53	0.49
Virginia	15,250	17,460	19,790	3,323,266	3,537,719	3,878,988	0.46	0.49	0.51
Washington	13,360	14,760	16,920	2,822,223	2,863,705	3,160,350	0.47	0.52	0.54
West Virginia	1,980	1,890	2,020	746,442	758,904	767,134	0.27	0.25	0.26
Wisconsin	8,460	8,720	9,500	2,855,830	2,897,937	2,918,155	0.30	0.30	0.33
Wyoming	860	840	730	243,944	259,508	275,617	0.35	0.32	0.26
Puerto Rico	660	1,410	1,690	1,132,658	1,133,988	1,260,703	0.06	0.12	0.13

[a] Coefficients of variation for estimates of employed S&E doctorate holders presented in appendix table 8-13.

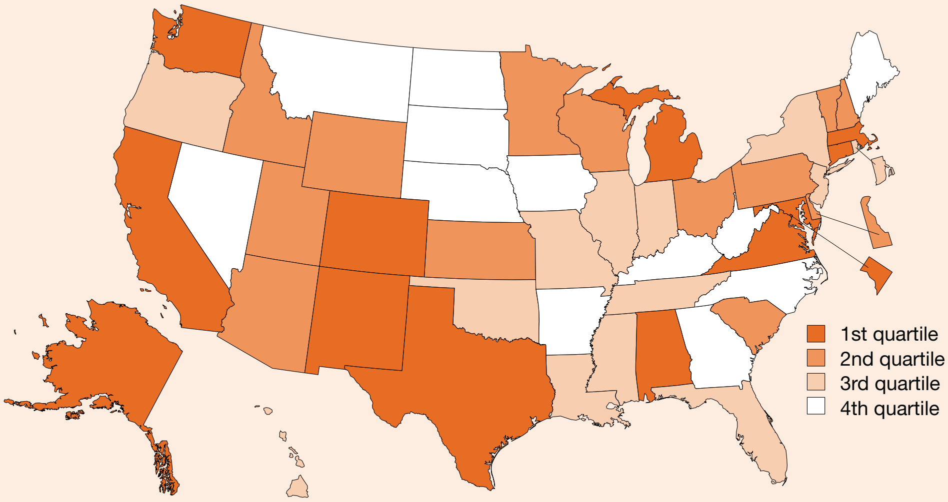
NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients; and Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

Engineers as Share of Workforce

Figure 8-30
Engineers as share of workforce: 2008



1st quartile (2.47%–1.20%)	2nd quartile (1.16%–0.99%)	3rd quartile (0.96%–0.75%)	4th quartile (0.74%–0.54%)
Alabama ‡	Arizona	Florida	Arkansas ‡
Alaska ‡	Delaware ‡	Hawaii ‡	Georgia
California	Idaho ‡	Illinois	Iowa
Colorado	Kansas ‡	Indiana	Kentucky ‡
Connecticut	Minnesota	Louisiana ‡	Maine ‡
District of Columbia	New Hampshire ‡	Mississippi ‡	Montana ‡
Maryland	Ohio	Missouri	Nebraska ‡
Massachusetts	Pennsylvania	New Jersey	Nevada ‡
Michigan	South Carolina ‡	New York	North Carolina
New Mexico ‡	Utah	Oklahoma ‡	North Dakota ‡
Texas	Vermont ‡	Oregon	South Dakota ‡
Virginia	Wisconsin	Rhode Island ‡	West Virginia ‡
Washington	Wyoming ‡	Tennessee	

‡ EPSCoR state

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-30.

Findings

- In the United States, 1.63 million individuals were employed in engineering occupations in 2008, an increase over the 1.48 million engineers employed in 2004. Between 2004 and 2008, the percentage of the workforce employed in engineering occupations remained unchanged at 1.06%.
- The concentration of engineers in individual states ranged from 0.54% to 1.87% in 2008.
- The states with the highest percentage of engineers in their workforces were centers of automobile and aircraft manufacturing.
- States ranking highest on this indicator also ranked high on employment in high-technology establishments as share of total employment.

This indicator shows the representation of trained engineers in a state's workforce. Engineers design and operate production processes and create new products and services. The indicator encompasses the standard occupational codes for engineering fields: aerospace, agricultural, biomedical, chemical, civil, computer hardware, electrical and electronics, environmental, industrial, marine and naval architectural, materials, mechanical, mining and geological, nuclear, and petroleum.

State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work. The survey is conducted as part of a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. State data on the size of the civilian workforce are BLS estimates based on the Current Population Survey, which assigns workers to a state based on where they live.

Situations in which workers live in one state and work in another introduce some imprecision into the calculation of this indicator. The treatment of postsecondary teachers is another source of imprecision. Because OES data do not classify postsecondary teachers by field, in these data, faculty teaching in S&E fields are not counted as working in S&E occupations. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations.

Table 8-30

Engineers as share of workforce, by state: 2004, 2006, and 2008

	Engineers			Employed workforce			Engineers in workforce (%)		
State	2004	2006	2008	2004	2006	2008	2004	2006	2008
United States	1,480,520	1,535,620	1,626,330	139,213,523	144,581,912	153,999,337	1.06	1.06	1.06
Alabama	22,170	26,210	26,430	2,014,678	2,120,573	2,162,479	1.10	1.24	1.22
Alaska	3,480	3,330	4,450	312,922	323,531	357,136	1.11	1.03	1.25
Arizona	36,180	35,630	35,850	2,649,243	2,854,381	3,132,667	1.37	1.25	1.14
Arkansas	5,900	7,210	7,340	1,228,163	1,292,886	1,370,259	0.48	0.56	0.54
California	220,120	231,480	240,860	16,444,457	17,029,307	18,391,844	1.34	1.36	1.31
Colorado	34,370	37,040	41,130	2,384,562	2,537,037	2,730,447	1.44	1.46	1.51
Connecticut	26,160	24,070	23,920	1,714,758	1,765,075	1,876,125	1.53	1.36	1.27
Delaware	3,810	4,810	5,120	408,022	424,506	442,902	0.93	1.13	1.16
District of Columbia	10,490	8,920	8,220	285,567	296,957	332,703	3.67	3.00	2.47
Florida	59,070	67,810	69,040	8,056,259	8,692,761	9,231,462	0.73	0.78	0.75
Georgia	30,550	30,170	36,020	4,257,465	4,522,025	4,847,650	0.72	0.67	0.74
Hawaii	4,560	5,380	5,020	597,147	628,277	654,261	0.76	0.86	0.77
Idaho	8,250	9,270	7,870	670,746	723,621	754,879	1.23	1.28	1.04
Illinois	59,010	57,270	55,840	6,012,320	6,315,715	6,697,335	0.98	0.91	0.83
Indiana	30,380	28,380	30,780	3,017,271	3,108,806	3,230,367	1.01	0.91	0.95
Iowa	9,900	10,420	10,270	1,542,342	1,602,849	1,675,981	0.64	0.65	0.61
Kansas	19,020	17,480	16,930	1,378,713	1,400,169	1,496,943	1.38	1.25	1.13
Kentucky	12,870	12,950	13,880	1,859,902	1,922,163	2,042,915	0.69	0.67	0.68
Louisiana	15,790	15,250	18,270	1,926,594	1,910,348	2,078,935	0.82	0.80	0.88
Maine	4,830	4,230	4,480	661,163	678,843	706,829	0.73	0.62	0.63
Maryland	33,190	36,880	39,390	2,766,653	2,892,620	2,997,709	1.20	1.27	1.31
Massachusetts	50,370	51,750	54,330	3,204,653	3,234,860	3,424,018	1.57	1.60	1.59
Michigan	91,600	99,680	92,190	4,694,981	4,730,291	4,935,584	1.95	2.11	1.87
Minnesota	30,370	28,280	29,490	2,781,744	2,822,297	2,932,961	1.09	1.00	1.01
Mississippi	8,140	9,830	10,160	1,234,167	1,218,664	1,314,444	0.66	0.81	0.77
Missouri	21,070	22,870	25,950	2,821,802	2,885,857	3,012,126	0.75	0.79	0.86
Montana	2,580	2,840	3,570	456,624	478,162	506,159	0.57	0.59	0.71
Nebraska	5,810	5,820	6,350	940,047	945,270	995,635	0.62	0.62	0.64
Nevada	7,190	7,960	7,870	1,134,550	1,240,868	1,373,462	0.63	0.64	0.57
New Hampshire	7,890	8,090	7,870	693,648	711,512	738,858	1.14	1.14	1.07
New Jersey	37,850	38,130	40,720	4,177,841	4,309,021	4,496,727	0.91	0.88	0.91
New Mexico	12,170	10,870	11,500	850,164	895,623	959,458	1.43	1.21	1.20
New York	64,920	68,540	74,570	8,810,155	9,072,733	9,679,617	0.74	0.76	0.77
North Carolina	31,400	30,040	33,400	4,028,598	4,250,619	4,543,754	0.78	0.71	0.74
North Dakota	2,230	2,520	2,530	338,221	346,359	369,671	0.66	0.73	0.68
Ohio	62,560	57,810	60,120	5,507,404	5,609,056	5,971,874	1.14	1.03	1.01
Oklahoma	12,520	13,840	14,040	1,608,849	1,650,877	1,748,416	0.78	0.84	0.80
Oregon	18,500	NA	18,740	1,722,058	1,796,165	1,957,953	1.07	NA	0.96
Pennsylvania	NA	61,620	63,340	5,889,957	6,009,858	6,394,884	NA	1.03	0.99
Rhode Island	5,270	5,430	5,150	531,121	547,618	567,597	0.99	0.99	0.91
South Carolina	21,260	22,460	22,750	1,900,122	1,988,378	2,152,965	1.12	1.13	1.06
South Dakota	2,050	2,210	2,440	409,263	417,100	444,890	0.50	0.53	0.55
Tennessee	21,100	21,230	23,130	2,733,793	2,835,530	3,041,276	0.77	0.75	0.76
Texas	120,810	123,990	146,520	10,456,224	10,921,673	11,701,585	1.16	1.14	1.25
Utah	11,560	13,090	14,350	1,169,163	1,272,801	1,383,743	0.99	1.03	1.04
Vermont	3,440	3,780	3,790	337,709	348,026	355,432	1.02	1.09	1.07
Virginia	47,180	50,780	54,280	3,704,593	3,878,988	4,124,766	1.27	1.31	1.32
Washington	45,140	49,840	55,490	3,008,352	3,160,350	3,476,766	1.50	1.58	1.60
West Virginia	4,920	5,230	5,320	744,034	767,134	806,152	0.66	0.68	0.66
Wisconsin	29,590	30,990	32,010	2,871,034	2,918,155	3,084,130	1.03	1.06	1.04
Wyoming	2,290	2,570	3,260	263,705	275,617	292,606	0.87	0.93	1.11
Puerto Rico	7,290	8,280	7,990	1,226,251	1,260,703	1,366,307	0.59	0.66	0.58

NA = not available

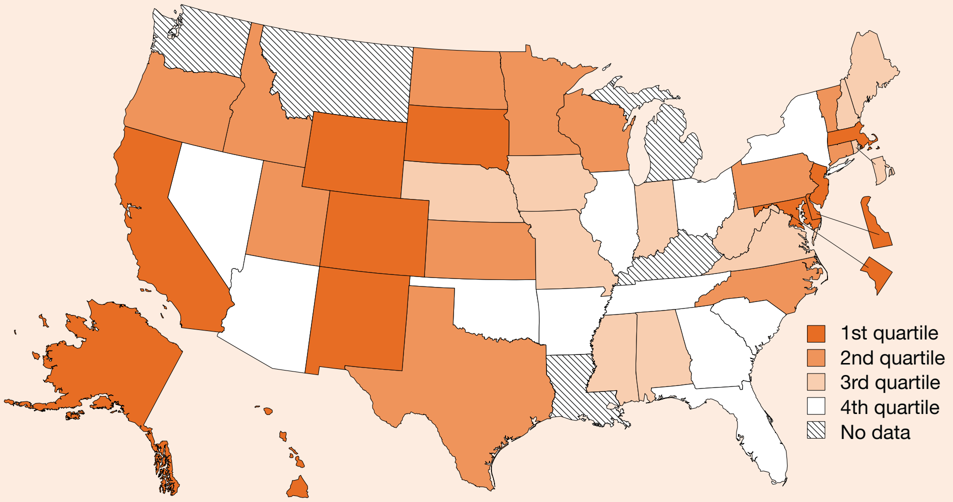
NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted. All 2008 workforce data with the exception of Puerto Rico reflect revised population controls and model reestimation.

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

Life and Physical Scientists as Share of Workforce

Figure 8-31
Life and physical scientists as share of workforce: 2008



1st quartile (1.70%–0.50%)	2nd quartile (0.48%–0.40%)	3rd quartile (0.39%–0.35%)	4th quartile (0.33%–0.20%)	No data
Alaska ‡	Connecticut	Alabama ‡	Arizona	Kentucky ‡
California	Idaho ‡	Indiana	Arkansas ‡	Louisiana ‡
Colorado	Kansas ‡	Iowa	Florida	Michigan
Delaware ‡	Minnesota	Maine ‡	Georgia	Montana ‡
District of Columbia	North Carolina	Mississippi ‡	Illinois	Washington
Hawaii ‡	North Dakota ‡	Missouri	Nevada ‡	
Maryland	Oregon	Nebraska ‡	New York	
Massachusetts	Pennsylvania	New Hampshire ‡	Ohio	
New Jersey	Texas	Rhode Island ‡	Oklahoma ‡	
New Mexico ‡	Utah	Virginia	South Carolina ‡	
South Dakota ‡	Vermont ‡	West Virginia ‡	Tennessee	
Wyoming ‡	Wisconsin			

‡ EPSCoR state

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-31.

Findings

- About 621,000 individuals (0.40% of the workforce) were employed as life and physical scientists in the United States in 2008, similar to the 546,160 life and physical scientists employed in 2004, which represented 0.39% of the workforce.
- In 2008, individual states had indicator values ranging from 0.20% to 1.04%, which showed major differences in the concentration of jobs in the life and physical sciences.
- States with the highest concentrations of life and physical scientists in their workforces were uniformly distributed throughout the United States.
- EPSCoR states appeared to be fairly evenly distributed throughout all four quartiles for this indicator.

This indicator shows a state's ability to attract and retain life and physical scientists. Life scientists are identified from standard occupational codes that include agricultural and food scientists, biological scientists, conservation scientists and foresters, and medical scientists. Physical scientists are identified from standard occupational codes that include astronomers, physicists, atmospheric and space scientists, chemists, materials scientists, environmental scientists, and geoscientists. A high share of life and physical scientists in a state's workforce could indicate several scenarios, ranging from a robust cluster of life sciences companies to the presence of forests or national parks, which require foresters, wildlife specialists, and conservationists to manage the natural assets in these areas.

State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work. The survey is conducted as part of a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. State data on the size of the civilian workforce are BLS estimates based on the Current Population Survey, which assigns workers to a state based on where they live.

Situations in which workers live in one state and work in another introduce some imprecision into the calculation of this indicator. The treatment of postsecondary teachers is another source of imprecision. Because OES data do not classify postsecondary teachers by field, in these data, faculty teaching in S&E fields are not counted as working in S&E occupations. Estimates for jurisdictions with smaller populations are generally less precise than estimates for jurisdictions with larger populations.

Table 8-31

Life and physical scientists as share of workforce, by state: 2004, 2006, and 2008

	Life and physical scientists			Employed workforce			Life and physical scientists in workforce (%)		
State	2004	2006	2008	2004	2006	2008	2004	2006	2008
United States	546,160	577,890	621,020	139,213,523	144,581,912	153,999,337	0.39	0.40	0.40
Alabama	5,630	5,690	7,570	2,014,678	2,120,573	2,162,479	0.28	0.27	0.35
Alaska	3,090	3,010	3,720	312,922	323,531	357,136	0.99	0.93	1.04
Arizona	6,940	6,460	7,660	2,649,243	2,854,381	3,132,667	0.26	0.23	0.24
Arkansas	2,890	2,880	3,180	1,228,163	1,292,886	1,370,259	0.24	0.22	0.23
California	68,020	72,590	92,000	16,444,457	17,029,307	18,391,844	0.41	0.43	0.50
Colorado	NA	14,130	15,040	2,384,562	2,537,037	2,730,447	NA	0.56	0.55
Connecticut	8,460	7,750	7,550	1,714,758	1,765,075	1,876,125	0.49	0.44	0.40
Delaware	3,100	2,940	3,420	408,022	424,506	442,902	0.76	0.69	0.77
District of Columbia	5,860	6,370	5,650	285,567	296,957	332,703	2.05	2.15	1.70
Florida	20,490	22,100	22,280	8,056,259	8,692,761	9,231,462	0.25	0.25	0.24
Georgia	13,090	9,820	9,610	4,257,465	4,522,025	4,847,650	0.31	0.22	0.20
Hawaii	2,400	3,390	3,570	597,147	628,277	654,261	0.40	0.54	0.55
Idaho	9,930	3,860	3,100	670,746	723,621	754,879	1.48	0.53	0.41
Illinois	19,390	22,650	20,370	6,012,320	6,315,715	6,697,335	0.32	0.36	0.30
Indiana	NA	10,350	11,530	3,017,271	3,108,806	3,230,367	NA	0.33	0.36
Iowa	NA	5,390	5,900	1,542,342	1,602,849	1,675,981	NA	0.34	0.35
Kansas	4,640	NA	6,010	1,378,713	1,400,169	1,496,943	0.34	NA	0.40
Kentucky	5,300	4,990	NA	1,859,902	1,922,163	2,042,915	0.28	0.26	NA
Louisiana	6,130	6,090	NA	1,926,594	1,910,348	2,078,935	0.32	0.32	NA
Maine	2,430	2,650	2,750	661,163	678,843	706,829	0.37	0.39	0.39
Maryland	18,150	19,930	22,630	2,766,653	2,892,620	2,997,709	0.66	0.69	0.75
Massachusetts	20,700	23,260	26,930	3,204,653	3,234,860	3,424,018	0.65	0.72	0.79
Michigan	10,340	12,940	NA	4,694,981	4,730,291	4,935,584	0.22	0.27	NA
Minnesota	11,700	13,450	13,990	2,781,744	2,822,297	2,932,961	0.42	0.48	0.48
Mississippi	4,540	4,490	4,890	1,234,167	1,218,664	1,314,444	0.37	0.37	0.37
Missouri	9,920	10,190	10,620	2,821,802	2,885,857	3,012,126	0.35	0.35	0.35
Montana	3,050	3,450	NA	456,624	478,162	506,159	0.67	0.72	NA
Nebraska	4,280	4,350	3,580	940,047	945,270	995,635	0.46	0.46	0.36
Nevada	3,210	3,460	3,400	1,134,550	1,240,868	1,373,462	0.28	0.28	0.25
New Hampshire	1,870	2,250	2,690	693,648	711,512	738,858	0.27	0.32	0.36
New Jersey	19,710	NA	25,170	4,177,841	4,309,021	4,496,727	0.47	NA	0.56
New Mexico	7,550	5,380	6,870	850,164	895,623	959,458	0.89	0.60	0.72
New York	NA	31,280	28,460	8,810,155	9,072,733	9,679,617	NA	0.34	0.29
North Carolina	19,190	NA	21,860	4,028,598	4,250,619	4,543,754	0.48	NA	0.48
North Dakota	1,570	1,610	1,650	338,221	346,359	369,671	0.46	0.46	0.45
Ohio	15,020	17,320	19,040	5,507,404	5,609,056	5,971,874	0.27	0.31	0.32
Oklahoma	NA	7,010	5,720	1,608,849	1,650,877	1,748,416	NA	0.42	0.33
Oregon	7,990	NA	9,170	1,722,058	1,796,165	1,957,953	0.46	NA	0.47
Pennsylvania	25,460	NA	28,610	5,889,957	6,009,858	6,394,884	0.43	NA	0.45
Rhode Island	2,790	2,120	2,080	531,121	547,618	567,597	0.53	0.39	0.37
South Carolina	5,190	5,680	5,220	1,900,122	1,988,378	2,152,965	0.27	0.29	0.24
South Dakota	1,770	1,900	2,350	409,263	417,100	444,890	0.43	0.46	0.53
Tennessee	7,380	7,680	7,920	2,733,793	2,835,530	3,041,276	0.27	0.27	0.26
Texas	47,540	50,040	46,710	10,456,224	10,921,673	11,701,585	0.45	0.46	0.40
Utah	5,820	6,330	6,520	1,169,163	1,272,801	1,383,743	0.50	0.50	0.47
Vermont	1,250	1,480	1,460	337,709	348,026	355,432	0.37	0.43	0.41
Virginia	NA	15,370	14,810	3,704,593	3,878,988	4,124,766	NA	0.40	0.36
Washington	NA	20,590	NA	3,008,352	3,160,350	3,476,766	NA	0.65	NA
West Virginia	2,850	3,230	2,890	744,034	767,134	806,152	0.38	0.42	0.36
Wisconsin	11,660	13,000	14,580	2,871,034	2,918,155	3,084,130	0.41	0.45	0.47
Wyoming	1,840	2,070	2,320	263,705	275,617	292,606	0.70	0.75	0.79
Puerto Rico	4,840	5,470	5,380	1,226,251	1,260,703	1,366,307	0.39	0.43	0.39

NA = not available

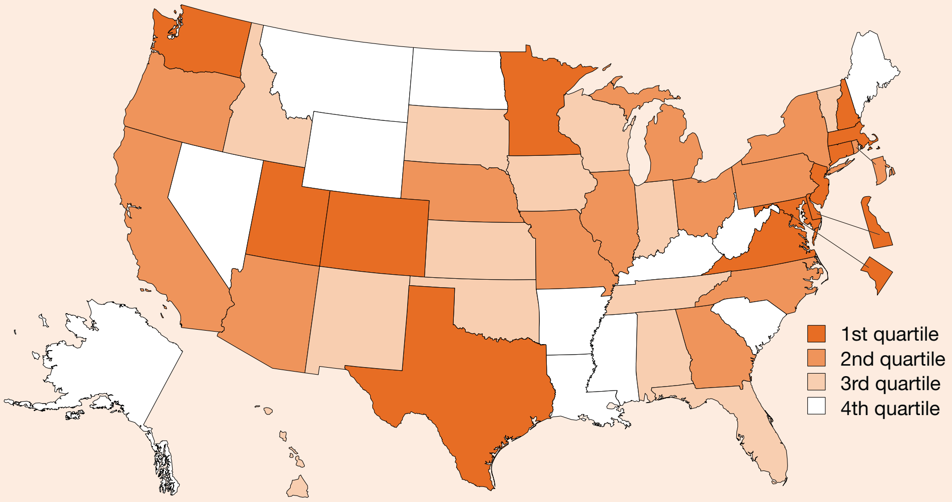
NOTE: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted. All 2008 workforce data with the exception of Puerto Rico reflect revised population controls and model reestimation.

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

Computer Specialists as Share of Workforce

Figure 8-32
Computer specialists as share of workforce: 2008



1st quartile (9.68%–2.10%)	2nd quartile (2.09%–1.74%)	3rd quartile (1.72%–1.20%)	4th quartile (1.19%–0.68%)
Colorado	Arizona	Alabama ‡	Alaska ‡
Connecticut	California	Florida	Arkansas ‡
Delaware ‡	Georgia	Hawaii ‡	Kentucky ‡
District of Columbia	Illinois	Idaho ‡	Louisiana ‡
Maryland	Michigan	Indiana	Maine ‡
Massachusetts	Missouri	Iowa	Mississippi ‡
Minnesota	Nebraska ‡	Kansas ‡	Montana ‡
New Hampshire ‡	New York	New Mexico ‡	Nevada ‡
New Jersey	North Carolina	Oklahoma ‡	North Dakota ‡
Texas	Ohio	South Dakota ‡	South Carolina ‡
Utah	Oregon	Tennessee	West Virginia ‡
Virginia	Pennsylvania	Vermont ‡	Wyoming ‡
Washington	Rhode Island ‡	Wisconsin	

‡ EPSCoR state

SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics. See table 8-32.

Findings

- In the United States, 3.20 million individuals (2.08% of the workforce) were employed as computer specialists in 2008, similar to the 2.81 million computer specialists employed in 2004, which accounted for 2.02% of the workforce.
- Individual states showed large differences in the intensity of computer-related operations in their economies, with 0.68% to 4.16% of their workforce employed in computer-related occupations in 2008.
- There was a significant concentration of computer-intensive occupations in the District of Columbia and the adjacent states of Maryland and Virginia. This may be due to the presence of many government offices, colleges and universities, and government contractors in the area that employ scientists and engineers, especially computer scientists.
- EPSCoR states tended to have smaller percentages of computer specialists in their workforces, suggesting that their economies are less technically oriented in this respect.

This indicator shows the extent to which a state's workforce makes use of specialists with advanced computer training. Computer specialists are identified from 10 standard occupational codes that include computer and information scientists, programmers, software engineers, support specialists, systems analysts, database administrators, and network and computer system administrators. Higher values may indicate a state workforce that is better able to thrive in an information economy or to embrace and utilize computer technology.

State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work. The survey is conducted as part of a cooperative program between the Bureau of Labor Statistics (BLS) and state employment security agencies. State data on the size of the civilian workforce are BLS estimates based on the Current Population Survey, which assigns workers to a state based on where they live.

Situations in which workers live in one state and work in another introduce some imprecision into the calculation of this indicator. The treatment of postsecondary teachers is another source of imprecision. Because OES data do not classify postsecondary teachers by field, in these data, faculty teaching in S&E fields are not counted as working in S&E occupations. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations.

Table 8-32

Computer specialists as share of workforce, by state: 2004, 2006, and 2008

State	Computer specialists			Employed workforce			Computer specialists in workforce (%)		
	2004	2006	2008	2004	2006	2008	2004	2006	2008
EPSCoR states	276,210	310,990	317,290	22,500,274	23,256,125	24,693,283	1.23	1.34	1.28
Non-EPSCoR states	2,476,430	2,613,670	2,713,430	116,427,682	121,028,830	128,973,351	2.13	2.16	2.10
Average EPSCoR state value	na	na	na	na	na	na	1.25	1.39	1.32
Average non-EPSCoR state value	na	na	na	na	na	na	2.17	2.21	2.15
United States	2,806,910	2,960,460	3,198,050	139,213,523	144,581,912	153,999,337	2.02	2.05	2.08
Alabama	28,320	32,720	33,010	2,014,678	2,120,573	2,162,479	1.41	1.54	1.53
Alaska	3,320	3,810	3,720	312,922	323,531	357,136	1.06	1.18	1.04
Arizona	45,930	49,180	54,520	2,649,243	2,854,381	3,132,667	1.73	1.72	1.74
Arkansas	12,470[a]	13,360	15,500	1,228,163	1,292,886	1,370,259	1.02	1.03	1.13
California	370,180	380,040	383,900	16,444,457	17,029,307	18,391,844	2.25	2.23	2.09
Colorado	74,940	76,200	79,930	2,384,562	2,537,037	2,730,447	3.14	3.00	2.93
Connecticut	44,120	44,160	40,900	1,714,758	1,765,075	1,876,125	2.57	2.50	2.18
Delaware	8,730[a]	11,930	11,950[a]	408,022	424,506	442,902	2.14	2.81	2.70
District of Columbia	28,040	31,810	32,210	285,567	296,957	332,703	9.82	10.71	9.68
Florida	137,740	143,450	141,320	8,056,259	8,692,761	9,231,462	1.71	1.65	1.53
Georgia	94,080	89,390	86,210	4,257,465	4,522,025	4,847,650	2.21	1.98	1.78
Hawaii	7,440	8,140	7,840	597,147	628,277	654,261	1.25	1.30	1.20
Idaho	8,710	10,180	9,410[a]	670,746	723,621	754,879	1.30	1.41	1.25
Illinois	114,860[a]	129,880	137,420	6,012,320	6,315,715	6,697,335	1.91	2.06	2.05
Indiana	37,540	37,230	39,850	3,017,271	3,108,806	3,230,367	1.24	1.20	1.23
Iowa	22,650	24,940	26,400	1,542,342	1,602,849	1,675,981	1.47	1.56	1.58
Kansas	20,850	24,110	25,750	1,378,713	1,400,169	1,496,943	1.51	1.72	1.72
Kentucky	23,800	23,510	24,250	1,859,902	1,922,163	2,042,915	1.28	1.22	1.19
Louisiana	18,500	17,090	16,020	1,926,594	1,910,348	2,078,935	0.96	0.89	0.77
Maine	6,860	7,640	7,660	661,163	678,843	706,829	1.04	1.13	1.08
Maryland	92,450	91,040	89,900	2,766,653	2,892,620	2,997,709	3.34	3.15	3.00
Massachusetts	103,280	109,430	111,910	3,204,653	3,234,860	3,424,018	3.22	3.38	3.27
Michigan	74,600[a]	89,280	88,980	4,694,981	4,730,291	4,935,584	1.59	1.89	1.80
Minnesota	67,600	71,930	75,230	2,781,744	2,822,297	2,932,961	2.43	2.55	2.56
Mississippi	8,770	8,510	9,290	1,234,167	1,218,664	1,314,444	0.71	0.70	0.71
Missouri	56,460	61,120	61,000[a]	2,821,802	2,885,857	3,012,126	2.00	2.12	2.03
Montana	4,500[a]	5,790	5,170[a]	456,624	478,162	506,159	0.99	1.21	1.02
Nebraska	15,890[a]	20,030	20,410	940,047	945,270	995,635	1.69	2.12	2.05
Nevada	11,540	12,940	12,880	1,134,550	1,240,868	1,373,462	1.02	1.04	0.94
New Hampshire	13,180	16,390	16,780	693,648	711,512	738,858	1.90	2.30	2.27
New Jersey	114,370	116,290	121,690	4,177,841	4,309,021	4,496,727	2.74	2.70	2.71
New Mexico	9,720[a]	11,060	11,490	850,164	895,623	959,458	1.14	1.23	1.20
New York	170,140	188,620	200,900[a]	8,810,155	9,072,733	9,679,617	1.93	2.08	2.08
North Carolina	77,240	80,150	81,630	4,028,598	4,250,619	4,543,754	1.92	1.89	1.80
North Dakota	4,250	4,650	3,140[a]	338,221	346,359	369,671	1.26	1.34	0.85
Ohio	93,300	99,960	111,160	5,507,404	5,609,056	5,971,874	1.69	1.78	1.86
Oklahoma	21,600[a]	26,200	27,600	1,608,849	1,650,877	1,748,416	1.34	1.59	1.58
Oregon	29,120	33,960	34,980	1,722,058	1,796,165	1,957,953	1.69	1.89	1.79
Pennsylvania	102,590	110,090	115,300	5,889,957	6,009,858	6,394,884	1.74	1.83	1.80
Rhode Island	7,150[a]	9,490	9,940[a]	531,121	547,618	567,597	1.35	1.73	1.75
South Carolina	20,730	23,070	25,130	1,900,122	1,988,378	2,152,965	1.09	1.16	1.17
South Dakota	5,090	5,160	5,860	409,263	417,100	444,890	1.24	1.24	1.32
Tennessee	36,870	36,570	38,490	2,733,793	2,835,530	3,041,276	1.35	1.29	1.27
Texas	209,360	224,330	245,730	10,456,224	10,921,673	11,701,585	2.00	2.05	2.10
Utah	25,340	30,060	30,750	1,169,163	1,272,801	1,383,743	2.17	2.36	2.22
Vermont	5,810	5,920	5,610	337,709	348,026	355,432	1.72	1.70	1.58
Virginia	151,810	169,830	171,440	3,704,593	3,878,988	4,124,766	4.10	4.38	4.16
Washington	83,480	80,140	101,030	3,008,352	3,160,350	3,476,766	2.77	2.54	2.91
West Virginia	7,230	7,250	6,900	744,034	767,134	806,152	0.97	0.95	0.86
Wisconsin	46,380	46,400	42,860	2,871,034	2,918,155	3,084,130	1.62	1.59	1.39
Wyoming	1,750	2,040	1,980	263,705	275,617	292,606	0.66	0.74	0.68
Puerto Rico	7,380	9,050	8,750	1,226,251	1,260,703	1,366,307	0.60	0.72	0.64

na = not applicable

EPSCoR = Experimental Program to Stimulate Competitive Research

[a] Value may be underreported because one or more codes for computer occupations suppressed by state or Bureau of Labor Statistics and not reported at state level.

NOTES: Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted. All 2008 workforce data with the exception of Puerto Rico reflect revised population controls and model reestimation. For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

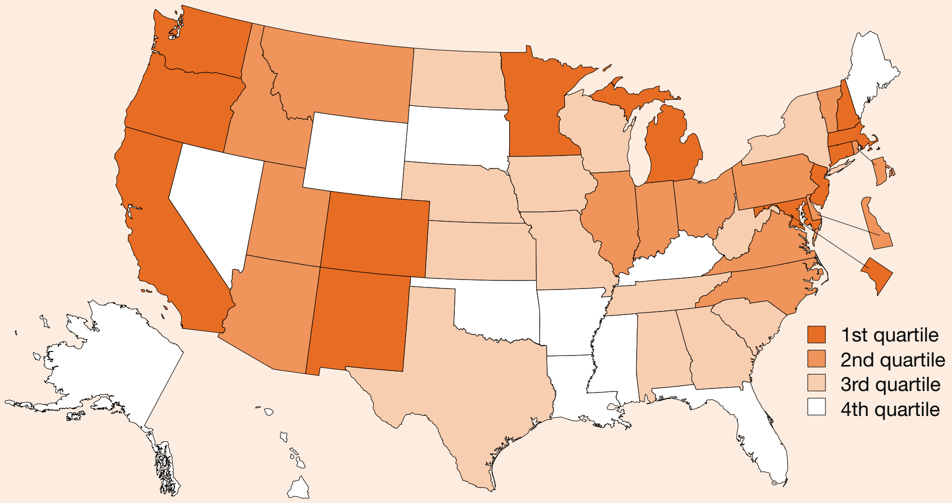
SOURCES: Bureau of Labor Statistics, Occupational Employment and Wage Estimates; and Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

R&D as Share of Gross Domestic Product

Figure 8-33

R&D as share of gross domestic product: 2007



1st quartile (7.53%–2.74%)	2nd quartile (2.61%–2.04%)	3rd quartile (2.00%–1.12%)	4th quartile (1.01%–0.41%)
California	Arizona	Alabama ‡	Alaska ‡
Colorado	Delaware ‡	Georgia	Arkansas ‡
Connecticut	Idaho ‡	Iowa	Florida
District of Columbia	Illinois	Kansas ‡	Hawaii ‡
Maryland	Indiana	Missouri	Kentucky ‡
Massachusetts	Montana ‡	Nebraska ‡	Louisiana ‡
Michigan	North Carolina	New York	Maine ‡
Minnesota	Ohio	North Dakota ‡	Mississippi ‡
New Hampshire ‡	Pennsylvania	South Carolina ‡	Nevada ‡
New Jersey	Rhode Island ‡	Tennessee	Oklahoma ‡
New Mexico ‡	Utah	Texas	South Dakota ‡
Oregon	Vermont ‡	West Virginia ‡	Wyoming ‡
Washington	Virginia	Wisconsin	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-33.

Findings

- The national value of R&D expenditures as a share of GDP rose slightly between 1998 and 2007, from 2.47% to 2.62%.
- In 2007, state values for this indicator ranged from 0.41% to 7.53%, indicating large differences in the geographic concentration of R&D activity.
- New Mexico, which has large federal R&D activities and a relatively small GDP, is an outlier on this indicator.
- States with high rankings on this indicator also tended to rank high on S&E doctorate holders as a share of the workforce.
- The total R&D performed in states in the EPSCoR group was approximately one-tenth of that performed in states in the non-EPSCoR group. EPSCoR state values on this indicator were more concentrated toward the low end of the distribution than comparable values for the ratio of academic R&D to state GDP.

This indicator shows the extent to which R&D plays a role in a state's economy. A high value indicates that a state has a high intensity of R&D activity, which may support future growth in knowledge-based industries. Industries that have a high percentage of R&D activity include pharmaceuticals, chemicals, computer equipment and services, electronic components, aerospace, and motor vehicles. R&D refers to R&D activities performed by federal and state agencies, businesses, universities, and nonprofit organizations. In 2007, business performed 72.0% of total R&D at the national level followed by colleges and universities at 13.3%; government facilities, including federally funded R&D centers, at 10.5%; and nonprofit institutions at 4.2%. Data for the value of gross domestic product (GDP) and for R&D expenditures are shown in current dollars.

The methodology for assigning industry R&D activity at the state level was modified in 2001, and 1998–2000 data were recalculated using the new methodology. State-level R&D data from years before 1998 are not comparable.

Table 8-33

R&D as share of gross domestic product, by state: 1998, 2002, and 2007

State	R&D performed ($millions)			State GDP ($millions)			R&D performed/GDP (%)		
	1998	2002	2007	1998	2002	2007	1998	2002	2007
EPSCoR states	18,832	24,247	29,581	1,231,448	1,451,648	1,981,871	1.53	1.67	1.49
Non-EPSCoR states	193,314	228,752	326,296	7,396,530	8,879,038	11,641,354	2.61	2.58	2.80
Average EPSCoR state value	na	na	na	na	na	na	1.79	1.83	1.64
Average non-EPSCoR state value	na	na	na	na	na	na	2.49	2.53	2.84
United States	214,752	255,705	359,739	8,679,660	10,398,403	13,715,741	2.47	2.46	2.62
Alabama	1,926	2,323	3,289	106,656	123,805	164,524	1.81	1.88	2.00
Alaska	NA	308	311	23,165	29,186	44,887	NA	1.06	0.69
Arizona	2,318	4,096	5,006	137,581	171,942	245,952	1.68	2.38	2.04
Arkansas	283	427	632	61,861	72,203	95,116	0.46	0.59	0.66
California	43,919	51,388	77,608	1,085,884	1,340,446	1,801,762	4.04	3.83	4.31
Colorado	4,565	4,218	6,828	143,160	182,154	235,848	3.19	2.32	2.90
Connecticut	3,559	6,774	10,228	145,373	166,073	212,252	2.45	4.08	4.82
Delaware	2,556	1,319	1,607	36,831	45,324	61,545	6.94	2.91	2.61
District of Columbia	2,606	2,706	3,862	51,682	67,717	92,516	5.04	4.00	4.17
Florida	4,773	5,498	7,158	417,169	522,719	741,861	1.14	1.05	0.96
Georgia	2,492	3,935	4,425	255,612	306,680	391,241	0.97	1.28	1.13
Hawaii	242	456	592	37,549	43,476	62,019	0.64	1.05	0.95
Idaho	1,127	1,370	1,115	29,800	36,651	52,110	3.78	3.74	2.14
Illinois	8,830	10,190	14,287	423,855	487,129	617,409	2.08	2.09	2.31
Indiana	3,089	4,326	5,980	178,909	205,015	249,229	1.73	2.11	2.40
Iowa	1,054	1,346	1,882	83,665	97,356	129,911	1.26	1.38	1.45
Kansas	1,518	1,865	1,697	76,005	89,573	116,986	2.00	2.08	1.45
Kentucky	645	1,128	1,406	108,813	120,726	152,099	0.59	0.93	0.92
Louisiana	542	858	1,073	118,085	134,308	207,407	0.46	0.64	0.52
Maine	159	429	485	31,731	38,625	48,021	0.50	1.11	1.01
Maryland	8,019	9,030	14,130	161,954	204,120	264,426	4.95	4.42	5.34
Massachusetts	13,382	14,316	24,557	236,079	284,386	352,178	5.67	5.03	6.97
Michigan	13,655	15,082	17,402	309,431	349,837	379,934	4.41	4.31	4.58
Minnesota	3,818	5,247	7,533	164,897	198,558	252,472	2.32	2.64	2.98
Mississippi	366	691	838	60,513	68,144	87,652	0.61	1.01	0.96
Missouri	1,868	2,478	3,754	164,267	188,351	229,027	1.14	1.32	1.64
Montana	191	236	859	19,884	23,560	34,266	0.96	1.00	2.51
Nebraska	315	663	900	52,076	59,934	80,360	0.60	1.11	1.12
Nevada	571	524	794	63,635	81,274	129,314	0.90	0.64	0.61
New Hampshire	1,340	1,435	2,146	39,102	46,188	57,820	3.43	3.11	3.71
New Jersey	11,368	13,020	19,552	314,117	372,754	461,295	3.62	3.49	4.24
New Mexico	3,032	4,689	5,663	45,918	52,510	75,192	6.60	8.93	7.53
New York	13,731	13,354	15,939	686,906	821,577	1,105,020	2.00	1.63	1.44
North Carolina	4,560	5,135	9,204	242,904	296,435	390,467	1.88	1.73	2.36
North Dakota	119	295	327	16,936	19,880	28,518	0.71	1.48	1.15
Ohio	6,970	8,310	10,041	348,723	389,773	462,506	2.00	2.13	2.17
Oklahoma	513	793	921	79,341	97,170	136,374	0.65	0.82	0.68
Oregon	1,910	2,892	4,333	100,951	117,131	158,268	1.89	2.47	2.74
Pennsylvania	8,762	9,763	13,510	361,800	423,110	533,212	2.42	2.31	2.53
Rhode Island	1,677	1,639	1,081	29,537	36,909	46,699	5.68	4.44	2.32
South Carolina	989	1,668	2,291	102,945	121,582	151,703	0.96	1.37	1.51
South Dakota	60	111	240	20,771	26,416	35,211	0.29	0.42	0.68
Tennessee	2,503	2,568	3,659	160,872	191,525	245,162	1.56	1.34	1.49
Texas	10,774	14,223	17,853	629,209	783,480	1,148,531	1.71	1.82	1.55
Utah	1,495	1,572	2,337	60,168	72,665	105,574	2.48	2.16	2.21
Vermont	175	398	534	15,935	19,553	24,627	1.10	2.04	2.17
Virginia	4,934	5,895	9,473	226,569	285,759	384,132	2.18	2.06	2.47
Washington	8,466	10,511	15,061	195,794	231,463	310,279	4.32	4.54	4.85
West Virginia	421	542	650	39,500	45,032	57,877	1.07	1.20	1.12
Wisconsin	2,501	3,585	4,555	160,681	188,600	233,406	1.56	1.90	1.95
Wyoming	65	80	129	14,859	19,619	31,544	0.44	0.41	0.41
Puerto Rico	NA	NA	NA	54,086	71,624	NA	NA	NA	NA

na = not applicable; NA = not available

EPSCoR = Experimental Program to Stimulate Competitive Research; GDP = gross domestic product

NOTES: R&D includes R&D performed by federal agencies, business, universities, other nonprofit organizations, and state agencies. R&D and GDP reported in current dollars. For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

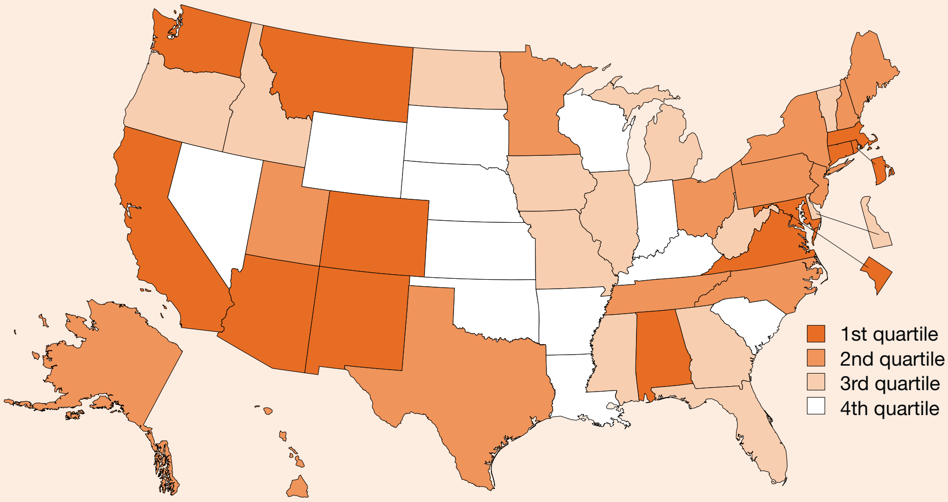
SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (various years); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2010

Federal R&D Obligations per Civilian Worker

Figure 8-34

Federal R&D obligations per civilian worker: 2007



1st quartile ($13,453–$805)	2nd quartile ($756–$424)	3rd quartile ($397–$276)	4th quartile ($235–$115)
Alabama ‡	Alaska ‡	Delaware ‡	Arkansas ‡
Arizona	Hawaii ‡	Florida	Indiana
California	Maine ‡	Georgia	Kansas ‡
Colorado	Minnesota	Idaho ‡	Kentucky ‡
Connecticut	New Hampshire ‡	Illinois	Louisiana ‡
District of Columbia	New Jersey	Iowa	Nebraska ‡
Maryland	New York	Michigan	Nevada ‡
Massachusetts	North Carolina	Mississippi ‡	Oklahoma ‡
Montana ‡	Ohio	Missouri	South Carolina ‡
New Mexico ‡	Pennsylvania	North Dakota ‡	South Dakota ‡
Rhode Island ‡	Tennessee	Oregon	Wisconsin
Virginia	Texas	Vermont ‡	Wyoming ‡
Washington	Utah	West Virginia ‡	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development; and Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-34.

Findings

- Federal R&D obligations have increased appreciably from about $68 billion in 1997 to about $111 billion in 2007, an increase of 63% in current dollars.
- In 2007, federal R&D obligations per civilian worker were concentrated in a few states; only 12 states and the District of Columbia exceeded the national average of $764 per worker.
- Federal R&D obligations in 2007 varied greatly among the states, ranging from $4,029 to $115 per civilian worker. Higher values were found in the states surrounding the District of Columbia and in sparsely populated states with national laboratories or federal facilities.
- EPSCoR states tended to be concentrated in the lower two quartiles of this indicator, showing that many EPSCoR states receive smaller amounts of federal R&D funding than would have been anticipated based on the size of their civilian workforce.

This indicator shows how federal R&D funding is disbursed geographically relative to the size of a state's civilian workforce. Federal R&D dollars are attributed to the states in which the recipients are located.

Federal obligations for R&D come from the National Science Foundation Survey of Federal Funds for Research and Development and include data reported by 11 federal agencies. The Department of Defense (DOD) disburses most—approximately 50%—federal R&D funding. The geographic distribution of DOD development funding to industry reflects the location of prime contractors only, not the subcontractors who perform much of the R&D. A high value may indicate the existence of a number of large prime contractors or major federally funded R&D facilities in a state.

The size of a state's civilian workforce is a nonseasonally adjusted annual estimate of employed workers based on the Bureau of Labor Statistics Current Population Survey, which assigns workers to a location based on residence. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations.

Table 8-34

Federal R&D obligations per civilian worker, by state: 1997, 2002, and 2007

State	Federal R&D obligations (current $thousands)			Civilian workers			Federal R&D obligations/ civilian worker ($)		
	1997	2002	2007	1997	2002	2007	1997	2002	2007
United States	68,364,994	83,629,201	111,210,200	130,988,267	136,781,272	145,595,173	522	611	764
Alabama	2,213,683	2,704,834	2,203,409	2,035,156	1,994,748	2,105,951	1,088	1,356	1,046
Alaska	99,928	273,779	249,799	289,963	305,112	330,587	345	897	756
Arizona	732,065	2,057,261	2,345,659	2,196,901	2,512,714	2,913,695	333	819	805
Arkansas	95,709	141,267	166,582	1,177,143	1,204,467	1,293,852	81	117	129
California	13,731,238	15,686,055	21,313,080	14,780,791	16,180,799	17,208,903	929	969	1,238
Colorado	1,340,231	1,608,971	2,625,822	2,154,294	2,304,109	2,602,015	622	698	1,009
Connecticut	846,458	1,916,926	1,987,490	1,674,937	1,700,949	1,780,473	505	1,127	1,116
Delaware	48,964	78,846	127,615	378,117	401,301	427,766	129	196	298
District of Columbia	2,232,284	2,849,531	4,130,639	262,789	284,615	307,049	8,495	10,012	13,453
Florida	3,326,418	2,300,550	2,715,997	7,040,660	7,662,511	8,779,299	472	300	309
Georgia	3,919,868	2,019,248	1,326,052	3,751,699	4,135,381	4,602,947	1,045	488	288
Hawaii	150,722	375,159	343,581	566,766	584,354	631,911	266	642	544
Idaho	205,660	230,910	281,334	598,004	646,142	733,652	344	357	383
Illinois	1,140,163	1,693,942	2,115,154	5,988,296	5,969,393	6,361,750	190	284	332
Indiana	410,646	525,745	572,444	3,014,499	3,002,515	3,065,590	136	175	187
Iowa	228,180	404,545	602,947	1,555,837	1,567,836	1,598,261	147	258	377
Kansas	255,490	290,516	246,693	1,329,797	1,350,960	1,418,666	192	215	174
Kentucky	91,291	321,284	221,222	1,809,785	1,838,495	1,932,028	50	175	115
Louisiana	211,036	431,989	418,396	1,890,102	1,892,636	1,921,343	112	228	218
Maine	68,683	254,518	377,059	624,410	650,943	671,337	110	391	562
Maryland	7,328,937	7,192,243	11,578,771	2,646,200	2,733,103	2,873,512	2,770	2,632	4,029
Massachusetts	3,437,962	4,658,616	6,741,246	3,158,851	3,243,409	3,255,611	1,088	1,436	2,071
Michigan	735,221	1,244,244	1,709,933	4,748,691	4,724,998	4,659,927	155	263	367
Minnesota	609,395	1,150,839	1,383,666	2,605,673	2,749,525	2,796,737	234	419	495
Mississippi	289,791	622,714	423,671	1,200,845	1,214,631	1,231,743	241	513	344
Missouri	1,130,148	1,202,671	1,142,325	2,780,185	2,829,985	2,878,399	407	425	397
Montana	79,347	112,924	652,591	427,504	445,281	485,615	186	254	1,344
Nebraska	82,981	144,671	187,239	904,492	921,201	953,769	92	157	196
Nevada	295,042	335,989	298,924	895,258	1,066,477	1,271,472	330	315	235
New Hampshire	278,697	296,575	317,036	635,469	679,818	712,048	439	436	445
New Jersey	1,318,793	2,021,450	2,141,156	4,031,022	4,117,265	4,276,561	327	491	501
New Mexico	1,933,123	2,746,139	3,201,259	768,596	823,191	909,968	2,515	3,336	3,518
New York	2,471,213	3,746,837	5,061,983	8,416,544	8,721,428	9,087,278	294	430	557
North Carolina	900,947	1,390,440	1,824,802	3,809,601	3,930,736	4,308,624	236	354	424
North Dakota	53,015	102,136	113,203	335,854	333,605	354,003	158	306	320
Ohio	1,879,784	2,103,409	2,602,628	5,448,161	5,503,109	5,640,081	345	382	461
Oklahoma	160,356	271,565	225,577	1,543,105	1,602,118	1,657,964	104	170	136
Oregon	319,587	502,284	504,150	1,652,997	1,704,131	1,827,285	193	295	276
Pennsylvania	1,893,867	3,162,026	3,277,761	5,775,178	5,869,224	6,013,406	328	539	545
Rhode Island	403,844	501,299	627,538	504,147	525,721	547,927	801	954	1,145
South Carolina	166,607	371,006	417,465	1,819,508	1,840,598	2,011,255	92	202	208
South Dakota	41,955	58,679	61,925	383,216	402,397	429,495	109	146	144
Tennessee	566,242	961,149	1,658,662	2,640,005	2,714,992	2,893,748	214	354	573
Texas	3,640,162	3,374,405	5,426,669	9,395,279	10,115,299	10,992,828	387	334	494
Utah	319,826	408,747	765,138	1,034,429	1,113,645	1,325,480	309	367	577
Vermont	49,885	136,374	107,999	315,806	331,763	340,073	158	411	318
Virginia	4,849,753	5,756,339	8,753,773	3,323,266	3,588,079	3,930,984	1,459	1,604	2,227
Washington	1,226,154	1,998,915	4,708,365	2,822,223	2,877,022	3,253,475	434	695	1,447
West Virginia	193,061	254,239	216,621	746,442	749,164	771,837	259	339	281
Wisconsin	332,214	594,816	670,963	2,855,830	2,860,915	2,937,903	116	208	228
Wyoming	28,368	39,585	36,187	243,944	258,462	279,090	116	153	130
Puerto Rico	58,943	135,294	85,850	1,132,658	1,169,760	1,241,426	52	116	69

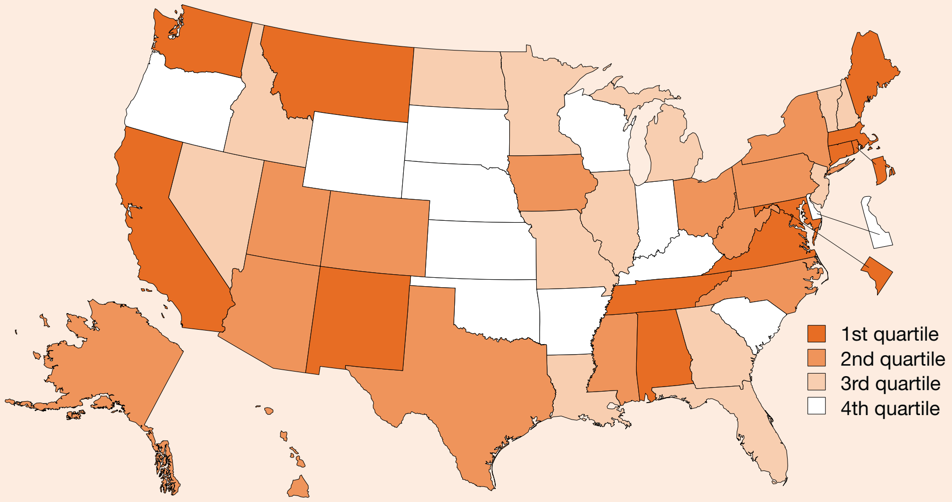
NOTES: Only 11 agencies required to report federal R&D obligations: Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security (established in 2002), Interior, and Transportation; Environmental Protection Agency; National Aeronautics and Space Administration; and National Science Foundation. These obligations represent approximately 98% of total federal R&D obligations. Civilian workers represent employed component of civilian labor force and reported as annual data not seasonally adjusted.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development (various years); and Bureau of Labor Statistics, Local Area Unemployment Statistics.

Science and Engineering Indicators 2010

Federal R&D Obligations per Individual in S&E Occupation

Figure 8-35
Federal R&D obligations per individual in S&E occupation: 2007



1st quartile ($95,724–$23,426)	2nd quartile ($22,915–$12,295)	3rd quartile ($11,698–$8,065)	4th quartile ($7,705–$4,394)
Alabama ‡	Alaska ‡	Florida	Arkansas ‡
California	Arizona	Georgia	Delaware ‡
Connecticut	Colorado	Idaho ‡	Indiana
District of Columbia	Hawaii ‡	Illinois	Kansas ‡
Maine ‡	Iowa	Louisiana ‡	Kentucky ‡
Maryland	Mississippi ‡	Michigan	Nebraska ‡
Massachusetts	New York	Minnesota	Oklahoma ‡
Montana ‡	North Carolina	Missouri	Oregon
New Mexico ‡	Ohio	Nevada ‡	South Carolina ‡
Rhode Island ‡	Pennsylvania	New Hampshire ‡	South Dakota ‡
Tennessee	Texas	New Jersey	Wisconsin
Virginia	Utah	North Dakota ‡	Wyoming ‡
Washington	West Virginia ‡	Vermont ‡	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development; and Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See table 8-35.

Findings

- The federal government obligated approximately $111 billion for R&D in 2007—about $20,000 for each person employed in an S&E occupation.
- The state distribution of federal R&D obligations per person employed in an S&E occupation ranged from $95,724 to $4,394 in 2007.
- The distribution for this indicator was highly skewed in 2007, with only 14 states and the District of Columbia above the national average. High values were reported in the District of Columbia and adjoining states and also in states where federal facilities or major defense contractors are located.
- EPSCoR states tended to rank in the lower two quartiles for this indicator, showing that many EPSCoR states receive smaller amounts of federal R&D funding than would have been anticipated based on the number of S&E workers in the state.

This indicator describes the relationship between federal R&D spending in a state and the number of employees in the state who work in S&E occupations. Federal R&D dollars are attributed to the states in which the recipients of federal obligations are located.

Federal obligations for R&D come from the National Science Foundation's Survey of Federal Funds for Research and Development and include data reported by 11 federal agencies. The Department of Defense (DOD) disburses most—approximately 50%—federal R&D funding. The geographic distribution of DOD development funding to industry reflects the location of prime contractors only, not the numerous subcontractors who perform much of the R&D.

S&E occupations are defined by standard occupational codes. They include engineers and computer, mathematical, life, physical, and social scientists. They exclude managers, technicians, elementary and secondary schoolteachers, and medical personnel. State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work. Because OES data do not classify postsecondary teachers by field, in these data, faculty teaching in S&E fields are not counted as working in S&E occupations.

Data on people in S&E occupations are sample based. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations.

Table 8-35

Federal R&D obligations per individual in S&E occupation, by state: 2003, 2005, and 2007

	Federal R&D obligations (current $millions)			Individuals in S&E occupations			Federal R&D obligations/individual in S&E occupation ($)		
State	2003	2005	2007	2003	2005	2007	2003	2005	2007
United States	91,247	106,743	111,212	4,961,540	5,233,520	5,591,990	18,391	20,396	19,888
Alabama	2,933	2,800	2,203	56,380	62,790	69,650	52,020	44,596	31,630
Alaska	246	234	250	10,600	11,230	11,990	23,210	20,796	20,851
Arizona	1,857	2,674	2,346	92,120	96,410	102,380	20,156	27,741	22,915
Arkansas	140	154	167	21,340	24,660	28,460	6,547	6,255	5,868
California	17,410	19,380	21,313	676,180	716,530	753,570	25,748	27,046	28,283
Colorado	1,612	2,037	2,626	124,140	126,110	138,990	12,985	16,150	18,893
Connecticut	2,068	2,154	1,987	81,380	83,930	80,280	25,411	25,658	24,751
Delaware	91	94	128	17,370	18,010	22,140	5,261	5,228	5,781
District of Columbia	2,916	3,993	4,131	54,890	63,410	63,150	53,127	62,978	65,416
Florida	2,522	2,198	2,716	221,070	241,000	244,140	11,408	9,120	11,125
Georgia	1,514	1,707	1,326	144,170	137,580	136,880	10,503	12,411	9,687
Hawaii	350	384	344	16,090	17,460	18,740	21,731	22,016	18,356
Idaho	216	273	281	22,150	23,880	24,330	9,757	11,436	11,550
Illinois	1,900	1,983	2,115	211,230	221,630	225,180	8,996	8,946	9,392
Indiana	561	554	572	78,410	79,910	83,080	7,158	6,928	6,885
Iowa	465	448	603	37,320	40,300	45,430	12,466	11,108	13,273
Kansas	190	198	247	51,970	51,630	50,040	3,656	3,835	4,936
Kentucky	232	263	221	45,230	44,530	49,030	5,131	5,901	4,507
Louisiana	442	402	418	41,900	41,030	38,450	10,547	9,799	10,871
Maine	145	240	377	15,020	15,500	15,960	9,650	15,473	23,622
Maryland	7,804	12,211	11,579	149,250	160,120	162,540	52,291	76,264	71,238
Massachusetts	5,157	5,702	6,741	184,690	193,180	205,610	27,920	29,516	32,785
Michigan	1,673	1,105	1,710	182,940	192,150	212,040	9,146	5,752	8,065
Minnesota	861	758	1,384	117,120	120,930	129,840	7,354	6,270	10,659
Mississippi	1,174	424	424	22,190	23,480	25,520	52,900	18,062	16,614
Missouri	1,270	4,040	1,142	84,150	92,260	102,170	15,091	43,793	11,177
Montana	130	177	653	11,450	11,940	13,240	11,314	14,811	49,320
Nebraska	146	145	187	30,710	31,530	31,420	4,765	4,603	5,952
Nevada	409	382	299	22,330	24,400	26,920	18,330	15,675	11,107
New Hampshire	363	364	317	23,430	26,840	28,450	15,498	13,574	11,142
New Jersey	1,786	2,344	2,141	161,420	174,270	186,120	11,063	13,451	11,503
New Mexico	2,850	3,279	3,201	33,600	32,530	33,440	84,823	100,808	95,724
New York	3,973	4,956	5,062	272,440	289,010	322,520	14,583	17,147	15,695
North Carolina	1,611	1,791	1,825	132,440	134,290	142,970	12,163	13,340	12,765
North Dakota	102	105	113	8,430	9,070	9,660	12,070	11,589	11,698
Ohio	2,396	2,370	2,603	177,100	180,900	196,390	13,529	13,100	13,254
Oklahoma	274	254	226	44,360	46,370	51,430	6,185	5,469	4,394
Oregon	480	557	504	61,230	62,030	67,890	7,843	8,987	7,424
Pennsylvania	3,788	3,235	3,278	185,560	204,270	218,890	20,413	15,835	14,976
Rhode Island	523	572	628	18,740	18,080	18,400	27,927	31,651	34,130
South Carolina	412	408	417	48,740	50,460	54,120	8,447	8,094	7,705
South Dakota	55	70	62	9,150	9,460	11,550	5,988	7,398	5,368
Tennessee	1,039	1,293	1,659	63,680	66,390	70,820	16,320	19,474	23,426
Texas	4,757	4,989	5,427	365,270	389,550	441,410	13,023	12,806	12,295
Utah	650	814	765	45,570	45,110	51,340	14,268	18,043	14,901
Vermont	182	171	108	11,420	12,770	12,760	15,926	13,371	8,464
Virginia	6,213	8,214	8,754	209,280	236,650	254,710	29,687	34,711	34,368
Washington	2,292	2,388	4,708	150,230	160,960	183,900	15,257	14,834	25,601
West Virginia	367	773	217	16,220	16,040	16,560	22,651	48,163	13,104
Wisconsin	657	648	671	93,320	93,590	99,380	7,042	6,926	6,752
Wyoming	41	34	36	6,130	7,350	8,110	6,704	4,564	4,439
Puerto Rico	112	101	86	19,940	20,950	NA	5,628	4,842	NA

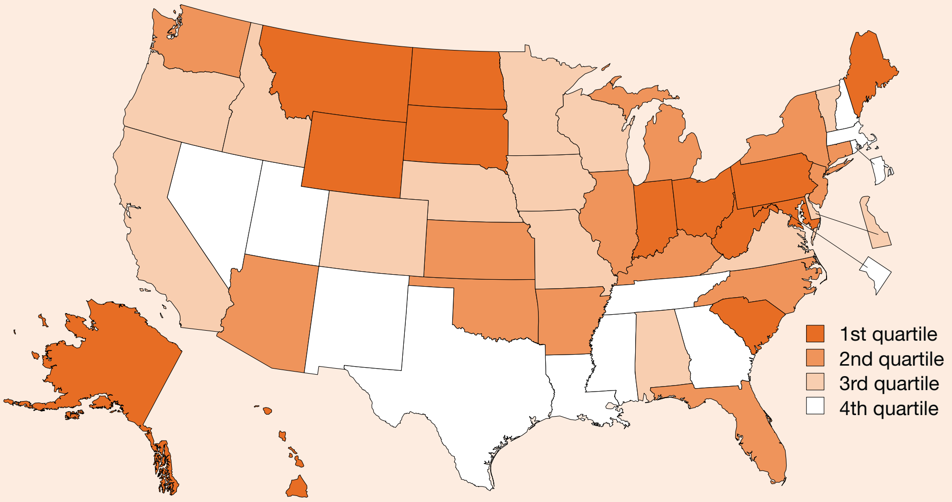
NOTES: Only 11 agencies required to report federal R&D obligations: Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Homeland Security (established in 2002), Interior, and Transportation; Environmental Protection Agency; National Aeronautics and Space Administration; and National Science Foundation. These obligations represent approximately 98% of total federal R&D obligations. National total for S&E occupations in the United States provided by Occupational Employment Statistics (OES). OES estimates for 2003 S&E occupations based on November data; estimates for remaining years based upon May data.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development (various years); and Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

Science and Engineering Indicators 2010

State Agency R&D Expenditures per $1 Million of Gross Domestic Product

Figure 8-36
State agency R&D expenditures per $1 million of gross domestic product: 2007



1st quartile ($618.20–$152.40)	2nd quartile ($137.98–$67.99)	3rd quartile ($67.97–$40.32)	4th quartile ($37.94–$8.95)
Alaska ‡	Arizona	Alabama ‡	District of Columbia
Hawaii ‡	Arkansas ‡	California	Georgia
Indiana	Connecticut	Colorado	Louisiana ‡
Maine ‡	Florida	Delaware ‡	Massachusetts
Maryland	Illinois	Idaho ‡	Mississippi ‡
Montana ‡	Kansas ‡	Iowa	Nevada ‡
North Dakota ‡	Kentucky ‡	Minnesota	New Hampshire ‡
Ohio	Michigan	Missouri	New Mexico ‡
Pennsylvania	New Jersey	Nebraska ‡	Rhode Island ‡
South Carolina ‡	New York	Oregon	Tennessee
South Dakota ‡	North Carolina	Vermont ‡	Texas
West Virginia ‡	Oklahoma ‡	Virginia	Utah
Wyoming ‡	Washington	Wisconsin	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of State Research and Development Expenditures; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-36.

Findings

- Nationally, state government agencies spent a total of $1.2 billion on R&D in 2007. This represented $89 for each $1 million of a state's GDP.
- State agency R&D expenditures accounted for 0.34% of total R&D expenditures in 2007, indicating that most R&D was funded by nonstate sources.
- In 2007, the state values for this indicator ranged from $618 per $1 million to $9 per $1 million of state GDP, reflecting varying approaches to the role of state government agencies in the funding of R&D.
- A substantial number of EPSCoR states are among those with the highest values for this indicator, suggesting that there is a state-level effort to improve R&D infrastructure in these states, not just a federal effort.

This indicator measures the ratio between the amount of state agency R&D funding and the size of a state's economy. State R&D expenditures include state-administered funds from all sources that support R&D performed by either a state agency or an external performer.

Data on state R&D funding come from National Science Foundation (NSF) surveys of state agencies covering 2006 and 2007 expenditures. The data cover funding administered by state government departments, agencies, independent commissions, and other state-run entities. They exclude state-run colleges and universities as well as laboratories or experiment stations controlled by state universities; funding administered by these institutions is classified as academic R&D. The data also exclude state legislatures' direct appropriations to nonstate agencies. Although the surveys are limited to R&D activities, the data may include some expenditures for non-R&D activities such as commercialization, environmental testing, and routine survey work.

Because of differences in the survey populations, definition of covered R&D activities, and collection methods, the results of previous NSF surveys on state government R&D are not comparable. Data for the value of gross domestic product (GDP) and for R&D expenditures are shown in current dollars.

Table 8-36
State agency R&D expenditures per $1 million of gross domestic product, by state: 2006 and 2007

State	State agency R&D expenditures (current $) 2006	2007	State GDP (current $millions) 2006	2007	State agency R&D($)/ $1 million GDP 2006	2007
EPSCoR states	195,833,394	232,177,940	1,898,423	1,981,871	103	117
Non-EPSCoR states	824,010,424	989,262,653	11,133,340	11,641,354	74	85
Average EPSCoR state value	na	na	na	na	141	160
Average non-EPSCoR state value	na	na	na	na	96	111
United States	1,021,016,894	1,223,449,593	13,119,937	13,715,741	78	89
Alabama	7,269,319	7,340,365	158,566	164,524	46	45
Alaska	10,019,060	9,526,100	43,117	44,887	232	212
Arizona	37,151,471	20,442,635	237,397	245,952	157	83
Arkansas	4,869,648	7,658,199	90,864	95,116	54	81
California	107,793,045	91,842,652	1,742,172	1,801,762	62	51
Colorado	8,997,236	11,924,981	226,266	235,848	40	51
Connecticut	19,209,064	29,285,710	204,964	212,252	94	138
Delaware	2,812,102	2,611,108	59,589	61,545	47	42
District of Columbia	1,173,076	2,009,000	88,174	92,516	13	22
Florida	42,329,624	96,968,573	716,505	741,861	59	131
Georgia	10,620,188	4,886,946	376,410	391,241	28	12
Hawaii	12,067,849	22,643,330	58,676	62,019	206	365
Idaho	2,280,873	2,739,006	48,441	52,110	47	53
Illinois	37,184,281	41,974,809	583,990	617,409	64	68
Indiana	6,220,575	40,534,381	238,693	249,229	26	163
Iowa	13,564,062	6,790,053	121,945	129,911	111	52
Kansas	14,348,384	11,752,696	110,645	116,986	130	100
Kentucky	17,558,997	11,960,634	146,415	152,099	120	79
Louisiana	11,216,568	6,587,314	203,167	207,407	55	32
Maine	17,509,051	27,525,552	46,340	48,021	378	573
Maryland	24,945,119	40,298,691	257,577	264,426	97	152
Massachusetts	10,729,419	5,600,189	335,313	352,178	32	16
Michigan	75,016,589	32,849,159	375,759	379,934	200	86
Minnesota	6,219,201	10,529,048	242,095	252,472	26	42
Mississippi	2,744,882	2,893,892	84,586	87,652	32	33
Missouri	18,465,303	15,567,277	220,092	229,027	84	68
Montana	8,606,319	8,200,230	31,994	34,266	269	239
Nebraska	5,602,163	4,043,480	75,290	80,360	74	50
Nevada	1,397,463	1,748,776	123,054	129,314	11	14
New Hampshire	2,040,544	1,685,178	56,073	57,820	36	29
New Jersey	25,900,482	59,747,701	448,426	461,295	58	130
New Mexico	3,105,000	672,921	72,161	75,192	43	9
New York	103,597,135	128,361,166	1,028,320	1,105,020	101	116
North Carolina	14,344,310	37,607,109	380,932	390,467	38	96
North Dakota	21,062,090	9,908,722	25,851	28,518	815	347
Ohio	55,068,629	114,086,509	451,600	462,506	122	247
Oklahoma	8,922,036	10,731,050	130,094	136,374	69	79
Oregon	7,382,722	7,389,914	150,984	158,268	49	47
Pennsylvania	117,320,158	103,973,448	508,769	533,212	231	195
Rhode Island	150,000	1,771,949	45,733	46,699	3	38
South Carolina	22,427,746	31,493,843	146,211	151,703	153	208
South Dakota	5,791,586	5,473,603	32,008	35,211	181	155
Tennessee	5,355,000	4,549,998	235,753	245,162	23	19
Texas	28,019,645	29,650,947	1,068,119	1,148,531	26	26
Utah	3,214,170	2,752,228	97,963	105,574	33	26
Vermont	1,680,533	1,529,805	23,628	24,627	71	62
Virginia	11,579,623	15,486,526	368,604	384,132	31	40
Washington	22,834,218	23,333,431	291,298	310,279	78	75
West Virginia	6,024,577	22,179,830	56,016	57,877	108	383
Wisconsin	10,949,155	12,828,572	223,394	233,406	49	55
Wyoming	6,326,604	19,500,357	29,904	31,544	212	618
Puerto Rico	1,458,790	2,326,241	NA	NA	NA	NA

na = not applicable; NA = not available

EPSCoR = Experimental Program to Stimulate Competitive Research; GDP = gross domestic product

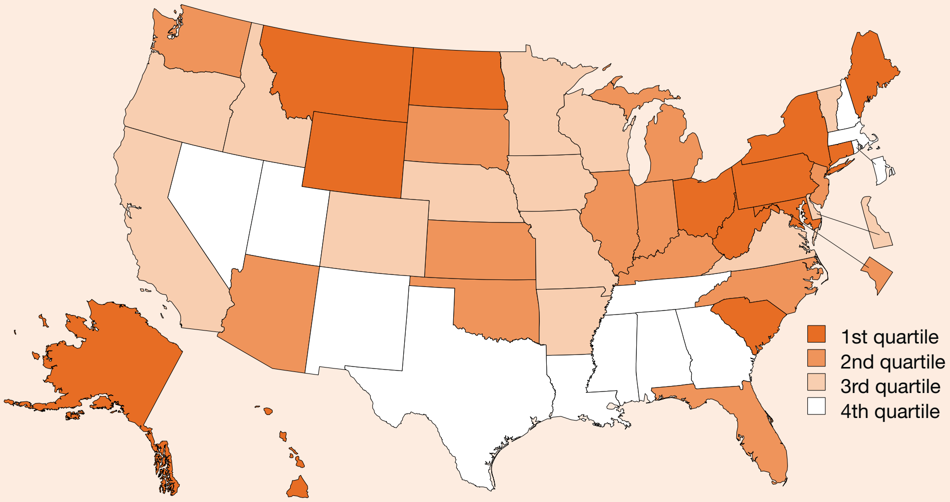
NOTES: For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of State Research and Development Expenditures (FY 2006 and FY 2007); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2010

State Agency R&D Expenditures per Civilian Worker

Figure 8-37
State agency R&D expenditures per civilian worker: 2007



1st quartile ($69.87–$14.02)	2nd quartile ($13.97–$6.19)	3rd quartile ($6.10–$3.73)	4th quartile ($3.49–$0.74)
Alaska ‡	Arizona	Arkansas ‡	Alabama ‡
Connecticut	District of Columbia	California	Georgia
Hawaii ‡	Florida	Colorado	Louisiana ‡
Maine ‡	Illinois	Delaware ‡	Massachusetts
Maryland	Indiana	Idaho ‡	Mississippi ‡
Montana ‡	Kansas ‡	Iowa	Nevada ‡
New York	Kentucky ‡	Minnesota	New Hampshire ‡
North Dakota ‡	Michigan	Missouri	New Mexico ‡
Ohio	New Jersey	Nebraska ‡	Rhode Island ‡
Pennsylvania	North Carolina	Oregon	Tennessee
South Carolina ‡	Oklahoma ‡	Vermont ‡	Texas
West Virginia ‡	South Dakota ‡	Virginia	Utah
Wyoming ‡	Washington	Wisconsin	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of State Research and Development Expenditures; and Bureau of Labor Statistics, Local Area Unemployment Statistics. See table 8-37.

Findings

- In 2007, state government agency R&D expenditures averaged $8.42 per civilian worker nationwide.
- State agency R&D funding per civilian worker across the United States was approximately 1% of the $764 in federal R&D obligations per worker in 2007.
- State agency R&D spending per civilian worker varied greatly among the states in 2007, ranging from a high of $69.87 to a low of $0.74.
- A number of EPSCoR states had high values for this indicator.

This indicator measures the extent of R&D activity funded by state government agencies relative to the size of the state's civilian workforce. State R&D expenditures include state-administered funds from all sources that support R&D performed by either a state agency or an external performer.

Data on state R&D funding come from National Science Foundation surveys of state agencies covering 2006 and 2007 expenditures. The data cover funding administered by state government departments, agencies, independent commissions, and other state-run entities. They exclude state-run colleges and universities as well as laboratories or experiment stations controlled by state universities; funding administered by these institutions is classified as academic R&D. The data also exclude state legislatures' direct appropriations to nonstate agencies. Although the surveys are limited to R&D activities, the data may include some expenditures for non-R&D activities such as commercialization, environmental testing, and routine survey work.

The size of a state's civilian workforce is a nonseasonally adjusted annual estimate of employed workers based on the Bureau of Labor Statistics Current Population Survey, which assigns workers to a location based on residence. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations.

Table 8-37
State agency R&D expenditures per civilian worker, by state: 2006 and 2007

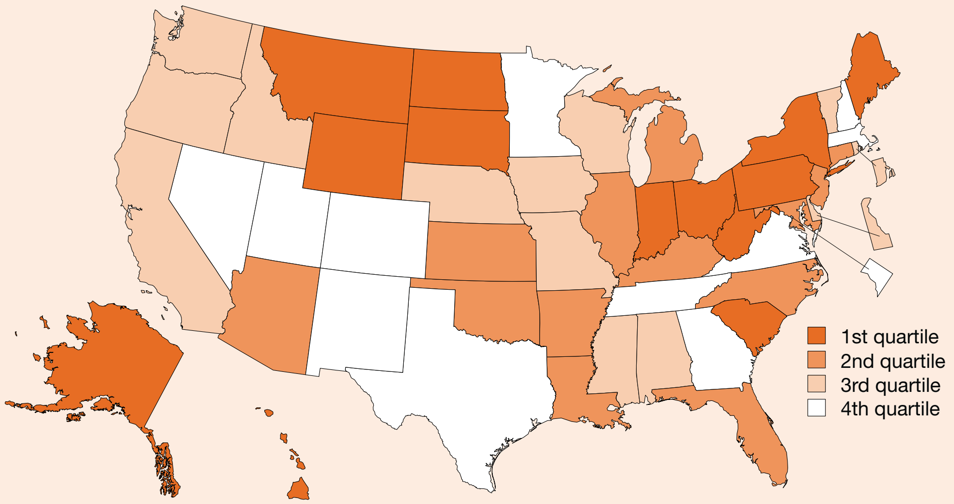
State	State agency R&D expenditures (current $)		Civilian workers		State agency R&D expenditures/civilian worker ($)	
	2006	2007	2006	2007	2006	2007
United States	1,022,475,684	1,225,775,834	144,581,912	145,595,173	7.07	8.42
Alabama	7,269,319	7,340,365	2,120,573	2,105,951	3.43	3.49
Alaska	10,019,060	9,526,100	323,531	330,587	30.97	28.82
Arizona	37,151,471	20,442,635	2,854,381	2,913,695	13.02	7.02
Arkansas	4,869,648	7,658,199	1,292,886	1,293,852	3.77	5.92
California	107,793,045	91,842,652	17,029,307	17,208,903	6.33	5.34
Colorado	8,997,236	11,924,981	2,537,037	2,602,015	3.55	4.58
Connecticut	19,209,064	29,285,710	1,765,075	1,780,473	10.88	16.45
Delaware	2,812,102	2,611,108	424,506	427,766	6.62	6.10
District of Columbia	1,173,076	2,009,000	296,957	307,049	3.95	6.54
Florida	42,329,624	96,968,573	8,692,761	8,779,299	4.87	11.05
Georgia	10,620,188	4,886,946	4,522,025	4,602,947	2.35	1.06
Hawaii	12,067,849	22,643,330	628,277	631,911	19.21	35.83
Idaho	2,280,873	2,739,006	723,621	733,652	3.15	3.73
Illinois	37,184,281	41,974,809	6,315,715	6,361,750	5.89	6.60
Indiana	6,220,575	40,534,381	3,108,806	3,065,590	2.00	13.22
Iowa	13,564,062	6,790,053	1,602,849	1,598,261	8.46	4.25
Kansas	14,348,384	11,752,696	1,400,169	1,418,666	10.25	8.28
Kentucky	17,558,997	11,960,634	1,922,163	1,932,028	9.14	6.19
Louisiana	11,216,568	6,587,314	1,910,348	1,921,343	5.87	3.43
Maine	17,509,051	27,525,552	678,843	671,337	25.79	41.00
Maryland	24,945,119	40,298,691	2,892,620	2,873,512	8.62	14.02
Massachusetts	10,729,419	5,600,189	3,234,860	3,255,611	3.32	1.72
Michigan	75,016,589	32,849,159	4,730,291	4,659,927	15.86	7.05
Minnesota	6,219,201	10,529,048	2,822,297	2,796,737	2.20	3.76
Mississippi	2,744,882	2,893,892	1,218,664	1,231,743	2.25	2.35
Missouri	18,465,303	15,567,277	2,885,857	2,878,399	6.40	5.41
Montana	8,606,319	8,200,230	478,162	485,615	18.00	16.89
Nebraska	5,602,163	4,043,480	945,270	953,769	5.93	4.24
Nevada	1,397,463	1,748,776	1,240,868	1,271,472	1.13	1.38
New Hampshire	2,040,544	1,685,178	711,512	712,048	2.87	2.37
New Jersey	25,900,482	59,747,701	4,309,021	4,276,561	6.01	13.97
New Mexico	3,105,000	672,921	895,623	909,968	3.47	0.74
New York	103,597,135	128,361,166	9,072,733	9,087,278	11.42	14.13
North Carolina	14,344,310	37,607,109	4,250,619	4,308,624	3.37	8.73
North Dakota	21,062,090	9,908,722	346,359	354,003	60.81	27.99
Ohio	55,068,629	114,086,509	5,609,056	5,640,081	9.82	20.23
Oklahoma	8,922,036	10,731,050	1,650,877	1,657,964	5.40	6.47
Oregon	7,382,722	7,389,914	1,796,165	1,827,285	4.11	4.04
Pennsylvania	117,320,158	103,973,448	6,009,858	6,013,406	19.52	17.29
Rhode Island	150,000	1,771,949	547,618	547,927	0.27	3.23
South Carolina	22,427,746	31,493,843	1,988,378	2,011,255	11.28	15.66
South Dakota	5,791,586	5,473,603	417,100	429,495	13.89	12.74
Tennessee	5,355,000	4,549,998	2,835,530	2,893,748	1.89	1.57
Texas	28,019,645	29,650,947	10,921,673	10,992,828	2.57	2.70
Utah	3,214,170	2,752,228	1,272,801	1,325,480	2.53	2.08
Vermont	1,680,533	1,529,805	348,026	340,073	4.83	4.50
Virginia	11,579,623	15,486,526	3,878,988	3,930,984	2.99	3.94
Washington	22,834,218	23,333,431	3,160,350	3,253,475	7.23	7.17
West Virginia	6,024,577	22,179,830	767,134	771,837	7.85	28.74
Wisconsin	10,949,155	12,828,572	2,918,155	2,937,903	3.75	4.37
Wyoming	6,326,604	19,500,357	275,617	279,090	22.95	69.87
Puerto Rico	1,458,790	2,326,241	1,260,703	1,241,426	1.16	1.87

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of State Research and Development Expenditures (FY 2006 and FY 2007); Bureau of Labor Statistics, Local Area Unemployment Statistics; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2010

State Agency R&D Expenditures per Individual in S&E Occupation

Figure 8-38
State agency R&D expenditures per individual in S&E occupation: 2007



1st quartile ($2,404–$398)	2nd quartile ($397–$155)	3rd quartile ($152–$96)	4th quartile ($86–$20)
Alaska ‡	Arizona	Alabama ‡	Colorado
Hawaii ‡	Arkansas ‡	California	District of Columbia
Indiana	Connecticut	Delaware ‡	Georgia
Maine ‡	Florida	Idaho ‡	Massachusetts
Montana ‡	Illinois	Iowa	Minnesota
New York	Kansas ‡	Mississippi ‡	Nevada ‡
North Dakota ‡	Kentucky ‡	Missouri	New Hampshire ‡
Ohio	Louisiana ‡	Nebraska ‡	New Mexico ‡
Pennsylvania	Maryland	Oregon	Tennessee
South Carolina ‡	Michigan	Rhode Island ‡	Texas
South Dakota ‡	New Jersey	Vermont ‡	Utah
West Virginia ‡	North Carolina	Washington	Virginia
Wyoming ‡	Oklahoma ‡	Wisconsin	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of State Research and Development Expenditures; and Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See table 8-38.

Findings

- In 2007, the average state agency R&D expenditure per person employed in an S&E occupation was $219, indicating that state agency funding for R&D was a very small fraction of total R&D funding.
- Nationally, state government agencies spent about $1.2 billion for R&D in 2007. By comparison, the federal government obligated more than $111 billion for R&D in 2007, about $20,000 for each person employed in an S&E occupation.
- State agency R&D funding per person employed in an S&E occupation ranged from $2,404 to $20 per state in 2007.
- Several EPSCoR states had the highest state agency R&D spending per S&E worker.

This indicator measures the extent of the R&D activity funded by a state's government agencies relative to the number of individuals engaged in S&E occupations in the state.

Data on state R&D funding come from National Science Foundation surveys of state agencies covering 2006 and 2007 expenditures. The data cover funding administered by state government departments, agencies, independent commissions, and other state-run entities. They exclude state-run colleges and universities as well as laboratories or experiment stations controlled by state universities; funding administered by these institutions is classified as academic R&D. The data also exclude state legislatures' direct appropriations to nonstate agencies. Although the surveys are limited to R&D activities, the data may include some expenditures for non-R&D activities such as commercialization, environmental testing, and routine survey work.

The denominator of this indicator measures individuals with bachelor's or higher degrees who work in S&E occupations. S&E occupations are defined by standard occupational codes. They include engineers and computer, mathematical, life, physical, and social scientists. They exclude managers, technicians, elementary and secondary schoolteachers, and medical personnel. State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work. Because OES data do not classify postsecondary teachers by field, in these data, faculty teaching in S&E fields are not counted as working in S&E occupations.

Table 8-38

State agency R&D expenditures per individual in S&E occupation, by state: 2006 and 2007

State	State agency R&D expenditures (currrent $)		Individuals in S&E occupations		State agency R&D expenditures/individual in S&E occupation ($)	
	2006	2007	2006	2007	2006	2007
United States	1,022,475,684	1,225,775,834	5,407,710	5,591,990	189	219
Alabama	7,269,319	7,340,365	66,100	69,650	110	105
Alaska	10,019,060	9,526,100	10,720	11,990	935	795
Arizona	37,151,471	20,442,635	98,110	102,380	379	200
Arkansas	4,869,648	7,658,199	24,860	28,460	196	269
California	107,793,045	91,842,652	730,010	753,570	148	122
Colorado	8,997,236	11,924,981	133,730	138,990	67	86
Connecticut	19,209,064	29,285,710	79,380	80,280	242	365
Delaware	2,812,102	2,611,108	21,550	22,140	130	118
District of Columbia	1,173,076	2,009,000	64,120	63,150	18	32
Florida	42,329,624	96,968,573	246,190	244,140	172	397
Georgia	10,620,188	4,886,946	136,470	136,880	78	36
Hawaii	12,067,849	22,643,330	18,940	18,740	637	1,208
Idaho	2,280,873	2,739,006	NA	24,330	NA	113
Illinois	37,184,281	41,974,809	222,470	225,180	167	186
Indiana	6,220,575	40,534,381	80,110	83,080	78	488
Iowa	13,564,062	6,790,053	43,670	45,430	311	149
Kansas	14,348,384	11,752,696	48,620	50,040	295	235
Kentucky	17,558,997	11,960,634	44,680	49,030	393	244
Louisiana	11,216,568	6,587,314	40,180	38,450	279	171
Maine	17,509,051	27,525,552	15,950	15,960	1,098	1,725
Maryland	24,945,119	40,298,691	159,470	162,540	156	248
Massachusetts	10,729,419	5,600,189	198,670	205,610	54	27
Michigan	75,016,589	32,849,159	208,520	212,040	360	155
Minnesota	6,219,201	10,529,048	125,930	129,840	49	81
Mississippi	2,744,882	2,893,892	24,910	25,520	110	113
Missouri	18,465,303	15,567,277	96,420	102,170	192	152
Montana	8,606,319	8,200,230	13,010	13,240	662	619
Nebraska	5,602,163	4,043,480	32,500	31,420	172	129
Nevada	1,397,463	1,748,776	26,930	26,920	52	65
New Hampshire	2,040,544	1,685,178	27,680	28,450	74	59
New Jersey	25,900,482	59,747,701	176,460	186,120	147	321
New Mexico	3,105,000	672,921	30,800	33,440	101	20
New York	103,597,135	128,361,166	306,810	322,520	338	398
North Carolina	14,344,310	37,607,109	138,790	142,970	103	263
North Dakota	21,062,090	9,908,722	9,360	9,660	2,250	1,026
Ohio	55,068,629	114,086,509	185,190	196,390	297	581
Oklahoma	8,922,036	10,731,050	50,770	51,430	176	209
Oregon	7,382,722	7,389,914	64,520	67,890	114	109
Pennsylvania	117,320,158	103,973,448	214,910	218,890	546	475
Rhode Island	150,000	1,771,949	18,060	18,400	8	96
South Carolina	22,427,746	31,493,843	53,230	54,120	421	582
South Dakota	5,791,586	5,473,603	10,120	11,550	572	474
Tennessee	5,355,000	4,549,998	67,040	70,820	80	64
Texas	28,019,645	29,650,947	408,710	441,410	69	67
Utah	3,214,170	2,752,228	49,690	51,340	65	54
Vermont	1,680,533	1,529,805	12,780	12,760	131	120
Virginia	11,579,623	15,486,526	251,720	254,710	46	61
Washington	22,834,218	23,333,431	171,780	183,900	133	127
West Virginia	6,024,577	22,179,830	17,150	16,560	351	1,339
Wisconsin	10,949,155	12,828,572	96,860	99,380	113	129
Wyoming	6,326,604	19,500,357	7,640	8,110	828	2,404
Puerto Rico	1,458,790	2,326,241	23,850	NA	61	NA

NA = not available

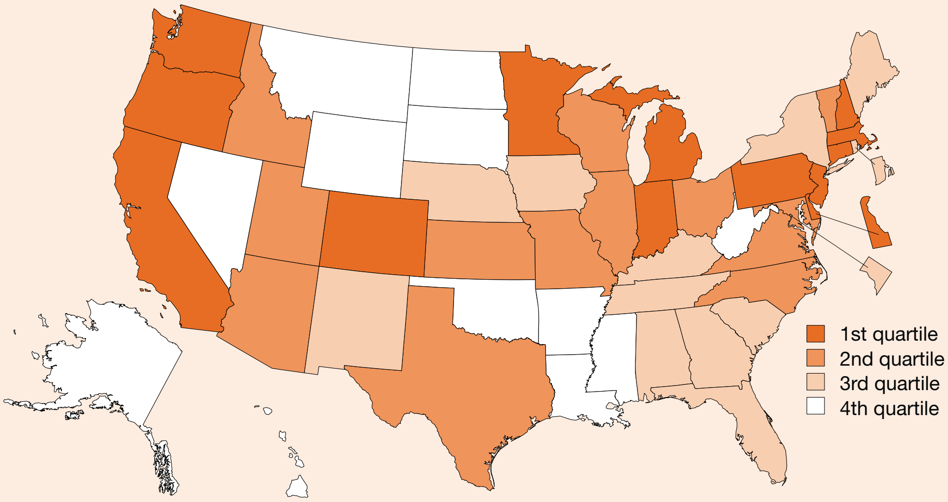
NOTES: National total for S&E occupations in the United States provided by Occupational Employment Statistics (OES). OES estimates for 2006 and 2007 S&E occupations based on May data.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of State Research and Development Expenditures (FY 2006, FY 2007); and Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

Science and Engineering Indicators 2010

Business-Performed R&D as Share of Private-Industry Output

Figure 8-39
Business-performed R&D as share of private-industry output: 2007



1st quartile (6.08%–2.16%)	2nd quartile (2.03%–1.30%)	3rd quartile (1.28%–0.61%)	4th quartile (0.52%–0.14%)
California	Arizona	Alabama ‡	Alaska ‡
Colorado	Idaho ‡	District of Columbia	Arkansas ‡
Connecticut	Illinois	Florida	Hawaii ‡
Delaware ‡	Kansas ‡	Georgia	Louisiana ‡
Indiana	Maryland	Iowa	Mississippi ‡
Massachusetts	Missouri	Kentucky ‡	Montana ‡
Michigan	North Carolina	Maine ‡	Nevada ‡
Minnesota	Ohio	Nebraska ‡	North Dakota ‡
New Hampshire ‡	Texas	New Mexico ‡	Oklahoma ‡
New Jersey	Utah	New York	South Dakota ‡
Oregon	Vermont ‡	Rhode Island ‡	West Virginia ‡
Pennsylvania	Virginia	South Carolina ‡	Wyoming ‡
Washington	Wisconsin	Tennessee	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-39.

Findings

- The amount of R&D performed by business rose from nearly $164 billion in 1998 to about $266 billion in 2007, an increase of more than 60% (in current dollars).
- The value of this indicator exhibited little overall change between 1998 and 2007.
- Business R&D was concentrated in a few states—only 12 states had indicator values that met or exceeded the national average in 2007.

This indicator measures the role of R&D in a state's business activity. Business R&D focuses on projects that are expected to yield new or improved products, processes, or services and to bring direct benefits to a company. A high value for this indicator shows that the businesses within a state are making a significant investment in their R&D activities.

Because industries differ in their reliance on R&D, the indicator reflects state differences in industrial structure as much as the behavior or priorities of individual businesses. Estimates for states with smaller economies are generally less precise than those for states with larger economies.

The methodology for making state-level assignments of the business R&D reported by companies with operations in multiple states changed in 1998. Therefore, pre-1998 data on the amount of R&D performed by industry in states are not comparable.

Table 8-39

Business-performed R&D as share of private-industry output, by state: 1998, 2002, and 2007

State	Business-performed R&D (current $millions) 1998	2002	2007	Private-industry output (current $millions) 1998	2002	2007	Business-performed R&D/ private-industry output (%) 1998	2002	2007
United States	163,658	185,505	265,919	7,652,500	9,131,170	12,064,609	2.14	2.03	2.20
Alabama	845	846	1,771	89,994	104,211	138,392	0.94	0.81	1.28
Alaska	37	51	58	18,175	23,302	36,914	0.20	0.22	0.16
Arizona	1,801	3,201	3,846	120,484	150,429	215,329	1.49	2.13	1.79
Arkansas	213	225	339	54,258	62,883	82,061	0.39	0.36	0.41
California	32,856	42,177	64,187	965,937	1,184,559	1,596,045	3.40	3.56	4.02
Colorado	3,180	2,823	5,223	126,013	160,289	207,494	2.52	1.76	2.52
Connecticut	3,346	6,077	9,444	132,955	150,755	192,695	2.52	4.03	4.90
Delaware	1,356	1,219	1,472	33,652	41,196	56,314	4.03	2.96	2.61
District of Columbia	D	194	379	32,710	43,937	62,311	1.83	0.44	0.61
Florida	3,265	3,707	4,569	365,813	459,933	655,459	0.89	0.81	0.70
Georgia	1,617	2,107	2,788	224,870	267,441	339,136	0.72	0.79	0.82
Hawaii	55	103	218	29,201	33,619	47,923	0.19	0.31	0.45
Idaho	1,103	992	726	25,510	31,197	45,004	4.32	3.18	1.61
Illinois	7,318	7,616	11,362	384,342	438,363	558,823	1.90	1.74	2.03
Indiana	2,922	3,572	4,939	161,797	184,923	224,499	1.81	1.93	2.20
Iowa	750	753	1,202	73,908	85,652	114,859	1.01	0.88	1.05
Kansas	1,384	1,427	1,304	65,697	77,183	100,600	2.11	1.85	1.30
Kentucky	606	656	890	94,081	103,514	128,916	0.64	0.63	0.69
Louisiana	377	248	373	103,343	116,505	184,848	0.36	0.21	0.20
Maine	137	250	265	27,363	33,121	41,206	0.50	0.75	0.64
Maryland	1,905	3,800	3,665	133,482	168,770	216,069	1.43	2.25	1.70
Massachusetts	10,367	10,609	19,488	214,890	258,688	320,565	4.82	4.10	6.08
Michigan	12,554	13,565	15,736	278,874	313,384	337,072	4.50	4.33	4.67
Minnesota	3,367	4,460	6,636	148,057	177,427	226,097	2.27	2.51	2.94
Mississippi	183	224	279	50,894	56,215	72,521	0.36	0.40	0.38
Missouri	1,505	1,592	2,736	146,453	166,436	200,977	1.03	0.96	1.36
Montana	63	66	134	16,607	19,565	28,927	0.38	0.34	0.46
Nebraska	195	342	489	44,485	50,901	69,174	0.44	0.67	0.71
Nevada	476	339	567	56,995	72,826	116,816	0.84	0.47	0.49
New Hampshire	1,138	1,153	1,814	35,812	41,991	52,268	3.18	2.75	3.47
New Jersey	11,107	11,566	17,892	282,938	335,111	413,706	3.93	3.45	4.32
New Mexico	1,450	331	568	37,455	41,702	62,107	3.87	0.79	0.91
New York	10,283	9,234	10,916	614,396	736,066	993,104	1.67	1.25	1.10
North Carolina	3,483	3,704	6,829	212,790	259,825	338,159	1.64	1.43	2.02
North Dakota	46	154	126	14,277	16,671	24,359	0.32	0.92	0.52
Ohio	5,742	6,230	7,265	312,647	346,524	410,857	1.84	1.80	1.77
Oklahoma	369	412	527	65,997	80,492	114,350	0.56	0.51	0.46
Oregon	1,345	2,320	3,629	88,532	100,222	138,781	1.52	2.31	2.61
Pennsylvania	7,393	7,064	10,387	324,847	381,405	480,942	2.28	1.85	2.16
Rhode Island	1,332	1,121	411	25,892	32,294	40,846	5.14	3.47	1.01
South Carolina	996	1,054	1,426	87,771	102,565	126,253	1.13	1.03	1.13
South Dakota	40	53	132	17,932	23,084	30,910	0.22	0.23	0.43
Tennessee	2,440	1,289	1,638	142,438	169,564	218,172	1.71	0.76	0.75
Texas	8,984	10,744	13,889	558,165	691,968	1,026,886	1.61	1.55	1.35
Utah	1,119	1,116	1,764	51,610	61,934	91,319	2.17	1.80	1.93
Vermont	114	286	413	13,976	16,974	21,249	0.82	1.68	1.94
Virginia	2,540	2,920	4,840	186,444	235,685	314,689	1.36	1.24	1.54
Washington	7,072	8,579	12,687	168,427	198,461	266,138	4.20	4.32	4.77
West Virginia	D	264	233	33,440	37,308	47,466	1.00	0.71	0.49
Wisconsin	1,929	2,649	3,411	143,368	167,489	207,614	1.35	1.58	1.64
Wyoming	20	21	37	12,506	16,611	27,388	0.16	0.13	0.14
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

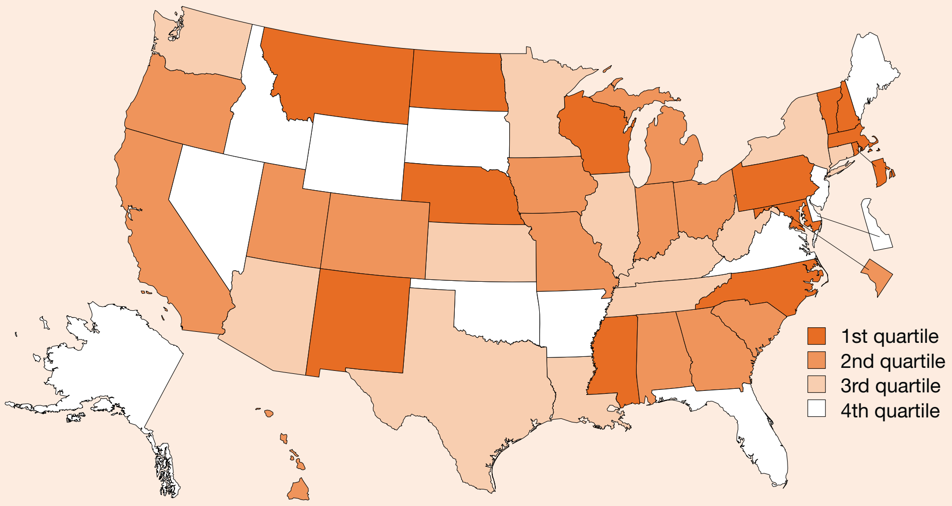
D = suppressed to avoid disclosure of confidential information; NA = not available

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (various years); and Bureau of Economic Analysis, Gross Domestic Product data.

Science and Engineering Indicators 2010

Academic R&D per $1,000 of Gross Domestic Product

Figure 8-40
Academic R&D per $1,000 of gross domestic product: 2008



1st quartile ($10.05–$4.43)	2nd quartile ($4.37–$3.68)	3rd quartile ($3.53–$2.66)	4th quartile ($2.65–$1.45)
Maryland	Alabama ‡	Arizona	Alaska ‡
Massachusetts	California	Connecticut	Arkansas ‡
Mississippi ‡	Colorado	Illinois	Delaware ‡
Montana ‡	District of Columbia	Kansas ‡	Florida
Nebraska ‡	Georgia	Kentucky ‡	Idaho ‡
New Hampshire ‡	Hawaii ‡	Louisiana ‡	Maine ‡
New Mexico ‡	Indiana	Minnesota	Nevada ‡
North Carolina	Iowa	New York	New Jersey
North Dakota ‡	Michigan	Tennessee	Oklahoma ‡
Pennsylvania	Missouri	Texas	South Dakota ‡
Rhode Island ‡	Ohio	Washington	Virginia
Vermont ‡	Oregon	West Virginia ‡	Wyoming ‡
Wisconsin	South Carolina ‡		
	Utah		

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-40.

Findings

- Expenditures for research performed in academic institutions have doubled in a decade, rising from $25.8 billion in 1998 to $51.8 billion in 2008 (in current dollars).
- In the United States, growth in academic research increased more rapidly than GDP, causing the value of this indicator to increase by 23% between 1998 and 2008. Most of this change occurred between 1998 and 2003; there was no significant change between 2003 and 2008.
- The largest percentage increases in academic R&D as a share of GDP occurred in two EPSCoR states, where the value of this indicator more than doubled between 1998 and 2008.
- The EPSCoR states were concentrated in the highest and lowest quartiles of the state ranking for this indicator, showing considerable variation in the amount of academic R&D being conducted in each EPSCoR state relative to the size of the state's economy.

This indicator measures the extent of spending on academic research performed in a state relative to the size of the state's economy. Academic R&D is more basic and less product-oriented than R&D performed by business. It can be a valuable basis for future economic development. In this indicator, data for Maryland exclude expenditures by the Applied Physics Laboratory at the Johns Hopkins University.

Data for the value of gross domestic product (GDP) by state and for R&D expenditures are shown in current dollars.

Table 8-40

Academic R&D per $1,000 of gross domestic product, by state: 1998, 2003, and 2008

	Academic R&D (current $thousands)			State GDP (current $millions)			Academic R&D ($)/ $1,000 GDP		
State	1998	2003	2008	1998	2003	2008	1998	2003	2008
EPSCoR states	3,441,370	5,430,010	6,948,937	1,231,448	1,540,024	2,068,625	2.79	3.53	3.36
Non-EPSCoR states	22,097,707	34,288,279	44,466,163	7,396,530	9,274,429	11,999,705	2.99	3.70	3.71
Average EPSCoR state value	na	na	na	na	na	na	2.84	3.69	3.51
Average non-EPSCoR state value	na	na	na	na	na	na	3.18	3.90	3.90
United States	25,771,999	39,999,163	51,784,120	8,679,657	10,886,172	14,165,565	2.97	3.67	3.66
Alabama	442,088	550,756	707,801	106,656	130,210	170,014	4.14	4.23	4.16
Alaska	76,358	142,413	111,418	23,165	31,219	47,912	3.30	4.56	2.33
Arizona	405,999	617,978	831,192	137,581	182,011	248,888	2.95	3.40	3.34
Arkansas	117,108	183,908	246,786	61,861	75,685	98,331	1.89	2.43	2.51
California	3,392,094	5,357,900	7,026,354	1,085,884	1,406,511	1,846,757	3.12	3.81	3.80
Colorado	489,419	694,862	924,073	143,160	187,397	248,603	3.42	3.71	3.72
Connecticut	406,618	594,507	731,711	145,373	169,885	216,174	2.80	3.50	3.38
Delaware	72,779	104,650	133,231	36,831	48,587	61,828	1.98	2.15	2.15
District of Columbia	232,922	280,874	369,020	51,682	71,719	97,235	4.51	3.92	3.80
Florida	712,704	1,204,592	1,591,774	417,169	559,021	744,120	1.71	2.15	2.14
Georgia	804,151	1,176,523	1,521,486	255,612	317,922	397,756	3.15	3.70	3.83
Hawaii	148,007	184,602	278,751	37,549	46,441	63,847	3.94	3.97	4.37
Idaho	72,395	105,039	113,482	29,800	38,148	52,747	2.43	2.75	2.15
Illinois	1,030,955	1,614,270	1,972,752	423,855	510,296	633,697	2.43	3.16	3.11
Indiana	426,328	725,752	954,188	178,909	215,434	254,861	2.38	3.37	3.74
Iowa	358,613	498,669	527,769	83,665	102,210	135,702	4.29	4.88	3.89
Kansas	213,250	310,111	403,512	76,005	93,560	122,731	2.81	3.31	3.29
Kentucky	241,520	377,635	506,057	108,813	124,892	156,436	2.22	3.02	3.23
Louisiana	354,011	514,403	660,139	118,085	146,726	222,218	3.00	3.51	2.97
Maine	35,265	83,935	128,090	31,731	40,152	49,709	1.11	2.09	2.58
Maryland	1,330,288	2,040,747	2,747,001	161,954	213,306	273,333	8.21	9.57	10.05
Massachusetts	1,348,220	1,821,924	2,271,757	236,079	293,840	364,988	5.71	6.20	6.22
Michigan	882,700	1,390,083	1,593,654	309,431	359,030	382,544	2.85	3.87	4.17
Minnesota	367,779	517,912	698,920	164,897	208,179	262,847	2.23	2.49	2.66
Mississippi	152,683	324,236	406,459	60,513	72,259	91,782	2.52	4.49	4.43
Missouri	484,502	807,075	960,171	164,267	195,547	237,797	2.95	4.13	4.04
Montana	76,655	141,220	185,791	19,884	25,526	35,891	3.86	5.53	5.18
Nebraska	186,320	300,540	376,092	52,076	64,628	83,273	3.58	4.65	4.52
Nevada	83,888	154,515	190,893	63,635	87,828	131,233	1.32	1.76	1.45
New Hampshire	117,323	252,210	302,008	39,102	48,198	60,005	3.00	5.23	5.03
New Jersey	484,942	754,426	876,698	314,117	389,077	474,936	1.54	1.94	1.85
New Mexico	228,740	306,636	416,991	45,918	57,469	79,901	4.98	5.34	5.22
New York	1,929,694	3,078,092	4,044,815	686,906	850,243	1,144,481	2.81	3.62	3.53
North Carolina	899,507	1,397,859	1,980,833	242,904	306,018	400,192	3.70	4.57	4.95
North Dakota	56,945	133,615	180,764	16,936	21,672	31,208	3.36	6.17	5.79
Ohio	810,225	1,268,397	1,827,042	348,723	402,399	471,508	2.32	3.15	3.87
Oklahoma	208,873	295,098	333,230	79,341	103,452	146,448	2.63	2.85	2.28
Oregon	314,355	436,958	594,945	100,951	121,638	161,573	3.11	3.59	3.68
Pennsylvania	1,348,936	2,014,842	2,604,118	361,800	440,704	553,301	3.73	4.57	4.71
Rhode Island	111,979	187,131	236,627	29,537	39,357	47,364	3.79	4.75	5.00
South Carolina	248,474	435,328	576,219	102,945	127,885	156,384	2.41	3.40	3.68
South Dakota	25,474	49,977	91,797	20,771	27,418	36,959	1.23	1.82	2.48
Tennessee	346,742	600,004	787,122	160,872	200,279	252,127	2.16	3.00	3.12
Texas	1,697,344	2,764,769	3,744,182	629,209	828,797	1,223,511	2.70	3.34	3.06
Utah	249,147	385,158	425,683	60,168	75,428	109,777	4.14	5.11	3.88
Vermont	58,585	106,581	117,210	15,935	20,575	25,442	3.68	5.18	4.61
Virginia	497,209	776,067	1,052,601	226,569	302,540	397,025	2.19	2.57	2.65
Washington	543,239	871,113	1,058,170	195,794	240,813	322,778	2.77	3.62	3.28
West Virginia	64,150	125,417	170,869	39,500	46,452	61,652	1.62	2.70	2.77
Wisconsin	535,997	877,800	1,117,152	160,681	195,904	240,429	3.34	4.48	4.65
Wyoming	48,500	60,054	74,720	14,859	21,685	35,310	3.26	2.77	2.12
Puerto Rico	87,592	78,410	100,401	54,086	74,827	NA	1.62	1.05	NA

na = not applicable; NA = not available

EPSCoR = Experimental Program to Stimulate Competitive Research; GDP = gross domestic product

NOTES: Academic R&D reported for institutions with R&D over $150,000. For Maryland, academic R&D excludes R&D performed by Applied Physics Laboratory at Johns Hopkins University. For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

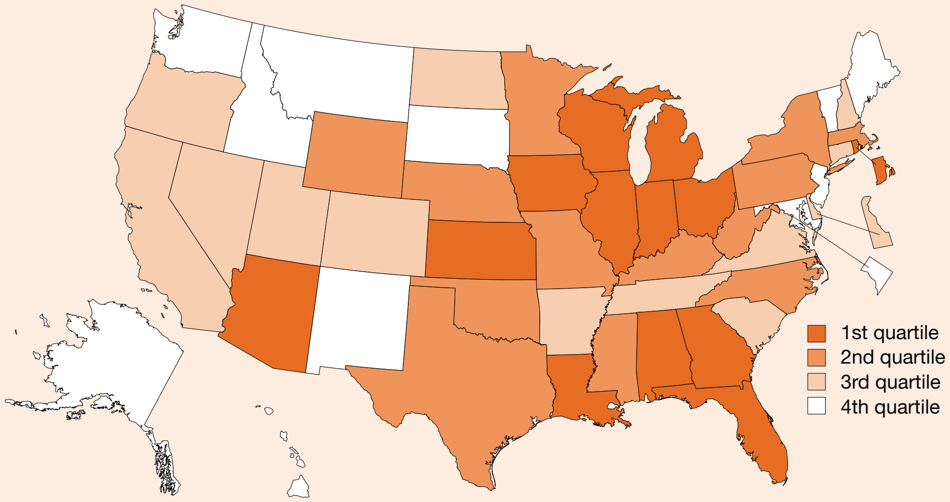
SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures (various years); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2010

S&E Doctorates Conferred per 1,000 Employed S&E Doctorate Holders

Figure 8-41

S&E doctorates conferred per 1,000 employed S&E doctorate holders: 2006



1st quartile (85.5–56.9)	2nd quartile (56.5–46.9)	3rd quartile (43.4–35.6)	4th quartile (34.3–11.5)
Alabama ‡	Kentucky ‡	Arkansas ‡	Alaska ‡
Arizona	Massachusetts	California	District of Columbia
Florida	Minnesota	Colorado	Hawaii ‡
Georgia	Mississippi ‡	Connecticut	Idaho ‡
Illinois	Missouri	Delaware ‡	Maine ‡
Indiana	Nebraska ‡	Nevada ‡	Maryland
Iowa	New York	New Hampshire ‡	Montana ‡
Kansas ‡	North Carolina	North Dakota ‡	New Jersey
Louisiana ‡	Oklahoma ‡	Oregon	New Mexico ‡
Michigan	Pennsylvania	South Carolina ‡	South Dakota ‡
Ohio	Texas	Tennessee	Vermont ‡
Rhode Island ‡	West Virginia ‡	Utah	Washington
Wisconsin	Wyoming ‡	Virginia	

‡ EPSCoR state

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates and Survey of Doctorate Recipients. See table 8-41.

Findings

- In 2006, about 29,000 S&E doctorates were awarded by U.S. academic institutions, approximately 19% more than in 2001 and 12% more than in 1997.
- Nationwide, the value of this indicator declined between 1997 and 2006, reflecting an increase in the stock of employed S&E doctorate holders in the United States.
- Low state values on this indicator may indicate either a small S&E graduate-level educational program or a concentration of S&E doctorate-level employment opportunities that attract significant numbers of S&E doctorate holders who were educated elsewhere. Low-ranking EPSCoR states tend to fall into the former category.

This indicator provides a measure of the rate at which the states are training new S&E doctorate recipients for entry into the workforce. High values indicate relatively large production of new doctorate holders compared with the existing stock of employed doctorate holders. States with relatively low values may need to attract S&E doctorate holders from elsewhere to meet the needs of local employers.

Data on doctorates conferred and on employed doctorate holders include those in computer sciences; mathematics; the biological, agricultural, or environmental life sciences; physical sciences; social sciences; psychology; engineering; and health fields. S&E doctorate data derive from the National Science Foundation's Survey of Doctorate Recipients, which excludes individuals with doctorates from foreign institutions and those above the age of 75. The Survey of Doctorate Recipients is a sample survey. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations. Data for doctorates conferred are presented by the location where the doctorate was earned; data for S&E doctorate holders are presented by employment location regardless of residence.

The indicator does not take into account the postgraduation mobility of recent S&E doctorate recipients to their place of employment. Graduate students with temporary visas may decide to return home after graduation to begin their careers. The indicator also does not take into account individuals with non-U.S. S&E doctorates who are working in the United States.

Table 8-41

S&E doctorates conferred per 1,000 employed S&E doctorate holders, by state: 1997, 2001, and 2006

	S&E doctorates conferred			Employed S&E doctorate holders[a]			S&E doctorates conferred/1,000 employed S&E doctorate holders		
State	1997	2001	2006	1997	2001	2006	1997	2001	2006
United States	25,948	24,466	29,015	516,560	572,800	618,370	50.2	42.7	46.9
Alabama	339	311	359	6,610	5,330	5,900	51.3	58.3	60.8
Alaska	18	25	18	1,110	1,200	1,110	16.2	20.8	16.2
Arizona	444	382	498	6,280	7,070	8,410	70.7	54.0	59.2
Arkansas	70	68	111	2,320	2,560	2,840	30.2	26.6	39.1
California	3,289	3,095	3,748	70,490	80,870	87,370	46.7	38.3	42.9
Colorado	546	479	473	10,740	11,780	13,150	50.8	40.7	36.0
Connecticut	362	339	438	8,770	9,490	10,330	41.3	35.7	42.4
Delaware	118	106	121	3,710	3,540	3,110	31.8	29.9	38.9
District of Columbia	255	238	272	11,800	14,200	13,330	21.6	16.8	20.4
Florida	815	773	1,033	13,330	15,740	17,630	61.1	49.1	58.6
Georgia	555	604	771	9,880	11,990	12,940	56.2	50.4	59.6
Hawaii	108	91	86	2,550	2,580	2,850	42.4	35.3	30.2
Idaho	58	53	64	2,030	2,230	2,840	28.6	23.8	22.5
Illinois	1,276	1,238	1,372	21,260	22,110	24,110	60.0	56.0	56.9
Indiana	669	636	745	7,570	9,580	9,870	88.4	66.4	75.5
Iowa	409	366	418	4,120	4,390	4,890	99.3	83.4	85.5
Kansas	279	264	270	3,770	3,970	4,250	74.0	66.5	63.5
Kentucky	211	177	268	4,110	4,590	4,990	51.3	38.6	53.7
Louisiana	328	338	324	5,360	5,290	5,470	61.2	63.9	59.2
Maine	38	27	27	2,150	1,990	2,350	17.7	13.6	11.5
Maryland	714	707	876	21,020	22,730	26,220	34.0	31.1	33.4
Massachusetts	1,355	1,370	1,607	23,330	29,100	32,360	58.1	47.1	49.7
Michigan	943	881	1,040	15,050	17,380	17,900	62.7	50.7	58.1
Minnesota	485	466	557	9,810	11,410	11,850	49.4	40.8	47.0
Mississippi	145	133	187	3,000	3,170	3,310	48.3	42.0	56.5
Missouri	444	430	512	9,490	9,280	9,230	46.8	46.3	55.5
Montana	57	39	64	1,690	1,440	1,990	33.7	27.1	32.2
Nebraska	176	153	155	3,010	2,890	2,970	58.5	52.9	52.2
Nevada	44	49	95	1,620	2,030	2,620	27.2	24.1	36.3
New Hampshire	88	73	93	2,230	2,470	2,440	39.5	29.6	38.1
New Jersey	560	557	611	20,440	22,740	20,840	27.4	24.5	29.3
New Mexico	148	135	178	7,480	7,750	8,330	19.8	17.4	21.4
New York	2,160	1,985	2,350	40,080	43,980	45,840	53.9	45.1	51.3
North Carolina	719	722	886	13,730	16,760	18,880	52.4	43.1	46.9
North Dakota	51	41	50	1,350	1,080	1,380	37.8	38.0	36.2
Ohio	1,220	1,057	1,213	18,700	20,070	20,540	65.2	52.7	59.1
Oklahoma	221	224	220	4,580	4,360	4,420	48.3	51.4	49.8
Oregon	287	246	311	6,210	7,040	8,280	46.2	34.9	37.6
Pennsylvania	1,273	1,210	1,415	23,940	26,140	29,090	53.2	46.3	48.6
Rhode Island	148	139	205	2,450	2,640	3,020	60.4	52.7	67.9
South Carolina	231	238	257	4,780	5,130	5,920	48.3	46.4	43.4
South Dakota	37	33	36	1,060	1,000	1,050	34.9	33.0	34.3
Tennessee	395	374	428	8,520	8,980	9,980	46.4	41.6	42.9
Texas	1,620	1,575	1,924	28,570	32,490	35,970	56.7	48.5	53.5
Utah	275	243	240	4,800	4,820	5,540	57.3	50.4	43.3
Vermont	35	52	47	1,750	1,750	1,700	20.0	29.7	27.6
Virginia	615	571	705	15,250	17,460	19,790	40.3	32.7	35.6
Washington	474	454	545	13,360	14,760	16,920	35.5	30.8	32.2
West Virginia	79	66	112	1,980	1,890	2,020	39.9	34.9	55.4
Wisconsin	648	508	569	8,460	8,720	9,500	76.6	58.3	59.9
Wyoming	59	33	38	860	840	730	68.6	39.3	52.1
Puerto Rico	55	92	73	660	1,410	1,690	83.3	65.2	43.2

[a] Coefficients of variation for estimates of employed S&E doctorate holders provided in appendix table 8-13.

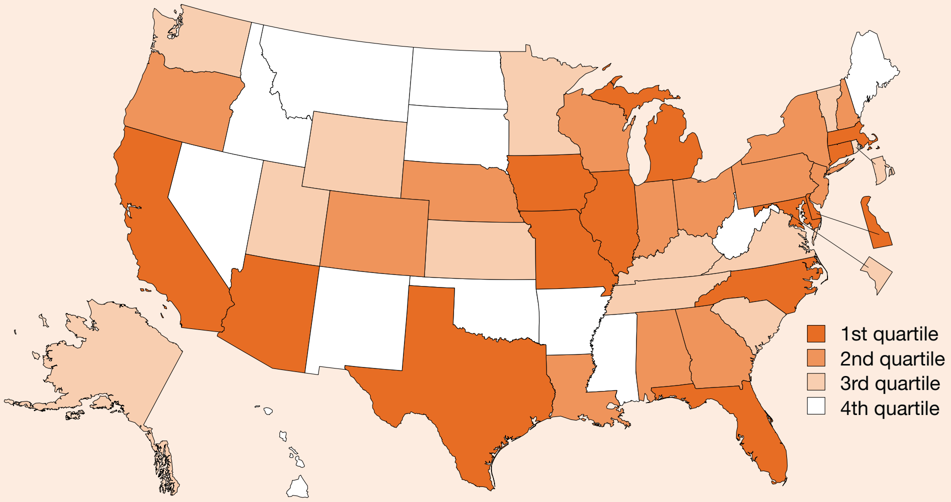
NOTE: Data on U.S. S&E doctorate holders classified by employment location.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates and Survey of Doctorate Recipients.

Science and Engineering Indicators 2010

Academic S&E Article Output per 1,000 S&E Doctorate Holders in Academia

Figure 8-42
Academic S&E article output per 1,000 S&E doctorate holders in academia: 2008/06



1st quartile (723–592)	2nd quartile (589–505)	3rd quartile (501–427)	4th quartile (424–236)
Arizona	Alabama ‡	Alaska ‡	Arkansas ‡
California	Colorado	District of Columbia	Hawaii ‡
Connecticut	Georgia	Kansas ‡	Idaho ‡
Delaware ‡	Indiana	Kentucky ‡	Maine ‡
Florida	Louisiana ‡	Minnesota	Mississippi ‡
Illinois	Nebraska ‡	Rhode Island ‡	Montana ‡
Iowa	New Hampshire ‡	South Carolina ‡	Nevada ‡
Maryland	New Jersey	Tennessee	New Mexico ‡
Massachusetts	New York	Utah	North Dakota ‡
Michigan	Ohio	Vermont ‡	Oklahoma ‡
Missouri	Oregon	Virginia	South Dakota ‡
North Carolina	Pennsylvania	Washington	West Virginia ‡
Texas	Wisconsin	Wyoming ‡	

‡ EPSCoR state

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See table 8-42.

Findings

- During the decade beginning in 1997, the number of scientific and technical articles published and number of S&E doctorate holders increased proportionally, resulting in no significant change in the nationwide value of this indicator.
- The publication rate for academic S&E doctorate holders in states in the top quartile of this indicator was nearly twice as high as for states in the bottom quartile.
- In the most recent data, the states with the highest values for this indicator were distributed across the nation.
- The average indicator value for EPSCoR states was considerably lower than the average indicator value for non-EPSCoR states.

The volume of peer-reviewed articles per 1,000 academic S&E doctorate holders is an approximate measure of their contribution to scientific knowledge. Publications are only one measure of academic productivity, which includes trained personnel, patents, and other outputs. A high value on this indicator shows that the S&E faculty in a state's academic institutions are generating a high volume of publications relative to other states. Academic institutions include 2-year colleges, 4-year colleges and universities, medical schools, and university-affiliated research centers. Research is more central to the mission of some of these institutions than others.

Publication counts are based on the number of articles that appear in a set of journals tracked by Thomson Scientific in the Science Citation Index and Social Sciences Citation Index. Academic article output is based on the most recent journal set; data for earlier years may differ slightly from previous publications due to changes in the journal set. Articles with authors from different institutions were counted fractionally. For instance, for a publication with authors at *N* institutions, each institution would be credited with 1/*N* of the article.

S&E doctorates include those in computer sciences; mathematics; the biological, agricultural, or environmental life sciences; physical sciences; social sciences; psychology; engineering; and health fields. S&E doctorate data derive from the National Science Foundation's Survey of Doctorate Recipients, which excludes those with doctorates from foreign institutions and those above the age of 75. The Survey of Doctorate Recipients is a sample survey. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations. Data for S&E doctorate holders in academia are presented by employment location regardless of residence.

Table 8-42

Academic S&E article output per 1,000 S&E doctorate holders in academia, by state: 1997, 2003, and 2008/06

	Academic S&E article output			S&E doctorate holders in academia[a]			Academic articles/ 1,000 academic doctorate holders		
State	1997	2003	2008	1997	2003	2006	1997	2003	2008/06
EPSCoR states	16,096	17,479	19,506	41,750	42,890	44,410	386	408	439
Non-EPSCoR states	120,252	129,972	146,975	201,710	232,390	243,740	596	559	603
Average EPSCoR state value	na	na	na	na	na	na	372	394	430
Average non-EPSCoR state value	na	na	na	na	na	na	585	546	582
United States	137,598	148,722	167,852	245,670	277,970	290,730	560	535	577
Alabama	1,838	1,851	1,974	4,640	3,240	3,430	396	571	576
Alaska	160	195	285	450	600	580	356	325	492
Arizona	2,133	2,152	2,455	3,050	3,660	4,010	699	588	612
Arkansas	575	664	716	1,520	1,850	1,940	379	359	369
California	16,862	18,744	21,001	26,050	29,830	29,070	647	628	722
Colorado	2,408	2,615	2,855	4,550	5,320	5,540	529	492	515
Connecticut	2,692	2,748	3,070	4,000	4,490	4,770	673	612	644
Delaware	476	580	650	750	800	950	635	725	684
District of Columbia	1,083	1,061	1,106	2,210	2,690	2,580	490	394	429
Florida	3,976	4,551	5,678	6,850	8,710	9,590	580	523	592
Georgia	3,076	3,640	4,299	5,780	7,240	7,750	532	503	555
Hawaii	531	572	697	1,380	1,910	1,670	385	299	417
Idaho	287	305	360	780	1,190	1,490	368	257	242
Illinois	6,469	6,959	7,662	10,620	10,930	11,860	609	637	646
Indiana	2,862	3,022	3,645	4,680	5,810	6,190	612	520	589
Iowa	2,130	2,220	2,232	3,100	3,390	3,530	687	655	632
Kansas	1,134	1,235	1,292	2,260	2,380	2,600	502	519	497
Kentucky	1,320	1,434	1,604	3,040	3,320	3,610	434	432	444
Louisiana	1,810	1,759	1,753	3,580	3,570	3,470	506	493	505
Maine	238	267	285	1,340	1,150	1,210	178	233	236
Maryland	4,259	4,946	5,453	6,400	7,060	7,590	666	700	718
Massachusetts	8,762	9,445	10,834	11,810	14,630	14,980	742	646	723
Michigan	4,620	5,071	5,804	7,850	9,050	9,410	589	560	617
Minnesota	2,300	2,287	2,634	4,490	5,600	5,730	512	408	460
Mississippi	583	710	840	1,940	2,060	2,020	301	345	416
Missouri	3,032	3,122	3,443	5,770	5,770	5,750	526	541	599
Montana	256	363	396	1,020	1,090	1,230	251	333	322
Nebraska	983	991	1,115	2,360	1,880	1,900	417	527	587
Nevada	352	458	571	980	1,260	1,620	359	364	352
New Hampshire	579	627	683	1,130	1,360	1,270	512	461	538
New Jersey	2,952	3,150	3,326	5,290	6,160	6,500	558	511	512
New Mexico	782	792	835	2,450	2,960	2,220	319	268	376
New York	11,781	12,179	13,378	20,900	22,360	23,110	564	545	579
North Carolina	4,762	5,321	6,170	7,740	9,650	10,310	615	551	598
North Dakota	262	315	411	900	740	970	292	426	424
Ohio	4,900	5,088	5,635	9,750	10,620	10,620	503	479	531
Oklahoma	853	933	1,081	2,680	2,900	2,890	318	322	374
Oregon	1,550	1,648	1,972	2,690	3,690	3,620	576	447	545
Pennsylvania	7,756	8,260	9,419	12,150	15,650	16,210	638	528	581
Rhode Island	828	871	1,020	1,730	2,180	2,040	479	399	500
South Carolina	1,155	1,428	1,587	3,230	3,000	3,720	358	476	427
South Dakota	136	165	202	700	670	690	194	246	293
Tennessee	2,123	2,310	2,826	4,720	5,210	5,640	450	443	501
Texas	8,415	9,423	10,755	13,760	15,240	17,170	612	618	626
Utah	1,492	1,538	1,786	3,080	2,770	3,580	485	555	499
Vermont	369	383	475	1,140	1,100	1,050	324	349	453
Virginia	2,822	2,991	3,593	5,830	7,630	8,050	484	392	446
Washington	3,091	3,412	3,605	5,410	6,740	7,190	571	506	501
West Virginia	400	375	417	1,190	1,190	1,320	336	315	316
Wisconsin	3,025	3,129	3,445	5,390	5,180	5,970	561	604	577
Wyoming	189	204	255	560	490	520	337	417	490
Puerto Rico	167	212	265	640	1,360	1,270	261	156	209

na = not applicable

EPSCoR = Experimental Program to Stimulate Competitive Research

[a] Coefficients of variation for estimates of S&E doctorate holders in academia presented in appendix table 8-14.

NOTES: For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction. Workforce represents employed component of civilian labor force and reported as annual data not seasonally adjusted. Most recent indicator values calculated using doctorate holder data for 2006 and publication data for 2008.

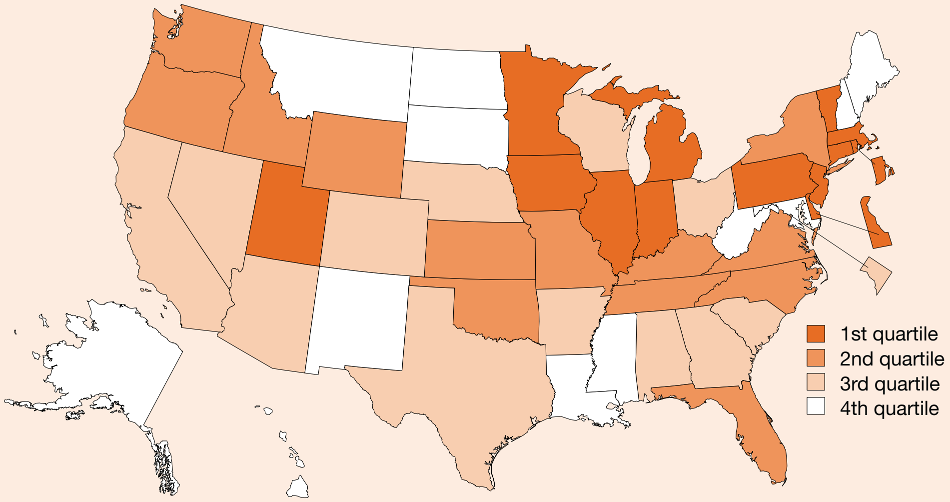
SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science and Engineering Indicators 2010

Academic S&E Article Output per $1 Million of Academic R&D

Figure 8-43

Academic S&E article output per $1 million of academic R&D: 2008



1st quartile (4.88–3.62)	2nd quartile (3.59–3.11)	3rd quartile (3.09–2.75)	4th quartile (2.66–1.98)
Connecticut	Florida	Alabama ‡	Alaska ‡
Delaware ‡	Idaho ‡	Arizona	Hawaii ‡
Illinois	Kansas ‡	Arkansas ‡	Louisiana ‡
Indiana	Kentucky ‡	California	Maine ‡
Iowa	Missouri	Colorado	Maryland
Massachusetts	New York	District of Columbia	Mississippi ‡
Michigan	North Carolina	Georgia	Montana ‡
Minnesota	Oklahoma ‡	Nebraska ‡	New Hampshire ‡
New Jersey	Oregon	Nevada ‡	New Mexico ‡
Pennsylvania	Tennessee	Ohio	North Dakota ‡
Rhode Island ‡	Virginia	South Carolina ‡	South Dakota ‡
Utah	Washington	Texas	West Virginia ‡
Vermont ‡	Wyoming ‡	Wisconsin	

‡ EPSCoR state

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures. See table 8-43.

Findings

- From 1998 to 2008, the number of academic S&E publications rose from about 138,000 to about 168,000—an increase of 22% that may reflect both an increase in publications and an increase in the size of the journal set.
- In 2008, academic researchers produced an average of 3.2 publications per $1 million of academic R&D, compared with 5.4 in 1998. This partly reflects the effect of general price inflation but may also indicate rising academic research costs.
- Between 1998 and 2008, the value for this indicator decreased in all states but one and by 40% nationwide.
- EPSCoR states tended to cluster in the lower quartiles for this indicator.

This indicator shows the relationship between the number of academic S&E publications and expenditures for academic R&D. A high value for this indicator means that the S&E publications output of a state's academic institutions is high relative to their R&D spending. Academic institutions include 2-year colleges, 4-year colleges and universities, medical schools, and university-affiliated research centers. This indicator is not an efficiency measure; it is affected by the highly variable costs of R&D and by publishing conventions in different fields and institutions. It may also reflect variations in field emphasis among states and institutions.

Publication counts are based on the number of articles that appear in a set of journals tracked by Thomson Scientific in the Science Citation Index and Social Sciences Citation Index. Academic article output is based on the most recent journal set; data for earlier years may differ slightly from previous publications due to changes in the journal set. Articles with authors from different institutions were counted fractionally. For instance, for a publication with authors at *N* institutions, each institution would be credited with $1/N$ of the article.

In this indicator, Maryland data exclude expenditures by the Applied Physics Laboratory (APL) at the Johns Hopkins University. APL employs more than 3,000 workers and supports the Department of Defense, the National Aeronautics and Space Administration, and other government agencies. It does not focus on academic research.

Table 8-43

Academic S&E article output per $1 million of academic R&D, by state: 1998, 2003, and 2008

	Academic S&E article output			Academic R&D (current $millions)			Academic articles/ $1 million academic R&D		
State	1998	2003	2008	1998	2003	2008	1998	2003	2008
United States	138,147	148,722	167,852	25,772	39,999	51,784	5.36	3.72	3.24
Alabama	1,829	1,851	1,974	442	551	708	4.14	3.36	2.79
Alaska	157	195	285	76	142	111	2.05	1.37	2.56
Arizona	1,960	2,152	2,455	406	618	831	4.83	3.48	2.95
Arkansas	568	664	716	117	184	247	4.85	3.61	2.90
California	17,056	18,744	21,001	3,392	5,358	7,026	5.03	3.50	2.99
Colorado	2,467	2,615	2,855	489	695	924	5.04	3.76	3.09
Connecticut	2,793	2,748	3,070	407	595	732	6.87	4.62	4.20
Delaware	499	580	650	73	105	133	6.86	5.54	4.88
District of Columbia	1,089	1,061	1,106	233	281	369	4.68	3.78	3.00
Florida	4,085	4,551	5,678	713	1,205	1,592	5.73	3.78	3.57
Georgia	3,061	3,640	4,299	804	1,177	1,521	3.81	3.09	2.83
Hawaii	511	572	697	148	185	279	3.45	3.10	2.50
Idaho	273	305	360	72	105	113	3.77	2.91	3.17
Illinois	6,399	6,959	7,662	1,031	1,614	1,973	6.21	4.31	3.88
Indiana	2,884	3,022	3,645	426	726	954	6.77	4.16	3.82
Iowa	2,147	2,220	2,232	359	499	528	5.99	4.45	4.23
Kansas	1,117	1,235	1,292	213	310	404	5.24	3.98	3.20
Kentucky	1,245	1,434	1,604	242	378	506	5.16	3.80	3.17
Louisiana	1,794	1,759	1,753	354	514	660	5.07	3.42	2.66
Maine	242	267	285	35	84	128	6.87	3.19	2.23
Maryland	4,412	4,946	5,453	1,330	2,041	2,747	3.32	2.42	1.98
Massachusetts	8,722	9,445	10,834	1,348	1,822	2,272	6.47	5.18	4.77
Michigan	4,610	5,071	5,804	883	1,390	1,594	5.22	3.65	3.64
Minnesota	2,279	2,287	2,634	368	518	699	6.20	4.42	3.77
Mississippi	613	710	840	153	324	406	4.01	2.19	2.07
Missouri	3,037	3,122	3,443	485	807	960	6.27	3.87	3.59
Montana	299	363	396	77	141	186	3.91	2.57	2.13
Nebraska	1,002	991	1,115	186	301	376	5.38	3.30	2.96
Nevada	358	458	571	84	155	191	4.27	2.97	2.99
New Hampshire	594	627	683	117	252	302	5.07	2.49	2.26
New Jersey	2,813	3,150	3,326	485	754	877	5.80	4.17	3.79
New Mexico	724	792	835	229	307	417	3.17	2.58	2.00
New York	11,977	12,179	13,378	1,930	3,078	4,045	6.21	3.96	3.31
North Carolina	4,803	5,321	6,170	900	1,398	1,981	5.34	3.81	3.11
North Dakota	263	315	411	57	134	181	4.62	2.36	2.28
Ohio	4,902	5,088	5,635	810	1,268	1,827	6.05	4.01	3.08
Oklahoma	871	933	1,081	209	295	333	4.17	3.16	3.24
Oregon	1,531	1,648	1,972	314	437	595	4.87	3.77	3.31
Pennsylvania	7,839	8,260	9,419	1,349	2,015	2,604	5.81	4.10	3.62
Rhode Island	814	871	1,020	112	187	237	7.27	4.65	4.31
South Carolina	1,170	1,428	1,587	248	435	576	4.71	3.28	2.75
South Dakota	127	165	202	25	50	92	5.00	3.30	2.20
Tennessee	2,176	2,310	2,826	347	600	787	6.28	3.85	3.59
Texas	8,388	9,423	10,755	1,697	2,765	3,744	4.94	3.41	2.87
Utah	1,511	1,538	1,786	249	385	426	6.07	3.99	4.20
Vermont	359	383	475	59	107	117	6.13	3.60	4.06
Virginia	2,891	2,991	3,593	497	776	1,053	5.81	3.85	3.41
Washington	3,049	3,412	3,605	543	871	1,058	5.61	3.92	3.41
West Virginia	396	375	417	64	125	171	6.17	2.99	2.44
Wisconsin	3,059	3,129	3,445	536	878	1,117	5.71	3.56	3.08
Wyoming	192	204	255	49	60	75	3.95	3.40	3.41
Puerto Rico	189	212	265	88	78	100	2.16	2.70	2.64

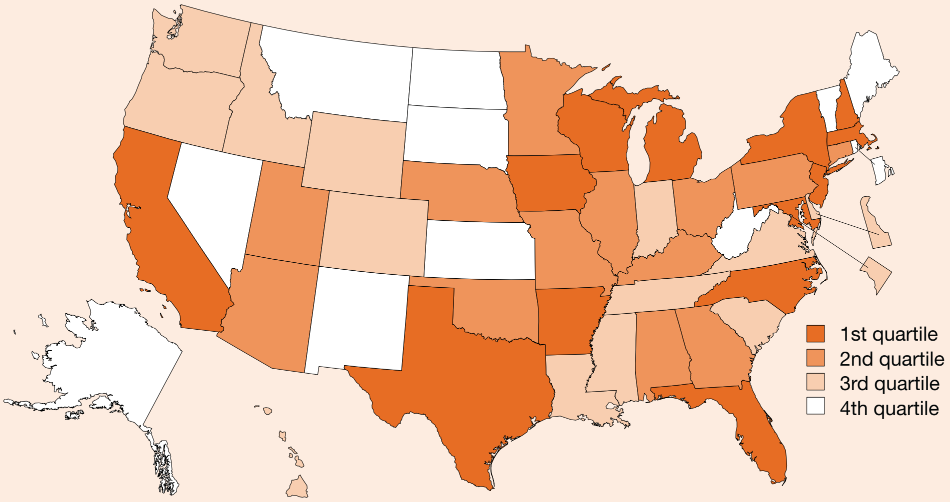
NA = not available

SOURCES: Thomson Reuters, Science Citation Index and Social Sciences Citation Index, http://thomsonreuters.com/products_services/science/; The Patent Board™; and National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures (various years).

Science and Engineering Indicators 2010

Academic Patents Awarded per 1,000 S&E Doctorate Holders in Academia

Figure 8-44
Academic patents awarded per 1,000 S&E doctorate holders in academia: 2006



1st quartile (24.7–11.1)	2nd quartile (10.8–7.3)	3rd quartile (6.9–5.2)	4th quartile (4.9–0.0)
Arkansas ‡	Alabama ‡	Colorado	Alaska ‡
California	Arizona	Delaware ‡	Kansas ‡
Florida	Connecticut	District of Columbia	Maine ‡
Iowa	Georgia	Hawaii ‡	Montana ‡
Maryland	Illinois	Idaho ‡	Nevada ‡
Massachusetts	Kentucky ‡	Indiana	New Mexico ‡
Michigan	Minnesota	Louisiana ‡	North Dakota ‡
New Hampshire ‡	Missouri	Mississippi ‡	Rhode Island ‡
New Jersey	Nebraska ‡	Oregon	South Dakota ‡
New York	Ohio	South Carolina ‡	Vermont ‡
North Carolina	Oklahoma ‡	Tennessee	West Virginia ‡
Texas	Pennsylvania	Virginia	
Wisconsin	Utah	Washington	
		Wyoming ‡	

‡ EPSCoR state

SOURCES: Patent and Trademark Office, Technology Assessment and Forecast Branch, U.S. Colleges and Universities-Utility Patent Grants; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients. See table 8-44.

Findings

- Throughout the United States, the number of patents awarded to academic institutions increased from about 2,500 in 1997 to about 3,400 in 2006, an increase of 36%; the number of academic S&E doctorate holders rose by 18% during the same period.
- In 2006, 11.6 academic patents were produced nationally for each 1,000 S&E doctorate holders employed in academia, slightly higher than the 10.1 patents produced in 1997.
- In 2006, states varied widely on this indicator, with values ranging from 0 to 24.7 patents per 1,000 S&E doctorate holders employed in academia, indicating a difference in patenting philosophy or mix of industries with which these academic institutions deal.
- California showed the highest level of both academic patenting and venture capital investment.

Since the early 1980s, academic institutions have increasingly been viewed as engines of economic growth. Growing attention has been paid to the role of academic R&D in creating new products, processes, and services. One indicator of such R&D results is the volume of academic patents awarded. Academic patenting is highly concentrated and partly reflects the resources devoted to institutional patenting offices.

This indicator is an approximate measure of the degree to which results with perceived economic value are generated by the doctoral academic workforce. Academia includes 2-year colleges, 4-year colleges and universities, medical schools, and university-affiliated research centers. Utility patents—commonly known as patents for inventions—include any new, useful, or improved method, process, machine, device, manufactured item, or chemical compound, and represent a key measure of intellectual property.

S&E doctorates include those in computer sciences; mathematics; biological, agricultural, or environmental life sciences; physical sciences; social sciences; psychology; engineering; and health fields. S&E doctorate data derive from the National Science Foundation's Survey of Doctorate Recipients, which excludes those with doctorates from foreign institutions and those above the age of 75. The Survey of Doctorate Recipients is a sample survey. Estimates for states with smaller populations are generally less precise than estimates for states with larger populations. Data for S&E doctorate holders are presented by employment location regardless of residence.

Table 8-44

Academic patents awarded per 1,000 S&E doctorate holders in academia, by state: 1997, 2001, and 2006

	Patents awarded to academic institutions			S&E doctorate holders in academia[a]			Academic patents/1,000 academic S&E doctorate holders		
State	1997	2001	2006	1997	2001	2006	1997	2001	2006
United States	2,482	3,282	3,382	245,670	261,780	290,730	10.1	12.5	11.6
Alabama	23	40	27	4,640	3,050	3,430	5.0	13.1	7.9
Alaska	2	0	0	450	530	580	4.4	0.0	0.0
Arizona	21	17	34	3,050	3,340	4,010	6.9	5.1	8.5
Arkansas	8	28	25	1,520	1,640	1,940	5.3	17.1	12.9
California	436	693	719	26,050	26,790	29,070	16.7	25.9	24.7
Colorado	32	31	29	4,550	5,120	5,540	7.0	6.1	5.2
Connecticut	34	37	51	4,000	4,420	4,770	8.5	8.4	10.7
Delaware	4	5	5	750	840	950	5.3	6.0	5.3
District of Columbia	28	13	15	2,210	2,840	2,580	12.7	4.6	5.8
Florida	96	106	171	6,850	8,250	9,590	14.0	12.8	17.8
Georgia	45	75	80	5,780	6,450	7,750	7.8	11.6	10.3
Hawaii	6	4	10	1,380	1,570	1,670	4.3	2.5	6.0
Idaho	6	6	10	780	980	1,490	7.7	6.1	6.7
Illinois	81	109	122	10,620	11,090	11,860	7.6	9.8	10.3
Indiana	39	17	32	4,680	5,710	6,190	8.3	3.0	5.2
Iowa	51	67	52	3,100	3,220	3,530	16.5	20.8	14.7
Kansas	7	18	4	2,260	2,270	2,600	3.1	7.9	1.5
Kentucky	16	20	28	3,040	3,240	3,610	5.3	6.2	7.8
Louisiana	26	42	23	3,580	3,470	3,470	7.3	12.1	6.6
Maine	0	2	5	1,340	1,200	1,210	0.0	1.7	4.1
Maryland	66	114	136	6,400	6,100	7,590	10.3	18.7	17.9
Massachusetts	188	218	234	11,810	13,390	14,980	15.9	16.3	15.6
Michigan	104	105	120	7,850	8,820	9,410	13.2	11.9	12.8
Minnesota	50	65	62	4,490	5,540	5,730	11.1	11.7	10.8
Mississippi	6	12	14	1,940	2,000	2,020	3.1	6.0	6.9
Missouri	40	55	42	5,770	5,710	5,750	6.9	9.6	7.3
Montana	4	4	6	1,020	810	1,230	3.9	4.9	4.9
Nebraska	27	21	19	2,360	1,960	1,900	11.4	10.7	10.0
Nevada	2	4	4	980	1,260	1,620	2.0	3.2	2.5
New Hampshire	3	10	18	1,130	1,240	1,270	2.7	8.1	14.2
New Jersey	52	81	80	5,290	5,860	6,500	9.8	13.8	12.3
New Mexico	19	17	9	2,450	2,910	2,220	7.8	5.8	4.1
New York	224	282	284	20,900	21,770	23,110	10.7	13.0	12.3
North Carolina	96	148	131	7,740	9,050	10,310	12.4	16.4	12.7
North Dakota	5	4	4	900	660	970	5.6	6.1	4.1
Ohio	75	93	86	9,750	9,920	10,620	7.7	9.4	8.1
Oklahoma	17	22	27	2,680	2,800	2,890	6.3	7.9	9.3
Oregon	27	23	20	2,690	3,250	3,620	10.0	7.1	5.5
Pennsylvania	138	213	147	12,150	13,590	16,210	11.4	15.7	9.1
Rhode Island	9	19	9	1,730	1,730	2,040	5.2	11.0	4.4
South Carolina	14	14	22	3,230	3,030	3,720	4.3	4.6	5.9
South Dakota	2	2	2	700	640	690	2.9	3.1	2.9
Tennessee	25	42	37	4,720	4,800	5,640	5.3	8.8	6.6
Texas	125	155	191	13,760	14,270	17,170	9.1	10.9	11.1
Utah	38	48	35	3,080	3,100	3,580	12.3	15.5	9.8
Vermont	3	3	4	1,140	1,050	1,050	2.6	2.9	3.8
Virginia	49	41	48	5,830	7,180	8,050	8.4	5.7	6.0
Washington	42	56	42	5,410	6,390	7,190	7.8	8.8	5.8
West Virginia	2	4	2	1,190	1,150	1,320	1.7	3.5	1.5
Wisconsin	65	74	102	5,390	5,210	5,970	12.1	14.2	17.1
Wyoming	4	3	3	560	570	520	7.1	5.3	5.8
Puerto Rico	0	5	2	640	1,070	1,270	0.0	4.7	1.6

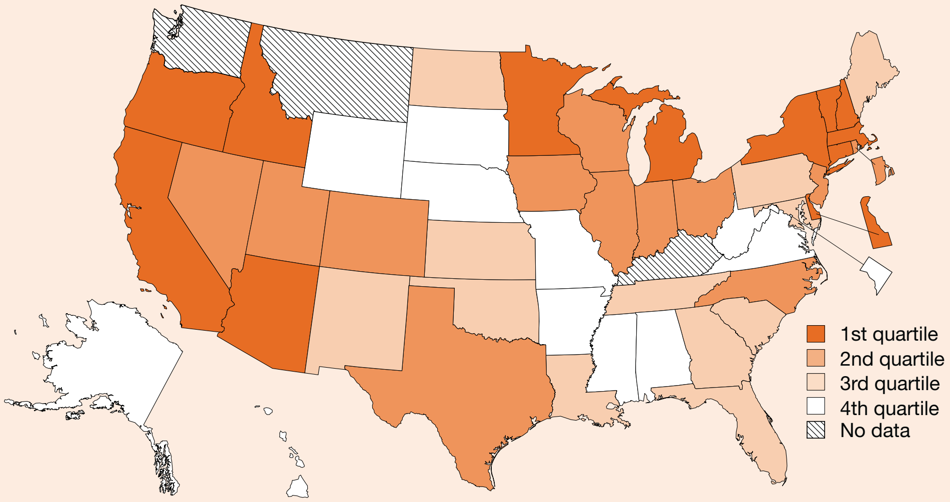
[a] Coefficients of variation for estimates of S&E doctorate holders in academia presented in appendix table 8-14.

SOURCES: Patent and Trademark Office, Technology Assessment and Forecast Branch, U.S. Colleges and Universities—Utility Patent Grants, Calendar Years 1969–2006; and National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients.

Science and Engineering Indicators 2010

Patents Awarded per 1,000 Individuals in S&E Occupations

Figure 8-45
Patents awarded per 1,000 individuals in S&E occupations, by state: 2008



1st quartile (49.8–14.6)	2nd quartile (13.7–10.8)	3rd quartile (10.6–6.2)	4th quartile (6.0–1.1)	No data
Arizona	Colorado	Florida	Alabama ‡	Kentucky ‡
California	Illinois	Georgia	Alaska ‡	Montana ‡
Connecticut	Indiana	Kansas ‡	Arkansas ‡	Washington
Delaware ‡	Iowa	Louisiana ‡	District of Columbia	
Idaho ‡	Nevada ‡	Maine ‡	Hawaii ‡	
Massachusetts	New Jersey	Maryland	Mississippi ‡	
Michigan	North Carolina	New Mexico ‡	Missouri	
Minnesota	Ohio	North Dakota ‡	Nebraska ‡	
New Hampshire ‡	Rhode Island ‡	Oklahoma ‡	South Dakota ‡	
New York	Texas	Pennsylvania	Virginia	
Oregon	Utah	South Carolina ‡	West Virginia ‡	
Vermont ‡	Wisconsin	Tennessee	Wyoming ‡	

‡ EPSCoR state

SOURCES: Patent and Trademark Office, Electronic Information Products Division/Patent Technology Monitoring Branch, Patent Counts by Country/State and Year, All Patents, All Types; and Bureau of Labor Statistics, Occupational Employment and Wage Estimates. See table 8-45.

Findings

- In 2008, about 77,000 utility patents were awarded to inventors residing in the United States, a decline from the 84,000 utility patents awarded in 2004.
- In 2008, the national average for this indicator was 13.4 patents, which was lower than the average of 16.6 in 2004. This decline may have been due to fewer patent applications being filed, a reduced capacity of USPTO to process applications and award patents, and/or an increase in the number of individuals working in S&E occupations.
- Idaho typically reports the highest values for this indicator, reflecting the presence of the Department of Energy's high-patenting Idaho National Laboratory. Values for the remaining states ranged from 35.4 to 1.5.
- Nearly 25% of all 2008 U.S. utility patents were awarded to residents of California.

This indicator shows state patent activity normalized to the number of employees in S&E occupations. People in S&E occupations include computer, mathematical, life, physical, and social scientists; engineers; and postsecondary teachers in any of these fields. Managers, elementary and secondary schoolteachers, and medical personnel are excluded.

This indicator includes only utility patents, commonly known as patents for inventions. Utility patents can be granted for any new, useful, or improved method, process, machine, device, manufactured item, or chemical compound and represent a key measure of intellectual property.

USPTO classifies patents geographically according to residence of the first-named inventor. Only U.S.-origin patents are included. State data on individuals in S&E occupations come from the Occupational Employment Statistics (OES) survey, which surveys states' workplaces and assigns workers to a state based on where they work.

Situations in which workers live in one state and work in another introduce some imprecision into the calculation of this indicator. The treatment of postsecondary teachers is another source of imprecision. Because OES data do not classify postsecondary teachers by field, faculty teaching in S&E fields are not counted as working in S&E occupations. Estimates for jurisdictions with smaller populations are generally less precise than estimates for jurisdictions with larger populations.

Table 8-45

Patents awarded per 1,000 individuals in S&E occupations, by state: 2004, 2006, and 2008

State	Patents awarded			Individuals in S&E occupations			Patents/1,000 individuals in S&E occupations		
	2004	2006	2008	2004	2006	2008	2004	2006	2008
United States	84,249	89,795	77,479	5,085,740	5,407,710	5,781,460	16.6	16.6	13.4
Alabama	375	357	279	57,560	66,100	68,580	6.5	5.4	4.1
Alaska	39	36	20	10,660	10,720	13,260	3.7	3.4	1.5
Arizona	1,621	1,705	1,584	95,380	98,110	102,100	17.0	17.4	15.5
Arkansas	132	138	108	22,150	24,860	29,310	6.0	5.6	3.7
California	19,488	22,275	19,181	693,670	730,010	791,750	28.1	30.5	24.2
Colorado	2,099	2,118	1,622	126,280	133,730	147,000	16.6	15.8	11.0
Connecticut	1,577	1,652	1,356	82,820	79,380	80,290	19.0	20.8	16.9
Delaware	342	357	325	17,980	21,550	22,330	19.0	16.6	14.6
District of Columbia	75	63	68	57,750	64,120	63,360	1.3	1.0	1.1
Florida	2,456	2,600	2,046	229,950	246,190	248,200	10.7	10.6	8.2
Georgia	1,326	1,487	1,344	141,710	136,470	147,380	9.4	10.9	9.1
Hawaii	76	84	77	16,360	18,940	18,830	4.6	4.4	4.1
Idaho	1,785	1,663	1,162	22,310	NA	23,310	80.0	NA	49.8
Illinois	3,162	3,294	2,741	219,530	222,470	224,370	14.4	14.8	12.2
Indiana	1,280	1,165	985	79,120	80,110	90,840	16.2	14.5	10.8
Iowa	658	666	561	39,280	43,670	46,180	16.8	15.3	12.1
Kansas	448	492	425	52,020	48,620	54,260	8.6	10.1	7.8
Kentucky	407	413	413	44,350	44,680	NA	9.2	9.2	NA
Louisiana	343	321	260	42,230	40,180	41,790	8.1	8.0	6.2
Maine	134	142	113	15,160	15,950	17,000	8.8	8.9	6.6
Maryland	1,313	1,410	1,232	154,310	159,470	167,070	8.5	8.8	7.4
Massachusetts	3,672	4,011	3,516	186,260	198,670	217,310	19.7	20.2	16.2
Michigan	3,756	3,758	2,996	183,140	208,520	204,290	20.5	18.0	14.7
Minnesota	2,754	2,957	2,535	119,380	125,930	134,440	23.1	23.5	18.9
Mississippi	136	119	102	23,190	24,910	27,270	5.9	4.8	3.7
Missouri	768	721	615	87,200	96,420	105,390	8.8	7.5	5.8
Montana	119	121	91	11,390	13,010	NA	10.4	9.3	NA
Nebraska	191	186	191	31,720	32,500	31,820	6.0	5.7	6.0
Nevada	410	386	375	23,980	26,930	27,300	17.1	14.3	13.7
New Hampshire	626	602	477	24,350	27,680	29,150	25.7	21.7	16.4
New Jersey	2,957	3,172	2,722	165,150	176,460	198,060	17.9	18.0	13.7
New Mexico	370	344	280	33,500	30,800	34,560	11.0	11.2	8.1
New York	5,846	5,627	4,885	272,930	306,810	326,510	21.4	18.3	15.0
North Carolina	1,794	1,974	1,841	135,380	138,790	153,680	13.3	14.2	12.0
North Dakota	53	66	63	8,420	9,360	9,450	6.3	7.1	6.7
Ohio	2,889	2,630	2,227	180,360	185,190	206,320	16.0	14.2	10.8
Oklahoma	447	544	417	NA	50,770	48,900	NA	10.7	8.5
Oregon	1,725	2,060	1,781	62,570	64,520	70,070	27.6	31.9	25.4
Pennsylvania	2,883	2,842	2,414	195,730	214,910	227,170	14.7	13.2	10.6
Rhode Island	309	269	218	19,660	18,060	18,090	15.7	14.9	12.1
South Carolina	524	577	395	51,030	53,230	57,770	10.3	10.8	6.8
South Dakota	82	74	54	9,420	10,120	11,870	8.7	7.3	4.5
Tennessee	681	669	586	65,120	67,040	72,760	10.5	10.0	8.1
Texas	5,930	6,308	5,712	383,180	408,710	463,850	15.5	15.4	12.3
Utah	683	684	642	43,030	49,690	52,570	15.9	13.8	12.2
Vermont	400	437	437	11,770	12,780	12,360	34.0	34.2	35.4
Virginia	1,077	1,094	1,030	220,180	251,720	259,280	4.9	4.3	4.0
Washington	2,221	3,286	3,517	154,610	171,780	NA	14.4	19.1	NA
West Virginia	100	103	74	16,100	17,150	17,000	6.2	6.0	4.4
Wisconsin	1,658	1,688	1,349	95,230	96,860	101,680	17.4	17.4	13.3
Wyoming	52	48	35	6,760	7,640	8,850	7.7	6.3	4.0
Puerto Rico	19	25	NA	20,410	23,850	22,970	0.9	1.0	NA

NA = not available

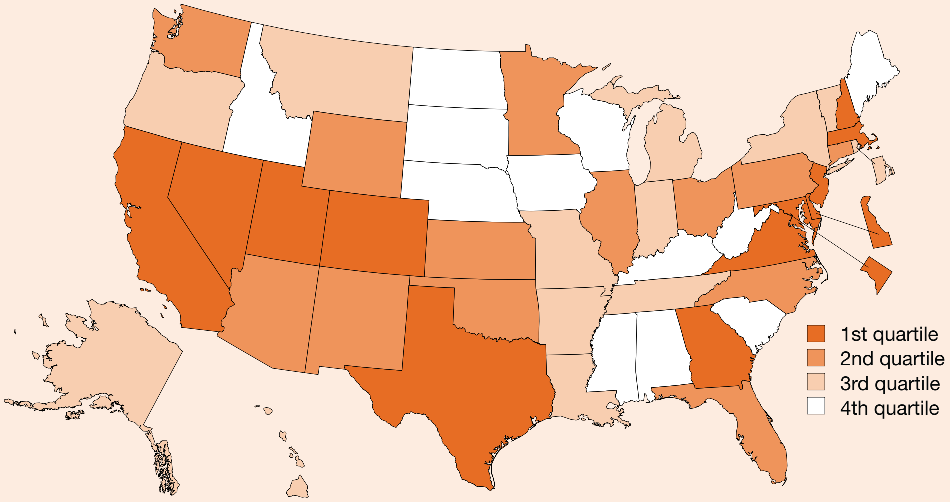
NOTES: Origin of utility patent determined by residence of first-named inventor. National total for S&E occupations in the United States provided by Occupational Employment Statistics (OES). OES estimates for 2004, 2006, and 2008 S&E occupations based on May data.

SOURCES: Patent and Trademark Office, Electronic Information Products Division/Patent Technology Monitoring Branch, Patent Counts by Country/State and Year, Utility Patents, January 1, 1963–December 31, 2008; and Bureau of Labor Statistics, Occupational Employment and Wage Estimates.

Science and Engineering Indicators 2010

High-Technology Share of All Business Establishments

Figure 8-46
High-technology share of all business establishments: 2006



1st quartile (14.60%–9.05%)	2nd quartile (8.99%–7.55%)	3rd quartile (7.53%–6.51%)	4th quartile (6.48%–4.86%)
California	Arizona	Alaska ‡	Alabama ‡
Colorado	Connecticut	Arkansas ‡	Idaho ‡
Delaware ‡	Florida	Hawaii ‡	Iowa
District of Columbia	Illinois	Indiana	Kentucky ‡
Georgia	Kansas ‡	Louisiana ‡	Maine ‡
Maryland	Minnesota	Michigan	Mississippi ‡
Massachusetts	New Mexico ‡	Missouri	Nebraska ‡
Nevada ‡	North Carolina	Montana ‡	North Dakota ‡
New Hampshire ‡	Ohio	New York	South Carolina ‡
New Jersey	Oklahoma ‡	Oregon	South Dakota ‡
Texas	Pennsylvania	Rhode Island ‡	West Virginia ‡
Utah	Washington	Tennessee	Wisconsin
Virginia	Wyoming ‡	Vermont ‡	

‡ EPSCoR state

SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations. See table 8-46.

Findings

- The number of establishments in high-technology industries rose from about 590,000 in 2003 to about 634,000 in 2006, an increase of 43,000, or 7%.
- The percentage of U.S. establishments in high-technology industries grew from 8.17% to 8.35% of the total business establishments during the 2003–06 period, and most states showed an increase in the percentage of their establishments in high-technology industries.
- Between 2003 and 2006, the largest growth in the number of establishments in high-technology industries occurred in California and Florida, which added 7,900 and 5,560 establishments, respectively.
- The state distribution of this indicator is similar to that of three other indicators: bachelor's degree holders, S&E doctoral degree holders, and S&E occupations, all expressed as a share of the workforce.
- EPSCoR states tended to cluster in the lower quartiles and exhibited a lower group average, indicating that these states had a business mix with a smaller percentage of establishments in high-technology industries.

This indicator measures the portion of a state's business establishments that are classified as being part of high-technology industries. High-technology industries are defined as those in which the proportion of employees in technology-oriented occupations is at least twice the average proportion for all industries. States often consider such industries desirable, in part because they tend to compensate workers better than other industries do. This indicator does not take into account establishment size. Each establishment with an employer identification number is counted without regard to the number of its employees.

The data pertaining to establishments for 2003, 2004, and 2006 are based on their classification according to the 2002 edition of the North American Industry Classification System (NAICS). See table 8-A in the "Introduction" for a list of the 46 industries (by 4-digit NAICS code) that are defined as high technology. Data for earlier years are not directly comparable.

Table 8-46
High-technology share of all business establishments, by state: 2003, 2004, and 2006

	High-technology establishments			All business establishments			High-technology/business establishments (%)		
State	2003	2004	2006	2003	2004	2006	2003	2004	2006
EPSCoR states	83,464	84,985	88,790	1,202,246	1,224,016	1,255,900	6.94	6.94	7.07
Non-EPSCoR states	504,364	515,962	541,875	6,001,637	6,123,459	6,308,168	8.40	8.43	8.59
Average EPSCoR state value	na	na	na	na	na	na	7.08	7.07	7.17
Average non-EPSCoR state value	na	na	na	na	na	na	8.23	8.25	8.40
United States	590,417	603,642	633,727	7,223,240	7,366,978	7,585,035	8.17	8.19	8.35
Alabama	6,347	6,407	6,613	99,453	100,521	103,236	6.38	6.37	6.41
Alaska	1,345	1,358	1,494	19,037	19,309	19,838	7.07	7.03	7.53
Arizona	10,433	10,901	11,942	120,966	125,330	137,532	8.62	8.70	8.68
Arkansas	4,012	4,142	4,373	64,058	65,127	66,647	6.26	6.36	6.56
California	77,614	79,288	85,514	822,751	838,615	875,682	9.43	9.45	9.77
Colorado	15,532	16,027	17,259	143,398	146,937	154,254	10.83	10.91	11.19
Connecticut	7,827	7,794	7,810	91,207	92,710	93,232	8.58	8.41	8.38
Delaware	3,964	3,907	3,700	24,739	25,344	25,563	16.02	15.42	14.47
District of Columbia	2,589	2,695	3,062	19,357	19,503	20,967	13.38	13.82	14.60
Florida	38,118	40,165	43,678	458,823	483,693	516,185	8.31	8.30	8.46
Georgia	18,820	19,424	20,825	208,350	214,200	225,577	9.03	9.07	9.23
Hawaii	2,097	2,152	2,325	30,950	31,538	33,063	6.78	6.82	7.03
Idaho	2,515	2,582	2,912	39,582	41,205	45,599	6.35	6.27	6.39
Illinois	27,606	28,200	28,821	310,589	315,093	320,756	8.89	8.95	8.99
Indiana	9,626	9,858	10,158	147,073	149,050	151,024	6.55	6.61	6.73
Iowa	4,316	4,324	4,548	80,745	81,334	82,542	5.35	5.32	5.51
Kansas	5,716	5,900	6,035	74,637	75,600	76,261	7.66	7.80	7.91
Kentucky	5,453	5,585	5,769	90,358	91,598	92,700	6.03	6.10	6.22
Louisiana	7,218	7,192	7,439	101,933	102,866	101,647	7.08	6.99	7.32
Maine	2,466	2,541	2,612	40,519	41,131	41,941	6.09	6.18	6.23
Maryland	13,428	13,974	14,632	132,782	135,699	140,021	10.11	10.30	10.45
Massachusetts	17,183	17,305	17,107	177,910	175,426	174,997	9.66	9.86	9.78
Michigan	16,937	16,988	17,049	236,221	237,392	235,245	7.17	7.16	7.25
Minnesota	12,834	13,055	13,348	145,364	148,276	150,896	8.83	8.80	8.85
Mississippi	3,269	3,274	3,336	59,565	60,364	60,442	5.49	5.42	5.52
Missouri	9,562	9,745	10,130	149,753	153,584	154,177	6.39	6.35	6.57
Montana	2,108	2,229	2,415	33,616	34,570	36,550	6.27	6.45	6.61
Nebraska	2,797	2,864	3,072	50,213	50,803	51,822	5.57	5.64	5.93
Nevada	5,387	5,493	5,975	53,080	55,713	61,061	10.15	9.86	9.79
New Hampshire	3,511	3,559	3,554	38,119	38,707	39,273	9.21	9.19	9.05
New Jersey	24,286	24,256	24,534	237,097	240,013	242,649	10.24	10.11	10.11
New Mexico	3,322	3,385	3,553	43,386	44,071	45,814	7.66	7.68	7.76
New York	35,926	36,706	37,346	500,559	509,873	514,992	7.18	7.20	7.25
North Carolina	14,869	15,426	16,908	207,500	212,457	221,898	7.17	7.26	7.62
North Dakota	964	972	1,035	20,371	20,763	21,286	4.73	4.68	4.86
Ohio	19,875	20,120	20,347	269,202	271,078	269,398	7.38	7.42	7.55
Oklahoma	6,859	6,965	7,301	85,633	87,180	89,440	8.01	7.99	8.16
Oregon	7,500	7,659	8,083	102,462	104,966	110,317	7.32	7.30	7.33
Pennsylvania	22,266	22,796	23,486	297,040	300,832	303,507	7.50	7.58	7.74
Rhode Island	1,976	2,043	2,059	29,172	29,900	30,322	6.77	6.83	6.79
South Carolina	5,869	6,048	6,551	98,735	100,947	105,060	5.94	5.99	6.24
South Dakota	1,206	1,234	1,266	24,314	24,693	25,419	4.96	5.00	4.98
Tennessee	8,196	8,226	8,772	129,458	131,355	134,776	6.33	6.26	6.51
Texas	45,062	45,522	47,520	481,804	489,782	508,092	9.35	9.29	9.35
Utah	5,474	5,716	6,531	60,011	62,644	68,612	9.12	9.12	9.52
Vermont	1,453	1,498	1,535	21,747	22,072	22,261	6.68	6.79	6.90
Virginia	18,868	19,758	21,678	182,783	188,533	196,849	10.32	10.48	11.01
Washington	13,171	13,480	14,411	166,229	170,848	179,368	7.92	7.89	8.03
West Virginia	2,257	2,259	2,308	40,225	40,732	40,480	5.61	5.55	5.70
Wisconsin	9,035	9,249	9,438	141,560	143,739	145,590	6.38	6.43	6.48
Wyoming	1,353	1,396	1,558	18,804	19,262	20,175	7.20	7.25	7.72
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

na = not applicable; NA = not available

EPSCoR = Experimental Program to Stimulate Competitive Research

NOTE: For explanation of EPSCoR and non-EPSCoR averages, see chapter introduction.

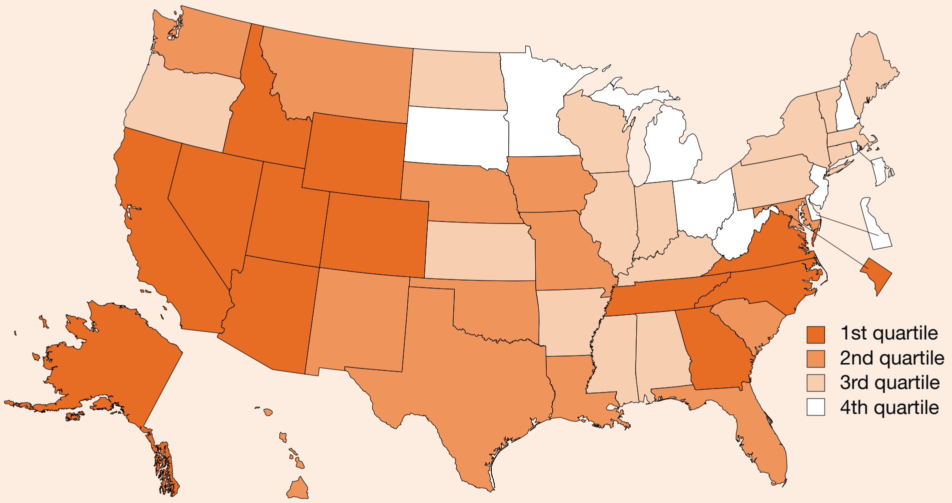
SOURCE: Census Bureau, 1989–2006 Business Information Tracking Series, special tabulations.

Science and Engineering Indicators 2010

Net High-Technology Business Formations as Share of All Business Establishments

Figure 8-47

Net high-technology business formations as share of all business establishments: 2006



1st quartile (0.93%–0.28%)	2nd quartile (0.27%–0.18%)	3rd quartile (0.16%–0.05%)	4th quartile (0.04% to –0.31%)
Alaska ‡	Florida	Alabama ‡	Delaware ‡
Arizona	Hawaii ‡	Arkansas ‡	Michigan
California	Iowa	Connecticut	Minnesota
Colorado	Louisiana ‡	Illinois	New Hampshire ‡
District of Columbia	Maryland	Indiana	New Jersey
Georgia	Missouri	Kansas ‡	Ohio
Idaho ‡	Montana ‡	Kentucky ‡	Rhode Island ‡
Nevada ‡	Nebraska ‡	Maine ‡	South Dakota ‡
North Carolina	New Mexico ‡	Massachusetts	West Virginia ‡
Tennessee	Oklahoma ‡	Mississippi ‡	
Utah	South Carolina ‡	New York	
Virginia	Texas	North Dakota ‡	
Wyoming ‡	Washington	Oregon	
		Pennsylvania	
		Vermont ‡	
		Wisconsin	

‡ EPSCoR state

SOURCE: Census Bureau, 1989–2004 Business Information Tracking Series, special tabulations. See table 8-47.

Findings

- In 2006, about 14,000 net new businesses in high-technology industries were formed in the United States. From a base of approximately 7.6 million total business establishments, 84,777 new business establishments were formed in high-technology industries and 70,746 ceased operations in those same industries.
- Almost all states showed more establishments beginning operations in high-technology industries than ceasing operations in 2006.
- Utah and Virginia showed the highest rates of net high-technology business formation in 2006. However, the largest numbers of net new businesses were formed in California, Texas, and Florida.
- EPSCoR states tended to be distributed throughout the state ranking, indicating that the rate of net high-technology business formation in many of these states was comparable to that in non-EPSCoR states.

The business base of a state is constantly changing as new businesses form and others cease to function. The term *net business formations* refers to the difference between the number of businesses that are formed and the number that cease operations during any particular year.

The ratio of the number of net business formations that occur in high-technology industries to the number of business establishments in a state indicates the changing role of high-technology industries in a state's economy. High positive values indicate an increasingly prominent role for these industries.

The data on business establishments in high-technology industries are based on their classification according to the 2002 edition of the North American Industry Classification System (NAICS). See table 8-A in the "Introduction" for a list of the 46 industries (by 4-digit NAICS code) that are defined as high technology. Data for years prior to 2002 are not directly comparable.

Changes in company name, ownership, or address are not counted as business formations or business deaths. Net business formations cannot be used to directly link the number of high-technology business establishments in different years because the primary industry of some establishments may have changed during the period.

Table 8-47

Net high-technology business formations as share of all business establishments, by state: 2004 and 2006

State	Net high-technology business formations 2004	Net high-technology business formations 2006	All business establishments 2004	All business establishments 2006	High-technology formations/business establishments (%) 2004	High-technology formations/business establishments (%) 2006
United States	11,598	14,031	7,366,978	7,585,035	0.16	0.18
Alabama	63	134	100,521	103,236	0.06	0.13
Alaska	22	66	19,309	19,838	0.11	0.33
Arizona	357	446	125,330	137,532	0.28	0.32
Arkansas	123	98	65,127	66,647	0.19	0.15
California	1,099	2,633	838,615	875,682	0.13	0.30
Colorado	490	509	146,937	154,254	0.33	0.33
Connecticut	–47	44	92,710	93,232	–0.05	0.05
Delaware	–52	–78	25,344	25,563	–0.21	–0.31
District of Columbia	66	195	19,503	20,967	0.34	0.93
Florida	1,743	1,009	483,693	516,185	0.36	0.20
Georgia	642	734	214,200	225,577	0.30	0.33
Hawaii	51	90	31,538	33,063	0.16	0.27
Idaho	54	151	41,205	45,599	0.13	0.33
Illinois	452	243	315,093	320,756	0.14	0.08
Indiana	208	164	149,050	151,024	0.14	0.11
Iowa	12	150	81,334	82,542	0.01	0.18
Kansas	160	114	75,600	76,261	0.21	0.15
Kentucky	116	42	91,598	92,700	0.13	0.05
Louisiana	–38	195	102,866	101,647	–0.04	0.19
Maine	81	31	41,131	41,941	0.20	0.07
Maryland	475	278	135,699	140,021	0.35	0.20
Massachusetts	156	193	175,426	174,997	0.09	0.11
Michigan	44	27	237,392	235,245	0.02	0.01
Minnesota	185	39	148,276	150,896	0.12	0.03
Mississippi	7	83	60,364	60,442	0.01	0.14
Missouri	195	279	153,584	154,177	0.13	0.18
Montana	108	98	34,570	36,550	0.31	0.27
Nebraska	64	98	50,803	51,822	0.13	0.19
Nevada	169	207	55,713	61,061	0.30	0.34
New Hampshire	30	13	38,707	39,273	0.08	0.03
New Jersey	-80	38	240,013	242,649	–0.03	0.02
New Mexico	37	98	44,071	45,814	0.08	0.21
New York	702	274	509,873	514,992	0.14	0.05
North Carolina	514	692	212,457	221,898	0.24	0.31
North Dakota	–1	34	20,763	21,286	0.00	0.16
Ohio	204	111	271,078	269,398	0.08	0.04
Oklahoma	75	236	87,180	89,440	0.09	0.26
Oregon	156	141	104,966	110,317	0.15	0.13
Pennsylvania	474	278	300,832	303,507	0.16	0.09
Rhode Island	67	8	29,900	30,322	0.22	0.03
South Carolina	175	230	100,947	105,060	0.17	0.22
South Dakota	16	9	24,693	25,419	0.06	0.04
Tennessee	39	372	131,355	134,776	0.03	0.28
Texas	401	1,221	489,782	508,092	0.08	0.24
Utah	283	382	62,644	68,612	0.45	0.56
Vermont	42	22	22,072	22,261	0.19	0.10
Virginia	845	986	188,533	196,849	0.45	0.50
Washington	346	476	170,848	179,368	0.20	0.27
West Virginia	16	-13	40,732	40,480	0.04	-0.03
Wisconsin	215	66	143,739	145,590	0.15	0.05
Wyoming	37	85	19,262	20,175	0.19	0.42
Puerto Rico	NA	NA	NA	NA	NA	NA

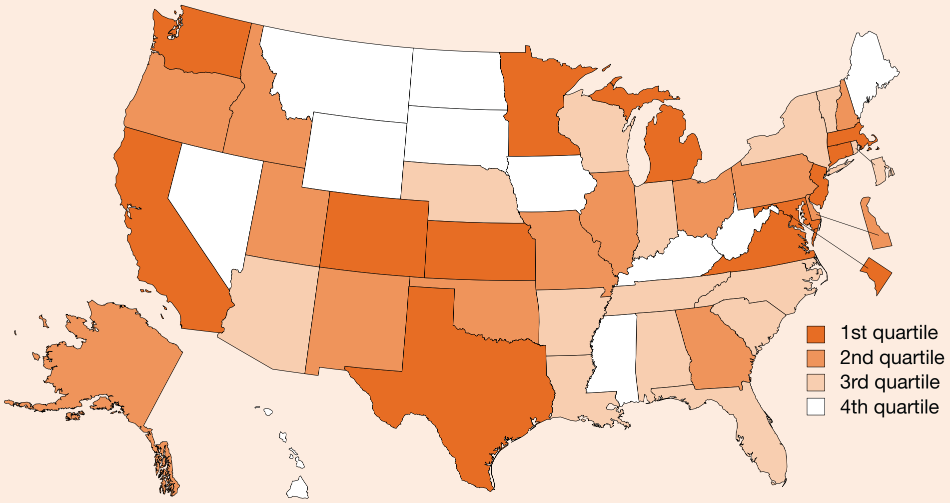
NA = not available

SOURCE: Census Bureau, 1989–2006 Business Information Tracking Series, special tabulations.

Science and Engineering Indicators 2010

Employment in High-Technology Establishments as Share of Total Employment

Figure 8-48
Employment in high-technology establishments as share of total employment: 2006



1st quartile (16.32%–12.45%)

California
Colorado
Connecticut
District of Columbia
Kansas ‡
Maryland
Massachusetts
Michigan
Minnesota
New Jersey
Texas
Virginia
Washington

2nd quartile (12.30%–10.58%)

Alaska ‡
Delaware ‡
Georgia
Idaho ‡
Illinois
Missouri
New Hampshire ‡
New Mexico ‡
Ohio
Oklahoma ‡
Oregon
Pennsylvania
Utah

3rd quartile (10.56%–8.21%)

Alabama ‡
Arizona
Arkansas ‡
Florida
Indiana
Louisiana ‡
Nebraska ‡
New York
North Carolina
Rhode Island ‡
South Carolina ‡
Tennessee
Vermont ‡
Wisconsin

4th quartile (8.07%–5.63%)

Hawaii ‡
Iowa
Kentucky ‡
Maine ‡
Mississippi ‡
Montana ‡
Nevada ‡
North Dakota ‡
South Dakota ‡
West Virginia ‡
Wyoming ‡

‡ EPSCoR state

SOURCE: Census Bureau, Business Information Tracking Series, special tabulations. See table 8-48.

Findings

- Employment in high-technology industries in the United States remained fairly steady between 2003 and 2006, at 13 million.
- Nationwide, the value of this indicator declined about 4%, from 11.96 in 2003 to 11.45 in 2006, as total employment grew during this period.
- On this indicator, states varied greatly in 2006, ranging from 5.6% to 16.3% of their workforce employed in high-technology industries.
- During the 2003–06 period, Washington, New York, Illinois, and Michigan recorded the largest net losses of jobs in high-technology industries, while California, Virginia, Florida, and Massachusetts posted the largest net gains of jobs in high-technology industries.
- States were distributed similarly on the high-technology employment and high-technology establishment indicators. EPSCoR states tended to have smaller percentages of their workforces employed in high-technology industries.

This indicator measures the extent to which a state's workforce is employed in high-technology industries. High-technology industries are defined as those in which the proportion of employees in technology-oriented occupations is at least twice the average proportion for all industries.

The data pertaining to establishments are based on their classification according to the 2002 edition of the North American Industry Classification System (NAICS). See table 8-A in the "Introduction" for a list of the 46 industries (by 4-digit NAICS code) that are defined as high technology. Data for years prior to 2002 are not directly comparable.

Table 8-48
Employment in high-technology establishments as share of total employment, by state: 2003, 2004, and 2006

	Employment in high-technology establishments			All employment			High-technology/ all employment (%)		
State	2003	2004	2006	2003	2004	2006	2003	2004	2006
United States	13,563,122	13,356,596	13,733,632	113,373,663	115,049,548	119,892,505	11.96	11.61	11.45
Alabama	152,879	158,927	162,197	1,597,265	1,628,733	1,713,185	9.57	9.76	9.47
Alaska	21,851	22,107	27,306	216,707	223,099	241,568	10.08	9.91	11.30
Arizona	234,603	238,462	246,648	1,997,990	2,043,729	2,334,665	11.74	11.67	10.56
Arkansas	95,180	101,124	93,648	988,822	1,007,283	1,041,868	9.63	10.04	8.99
California	1,781,830	1,767,202	1,826,638	12,986,496	13,260,306	13,830,274	13.72	13.33	13.21
Colorado	274,979	265,613	272,952	1,883,883	1,908,126	2,018,905	14.60	13.92	13.52
Connecticut	210,114	204,107	198,450	1,550,615	1,537,160	1,585,660	13.55	13.28	12.52
Delaware	52,349	54,164	47,749	385,098	391,647	388,178	13.59	13.83	12.30
District of Columbia	54,314	57,250	57,297	422,912	436,791	446,502	12.84	13.11	12.83
Florida	576,274	587,452	618,540	6,548,276	6,863,196	7,534,165	8.80	8.56	8.21
Georgia	413,384	411,977	428,272	3,386,590	3,451,802	3,622,522	12.21	11.94	11.82
Hawaii	25,777	26,203	28,848	458,952	473,181	512,488	5.62	5.54	5.63
Idaho	55,706	53,738	59,082	466,379	488,557	546,108	11.94	11.00	10.82
Illinois	646,285	617,306	619,777	5,204,887	5,216,180	5,356,504	12.42	11.83	11.57
Indiana	219,598	219,694	224,644	2,540,554	2,586,282	2,672,558	8.64	8.49	8.41
Iowa	102,387	96,100	96,190	1,232,709	1,241,688	1,295,143	8.31	7.74	7.43
Kansas	155,023	153,046	146,849	1,109,699	1,115,930	1,142,487	13.97	13.71	12.85
Kentucky	121,838	119,167	125,204	1,471,622	1,489,285	1,551,791	8.28	8.00	8.07
Louisiana	137,029	129,722	143,846	1,603,492	1,623,431	1,592,682	8.55	7.99	9.03
Maine	35,184	36,221	37,934	488,788	494,165	508,061	7.20	7.33	7.47
Maryland	315,887	323,966	326,546	2,088,552	2,151,093	2,231,888	15.12	15.06	14.63
Massachusetts	460,984	455,749	496,630	2,974,164	2,979,251	3,043,643	15.50	15.30	16.32
Michigan	499,133	486,706	475,350	3,884,881	3,895,217	3,817,762	12.85	12.49	12.45
Minnesota	315,994	309,303	329,927	2,381,860	2,392,481	2,475,859	13.27	12.93	13.33
Mississippi	66,566	61,858	64,558	912,004	928,181	940,329	7.30	6.66	6.87
Missouri	254,299	257,290	263,494	2,387,245	2,420,994	2,467,626	10.65	10.63	10.68
Montana	20,296	20,452	26,958	302,932	314,806	342,461	6.70	6.50	7.87
Nebraska	68,975	69,724	64,779	774,858	774,187	789,117	8.90	9.01	8.21
Nevada	61,847	64,648	66,875	970,678	1,021,842	1,165,243	6.37	6.33	5.74
New Hampshire	63,264	63,907	64,914	540,132	550,869	577,322	11.71	11.60	11.24
New Jersey	550,224	558,921	550,515	3,578,674	3,609,297	3,644,967	15.38	15.49	15.10
New Mexico	60,399	61,149	68,627	571,057	580,443	628,472	10.58	10.53	10.92
New York	823,992	798,462	790,696	7,415,430	7,431,893	7,531,772	11.11	10.74	10.50
North Carolina	349,424	345,316	358,501	3,337,552	3,365,050	3,523,954	10.47	10.26	10.17
North Dakota	20,584	20,176	22,450	258,878	265,632	278,395	7.95	7.60	8.06
Ohio	531,491	512,352	518,835	4,769,406	4,761,492	4,824,859	11.14	10.76	10.75
Oklahoma	132,887	133,871	141,575	1,184,312	1,194,830	1,276,743	11.22	11.20	11.09
Oregon	152,140	147,549	161,641	1,338,380	1,355,101	1,461,339	11.37	10.89	11.06
Pennsylvania	566,406	551,971	549,180	5,028,650	5,106,171	5,189,349	11.26	10.81	10.58
Rhode Island	35,806	36,577	41,020	427,369	434,600	440,715	8.38	8.42	9.31
South Carolina	163,373	164,035	170,200	1,550,227	1,560,401	1,631,690	10.54	10.51	10.43
South Dakota	18,890	19,897	20,202	299,723	307,944	325,045	6.30	6.46	6.22
Tennessee	219,898	217,191	245,517	2,298,836	2,346,903	2,472,939	9.57	9.25	9.93
Texas	1,158,481	1,101,175	1,144,997	8,049,300	8,116,465	8,709,575	14.39	13.57	13.15
Utah	99,856	101,547	114,815	900,331	934,939	1,038,879	11.09	10.86	11.05
Vermont	29,402	27,572	27,001	256,401	256,040	263,759	11.47	10.77	10.24
Virginia	459,017	489,703	502,890	2,932,471	3,054,221	3,173,767	15.65	16.03	15.85
Washington	401,413	329,698	347,710	2,292,462	2,268,155	2,420,633	17.51	14.54	14.36
West Virginia	46,635	46,172	45,284	561,317	568,581	583,033	8.31	8.12	7.77
Wisconsin	233,967	245,257	253,499	2,382,979	2,434,580	2,481,998	9.82	10.07	10.21
Wyoming	15,008	14,820	16,375	180,866	187,318	204,058	8.30	7.91	8.02
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not available

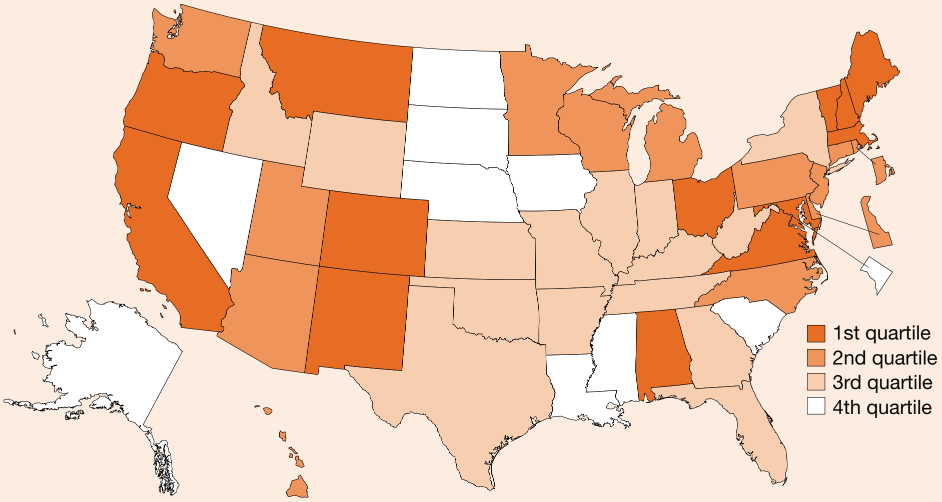
SOURCE: Census Bureau, 1989–2006 Business Information Tracking Series, special tabulations.

Science and Engineering Indicators 2010

Average Annual Federal SBIR Funding per $1 Million of Gross Domestic Product

Figure 8-49

Average annual federal SBIR funding per $1 million of gross domestic product: 2006–08



1st quartile ($626–$148)	2nd quartile ($147–$88)	3rd quartile ($76–$37)	4th quartile ($33–$12)
Alabama ‡	Arizona	Arkansas ‡	Alaska ‡
California	Connecticut	Florida	District of Columbia
Colorado	Delaware ‡	Georgia	Iowa
Maine ‡	Hawaii ‡	Idaho ‡	Louisiana ‡
Maryland	Michigan	Illinois	Mississippi ‡
Massachusetts	Minnesota	Indiana	Nebraska ‡
Montana ‡	New Jersey	Kansas ‡	Nevada ‡
New Hampshire ‡	North Carolina	Kentucky ‡	North Dakota ‡
New Mexico ‡	Pennsylvania	Missouri	South Carolina ‡
Ohio	Rhode Island ‡	New York	South Dakota ‡
Oregon	Utah	Oklahoma ‡	
Vermont ‡	Washington	Tennessee	
Virginia	Wisconsin	Texas	
		West Virginia ‡	
		Wyoming ‡	

‡ EPSCoR state

SOURCES: Small Business Administration, Office of Technology, SBIR Program Statistics (various years); and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-49.

Findings

- Significant growth has occurred in the SBIR program in recent years as total annual awards increased from about $1.1 billion in 1998–2000 to about $1.7 billion in 2006–08.
- SBIR funds are concentrated in relatively few states; the total of annual state awards may range from less than $1 million to more than $300 million.
- Many of the states with the highest rankings on this indicator are locations of federal laboratories or well-recognized academic research institutions from which innovative small businesses have emerged.
- States with a high ranking on this indicator also tended to rank high on the high-technology and venture capital indicators.

Funds awarded through the federal Small Business Innovation Research (SBIR) program support technological innovation in companies with 500 or fewer employees. Awards are made to evaluate the feasibility and scientific merit of new technology (up to $100,000) and to develop the technology to a point where it can be commercialized (up to $750,000). The total award dollars include both Phase 1 and Phase 2 SBIR awards.

Because of year-to-year fluctuations, this indicator is calculated using 3-year averages. The average annual SBIR award dollars won by small businesses in a state are divided by the average annual gross domestic product. A high value indicates that small business firms in a state are doing cutting-edge development work that attracts federal support.

Table 8-49

Average annual federal SBIR funding per $1 million of gross domestic product, by state: 1998–2000, 2002–04, and 2006–08

	Average SBIR funding (current $thousands)			Average state GDP (current $millions)			SBIR funding ($)/ $1 million GDP		
State	1998–2000	2002–04	2006–08	1998–2000	2002–04	2006–08	1998–2000	2002–04	2006–08
United States	1,060,758	1,725,643	1,731,667	9,209,969	10,963,871	13,676,177	115	157	127
Alabama	19,304	33,144	38,477	111,052	131,847	164,792	174	251	233
Alaska	318	495	707	24,840	31,836	45,182	13	16	16
Arizona	20,428	28,534	28,187	148,211	182,467	244,438	138	156	115
Arkansas	1,443	3,240	6,631	64,759	76,675	94,855	22	42	70
California	217,278	360,660	340,849	1,184,540	1,422,133	1,800,632	183	254	189
Colorado	55,158	80,814	79,329	157,102	188,960	237,064	351	428	335
Connecticut	20,674	29,454	22,096	152,037	172,690	212,468	136	171	104
Delaware	3,814	4,156	6,172	39,247	48,739	60,512	97	85	102
District of Columbia	3,675	5,840	3,011	55,596	72,450	93,076	66	81	32
Florida	21,897	37,526	42,914	443,689	563,008	731,715	49	67	59
Georgia	11,278	16,484	16,813	274,527	321,024	390,223	41	51	43
Hawaii	3,583	5,772	7,581	38,792	46,777	61,352	92	123	124
Idaho	1,001	3,664	3,164	32,481	39,142	50,779	31	94	62
Illinois	15,985	22,500	27,053	443,933	510,618	609,086	36	44	44
Indiana	5,068	10,689	16,932	186,355	216,259	246,664	27	49	69
Iowa	1,561	4,875	4,290	86,655	103,834	128,891	18	47	33
Kansas	3,374	4,938	4,326	79,160	93,853	116,894	43	53	37
Kentucky	2,298	4,237	5,602	111,398	125,786	152,345	21	34	37
Louisiana	1,453	3,126	4,326	124,551	148,154	213,844	12	21	20
Maine	1,948	5,604	7,094	33,545	40,656	48,052	58	138	148
Maryland	51,664	93,258	77,717	171,231	215,216	266,532	302	433	292
Massachusetts	164,078	242,323	219,333	254,548	295,018	350,605	645	821	626
Michigan	21,486	33,544	43,965	324,273	357,314	380,089	66	94	116
Minnesota	13,374	24,805	24,991	174,288	210,064	253,304	77	118	99
Mississippi	1,546	3,232	1,040	62,605	72,301	88,305	25	45	12
Missouri	5,721	7,342	8,645	169,985	196,271	229,120	34	37	38
Montana	3,622	7,045	8,278	20,552	25,513	34,046	176	276	243
Nebraska	1,641	2,998	2,438	53,653	64,322	79,552	31	47	31
Nevada	1,830	7,772	3,364	68,732	89,770	127,167	27	87	26
New Hampshire	12,602	22,174	22,501	40,944	48,606	57,806	308	456	389
New Jersey	30,790	47,712	40,718	328,735	390,642	462,949	94	122	88
New Mexico	19,136	21,965	22,293	48,547	57,810	76,080	394	380	293
New York	42,872	75,707	79,435	731,452	856,081	1,091,942	59	88	73
North Carolina	13,936	22,739	35,124	259,759	308,945	393,523	54	74	89
North Dakota	1,110	1,960	918	17,180	21,430	28,261	65	91	32
Ohio	44,859	67,535	70,856	360,448	405,302	463,139	124	167	153
Oklahoma	3,054	6,630	6,820	84,106	104,044	138,622	36	64	49
Oregon	14,627	19,556	26,881	105,886	123,868	156,930	138	158	171
Pennsylvania	36,393	64,864	77,650	375,843	441,249	531,060	97	147	146
Rhode Island	2,353	7,783	6,753	31,330	39,446	46,666	75	197	145
South Carolina	2,296	7,397	4,630	108,041	127,106	151,808	21	58	30
South Dakota	1,244	1,291	493	21,815	27,785	34,300	57	46	14
Tennessee	8,342	9,411	12,256	168,457	202,218	243,916	50	47	50
Texas	39,651	71,023	77,916	675,146	837,983	1,144,532	59	85	68
Utah	9,621	14,299	15,315	63,857	76,327	104,466	151	187	147
Vermont	3,317	4,808	4,760	16,835	20,656	24,538	197	233	194
Virginia	60,913	98,276	96,609	243,330	304,390	382,864	250	323	252
Washington	26,052	46,713	45,128	210,710	241,841	308,449	124	193	146
West Virginia	1,306	5,719	2,153	40,694	47,063	58,460	32	122	37
Wisconsin	8,724	17,592	24,686	168,477	196,807	232,039	52	89	106
Wyoming	1,060	2,418	2,447	16,040	21,575	32,243	66	112	76
Puerto Rico	236	216	8	57,876	75,220	NA	4	3	NA

NA = not available

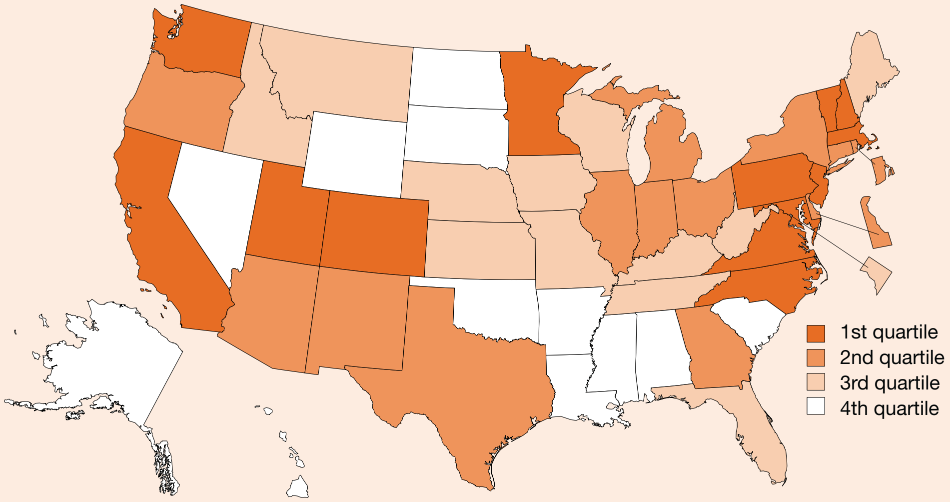
GDP = gross domestic product; SBIR = Small Business Innovation Research

SOURCES: Small Business Administration, Office of Technology, SBIR program statistics (various years); Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2010

Venture Capital Disbursed per $1,000 of Gross Domestic Product

Figure 8-50
Venture capital disbursed per $1,000 of gross domestic product: 2008



1st quartile ($8.15–$1.15)	2nd quartile ($1.14–$0.48)	3rd quartile ($0.43–$0.19)	4th quartile ($0.17–$0.00)
California	Arizona	District of Columbia	Alabama [‡]
Colorado	Connecticut	Florida	Alaska [‡]
Maryland	Delaware [‡]	Idaho [‡]	Arkansas [‡]
Massachusetts	Georgia	Iowa	Hawaii [‡]
Minnesota	Illinois	Kansas [‡]	Louisiana [‡]
New Hampshire [‡]	Indiana	Kentucky [‡]	Mississippi [‡]
New Jersey	Michigan	Maine [‡]	Nevada [‡]
North Carolina	New Mexico [‡]	Missouri	North Dakota [‡]
Pennsylvania	New York	Montana [‡]	Oklahoma [‡]
Utah	Ohio	Nebraska [‡]	South Carolina [‡]
Vermont [‡]	Oregon	Tennessee	South Dakota [‡]
Virginia	Rhode Island [‡]	West Virginia [‡]	Wyoming [‡]
Washington	Texas	Wisconsin	

[‡] EPSCoR state

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations; and Bureau of Economic Analysis, Gross Domestic Product data. See table 8-50.

Findings

- The total amount of venture capital invested in the United States increased from about $21 billion in 1998 to about $28 billion in 2008, an overall increase of 34%. However, this was a decade of great volatility, as U.S. venture capital investment peaked at $106 billion in 2000.
- Venture capital is concentrated in relatively few states. Companies in California received 50% of the total venture capital disbursed in the United States in 2008, followed by companies in Massachusetts with 11%.
- The distribution of venture capital is becoming more concentrated, making it more difficult for companies in many states to access this type of financing. Thirty-five states reported lower values for this indicator in 2008 than in 1998.
- The average indicator value for EPSCoR states was substantially lower than that of non-EPSCoR states. The state distribution of venture capital was similar to indicators of high-technology business activity.

Venture capital represents an important source of funding for startup companies. It supports the growth and expansion of these companies early in their development, before they establish a predictable sales history that would qualify them for other types of financing.

This indicator shows the relative magnitude of venture capital investments in a state after adjusting for the size of the state's economy. The indicator is expressed as dollars of venture capital disbursed per $1,000 of gross domestic product. High values indicate that companies in those states are successfully attracting venture capital to fuel their growth. Access to venture capital financing varies greatly among states.

Table 8-50

Venture capital disbursed per $1,000 of gross domestic product, by state: 1998, 2003, and 2008

	Venture capital disbursed (current $millions)			State GDP (current $millions)			Venture capital ($)/ $1,000 GDP		
State	1998	2003	2008	1998	2003	2008	1998	2003	2008
United States	21,037	19,776	28,284	8,679,660	10,886,172	14,165,565	2.42	1.82	2.00
Alabama	82	30	24	106,656	130,210	170,014	0.77	0.23	0.14
Alaska	0	0	0	23,165	31,219	47,912	0.00	0.00	0.00
Arizona	210	73	208	137,581	182,011	248,888	1.53	0.40	0.84
Arkansas	7	1	0	61,861	75,685	98,331	0.11	0.01	0.00
California	7,955	8,564	14,264	1,085,884	1,406,511	1,846,757	7.33	6.09	7.72
Colorado	726	628	813	143,160	187,397	248,603	5.07	3.35	3.27
Connecticut	373	212	127	145,373	169,885	216,174	2.57	1.25	0.59
Delaware	0	0	63	36,831	48,587	61,828	0.00	0.01	1.01
District of Columbia	47	56	31	51,682	71,719	97,235	0.91	0.78	0.32
Florida	552	309	240	417,169	559,021	744,120	1.32	0.55	0.32
Georgia	431	295	426	255,612	317,922	397,756	1.68	0.93	1.07
Hawaii	4	13	7	37,549	46,441	63,847	0.11	0.28	0.11
Idaho	30	52	12	29,800	38,148	52,747	1.02	1.37	0.23
Illinois	429	377	444	423,855	510,296	633,697	1.01	0.74	0.70
Indiana	39	25	124	178,909	215,434	254,861	0.22	0.11	0.48
Iowa	9	0	40	83,665	102,210	135,702	0.11	0.00	0.30
Kansas	10	25	46	76,005	93,560	122,731	0.14	0.27	0.37
Kentucky	38	5	30	108,813	124,892	156,436	0.34	0.04	0.19
Louisiana	68	1	8	118,085	146,726	222,218	0.58	0.01	0.04
Maine	62	1	20	31,731	40,152	49,709	1.94	0.02	0.41
Maryland	328	348	477	161,954	213,306	273,333	2.03	1.63	1.74
Massachusetts	2,009	2,744	2,974	236,079	293,840	364,988	8.51	9.34	8.15
Michigan	124	80	246	309,431	359,030	382,544	0.40	0.22	0.64
Minnesota	361	233	491	164,897	208,179	262,847	2.19	1.12	1.87
Mississippi	4	1	0	60,513	72,259	91,782	0.06	0.01	0.00
Missouri	611	78	87	164,267	195,547	237,797	3.72	0.40	0.36
Montana	0	0	16	19,884	25,526	35,891	0.00	0.00	0.43
Nebraska	29	205	16	52,076	64,628	83,273	0.56	3.17	0.19
Nevada	24	40	13	63,635	87,828	131,233	0.38	0.46	0.10
New Hampshire	185	154	181	39,102	48,198	60,005	4.73	3.20	3.02
New Jersey	476	886	708	314,117	389,077	474,936	1.52	2.28	1.49
New Mexico	8	4	69	45,918	57,469	79,901	0.17	0.06	0.87
New York	1,299	660	1,299	686,906	850,243	1,144,481	1.89	0.78	1.14
North Carolina	327	387	459	242,904	306,018	400,192	1.34	1.26	1.15
North Dakota	1	15	0	16,936	21,672	31,208	0.03	0.67	0.01
Ohio	309	179	248	348,723	402,399	471,508	0.89	0.44	0.53
Oklahoma	101	31	17	79,341	103,452	146,448	1.28	0.30	0.12
Oregon	54	108	176	100,951	121,638	161,573	0.53	0.88	1.09
Pennsylvania	562	499	693	361,800	440,704	553,301	1.55	1.13	1.25
Rhode Island	26	66	39	29,537	39,357	47,364	0.88	1.66	0.83
South Carolina	137	14	26	102,945	127,885	156,384	1.33	0.11	0.17
South Dakota	0	4	1	20,771	27,418	36,959	0.00	0.13	0.01
Tennessee	108	84	65	160,872	200,279	252,127	0.67	0.42	0.26
Texas	1,171	1,250	1,283	629,209	828,797	1,223,511	1.86	1.51	1.05
Utah	117	107	194	60,168	75,428	109,777	1.94	1.41	1.76
Vermont	1	5	43	15,935	20,575	25,442	0.09	0.25	1.69
Virginia	766	413	484	226,569	302,540	397,025	3.38	1.37	1.22
Washington	736	464	955	195,794	240,813	322,778	3.76	1.92	2.96
West Virginia	2	13	24	39,500	46,452	61,652	0.05	0.27	0.39
Wisconsin	90	38	75	160,681	195,904	240,429	0.56	0.19	0.31
Wyoming	0	0	2	14,859	21,685	35,310	0.00	0.00	0.04
Puerto Rico	NA	NA	NA	54,086	74,827	NA	NA	NA	NA

NA = not available

GDP = gross domestic product

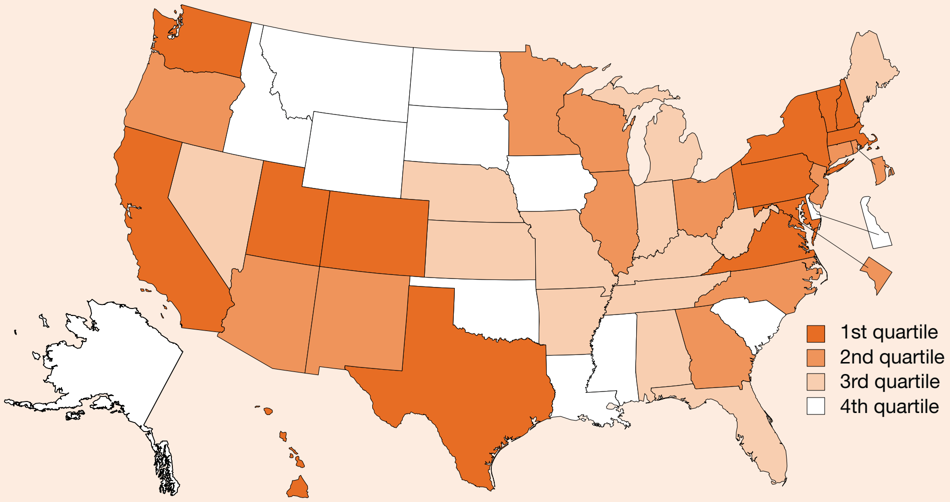
SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree™ Survey, special tabulations; Bureau of Economic Analysis, Gross Domestic Product data; and Government of Puerto Rico, Office of the Governor.

Science and Engineering Indicators 2010

Venture Capital Deals as Share of High-Technology Business Establishments

Figure 8-51

Venture capital deals as share of high-technology business establishments: 2006



1st quartile (2.31%–0.40%)	2nd quartile (0.39%–0.19%)	3rd quartile (0.15%–0.10%)	4th quartile (0.08%–0.00%)
California	Arizona	Alabama ‡	Alaska ‡
Colorado	Connecticut	Arkansas ‡	Delaware ‡
Hawaii ‡	District of Columbia	Florida	Idaho ‡
Maryland	Georgia	Indiana	Iowa
Massachusetts	Illinois	Kansas ‡	Louisiana ‡
New Hampshire ‡	Minnesota	Kentucky ‡	Mississippi ‡
New York	New Jersey	Maine ‡	Montana ‡
Pennsylvania	New Mexico ‡	Michigan	North Dakota ‡
Texas	North Carolina	Missouri	Oklahoma ‡
Utah	Ohio	Nebraska ‡	South Carolina ‡
Vermont ‡	Oregon	Nevada ‡	South Dakota ‡
Virginia	Rhode Island ‡	Tennessee	Wyoming ‡
Washington	Wisconsin	West Virginia ‡	

‡ EPSCoR state

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey™, special tabulations; and Census Bureau, Business Information Tracking Series, special tabulations. See table 8-51.

Findings

- The number of venture capital deals that involved U.S. companies increased from about 2,900 deals in 2003 to about 3,700 deals in 2006.
- In 2006, venture capital deals were concentrated in only a few states. Indicator values ranged from a high of 2.31% to a low of zero with a median value of 0.20%.
- Companies in high-technology industries located in Massachusetts were the most successful in accessing venture capital investments in 2006, with a 2.31% rate. California companies in high-technology industries obtained venture capital investment at a rate of 1.81%. No other states reached a rate of 1.00%.
- In 2006, companies in EPSCoR states tended to receive little venture capital investment, and no venture capital deals were reported in three EPSCoR states.

This indicator provides a measure of the extent to which high-technology companies in a state receive venture capital investments. The value of the indicator is calculated by dividing the number of venture capital deals by the number of companies operating in high-technology industries in that state. In most cases, a company will not receive more than one infusion of venture capital in a given year.

Venture capital investment can bring needed capital and management expertise that can help to grow a high-technology company. High values indicate that high-technology companies in a state are frequently using venture capital to facilitate their growth and development.

Table 8-51

Venture capital deals as share of high-technology business establishments, by state: 2003, 2004, and 2006

	Venture capital deals			High-technology establishments			Venture capital deals/ high-technology establishment (%)		
State	2003	2004	2006	2003	2004	2006	2003	2004	2006
United States	2,903	3,036	3,672	590,417	603,642	633,727	0.49	0.50	0.58
Alabama	9	5	7	6,347	6,407	6,613	0.14	0.08	0.11
Alaska	0	0	0	1,345	1,358	1,494	0.00	0.00	0.00
Arizona	16	12	29	10,433	10,901	11,942	0.15	0.11	0.24
Arkansas	3	1	6	4,012	4,142	4,373	0.07	0.02	0.14
California	1,122	1,225	1,549	77,614	79,288	85,514	1.45	1.55	1.81
Colorado	72	75	98	15,532	16,027	17,259	0.46	0.47	0.57
Connecticut	34	32	30	7,827	7,794	7,810	0.43	0.41	0.38
Delaware	1	1	3	3,964	3,907	3,700	0.03	0.03	0.08
District of Columbia	6	8	8	2,589	2,695	3,062	0.23	0.30	0.26
Florida	61	57	56	38,118	40,165	43,678	0.16	0.14	0.13
Georgia	55	73	81	18,820	19,424	20,825	0.29	0.38	0.39
Hawaii	6	4	10	2,097	2,152	2,325	0.29	0.19	0.43
Idaho	5	2	1	2,515	2,582	2,912	0.20	0.08	0.03
Illinois	58	51	55	27,606	28,200	28,821	0.21	0.18	0.19
Indiana	8	9	15	9,626	9,858	10,158	0.08	0.09	0.15
Iowa	1	4	2	4,316	4,324	4,548	0.02	0.09	0.04
Kansas	2	9	7	5,716	5,900	6,035	0.03	0.15	0.12
Kentucky	3	5	7	5,453	5,585	5,769	0.06	0.09	0.12
Louisiana	1	3	3	7,218	7,192	7,439	0.01	0.04	0.04
Maine	2	3	4	2,466	2,541	2,612	0.08	0.12	0.15
Maryland	84	85	110	13,428	13,974	14,632	0.63	0.61	0.75
Massachusetts	378	365	395	17,183	17,305	17,107	2.20	2.11	2.31
Michigan	17	19	18	16,937	16,988	17,049	0.10	0.11	0.11
Minnesota	58	47	39	12,834	13,055	13,348	0.45	0.36	0.29
Mississippi	4	5	1	3,269	3,274	3,336	0.12	0.15	0.03
Missouri	23	10	13	9,562	9,745	10,130	0.24	0.10	0.13
Montana	1	0	0	2,108	2,229	2,415	0.05	0.00	0.00
Nebraska	2	0	3	2,797	2,864	3,072	0.07	0.00	0.10
Nevada	6	5	7	5,387	5,493	5,975	0.11	0.09	0.12
New Hampshire	32	23	21	3,511	3,559	3,554	0.91	0.65	0.59
New Jersey	88	88	94	24,286	24,256	24,534	0.36	0.36	0.38
New Mexico	5	8	9	3,322	3,385	3,553	0.15	0.24	0.25
New York	119	149	209	35,926	36,706	37,346	0.33	0.41	0.56
North Carolina	76	57	62	14,869	15,426	16,908	0.51	0.37	0.37
North Dakota	2	1	0	964	972	1,035	0.21	0.10	0.00
Ohio	25	32	41	19,875	20,120	20,347	0.13	0.16	0.20
Oklahoma	2	11	6	6,859	6,965	7,301	0.03	0.16	0.08
Oregon	21	27	31	7,500	7,659	8,083	0.28	0.35	0.38
Pennsylvania	90	92	128	22,266	22,796	23,486	0.40	0.40	0.55
Rhode Island	10	7	7	1,976	2,043	2,059	0.51	0.34	0.34
South Carolina	4	5	3	5,869	6,048	6,551	0.07	0.08	0.05
South Dakota	1	3	1	1,206	1,234	1,266	0.08	0.24	0.08
Tennessee	22	23	11	8,196	8,226	8,772	0.27	0.28	0.13
Texas	165	162	188	45,062	45,522	47,520	0.37	0.36	0.40
Utah	22	27	39	5,474	5,716	6,531	0.40	0.47	0.60
Vermont	6	4	9	1,453	1,498	1,535	0.41	0.27	0.59
Virginia	80	73	89	18,868	19,758	21,678	0.42	0.37	0.41
Washington	81	114	143	13,171	13,480	14,411	0.61	0.85	0.99
West Virginia	5	3	3	2,257	2,259	2,308	0.22	0.13	0.13
Wisconsin	8	10	20	9,035	9,249	9,438	0.09	0.11	0.21
Wyoming	1	2	1	1,353	1,396	1,558	0.07	0.14	0.06
Puerto Rico	1	1	2	NA	NA	NA	NA	NA	NA

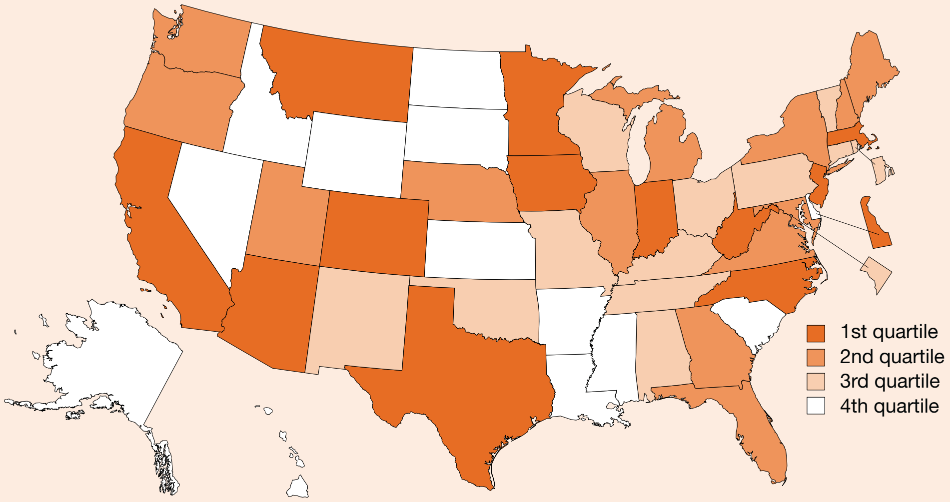
NA = not available

SOURCES: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree™ Survey, special tabulations; and Census Bureau, 1989–2006 Business Information Tracking Series, special tabulations.

Science and Engineering Indicators 2010

Venture Capital Disbursed per Venture Capital Deal

Figure 8-52
Venture capital disbursed per venture capital deal: 2008
(Millions of dollars)



1st quartile ($24.00–$7.34)	2nd quartile ($6.65–$4.91)	3rd quartile ($4.77–$2.79)	4th quartile ($2.38–$0.00)
Arizona	Florida	Alabama ‡	Alaska ‡
California	Georgia	Connecticut	Arkansas ‡
Colorado	Illinois	District of Columbia	Hawaii ‡
Delaware ‡	Maine ‡	Kentucky ‡	Idaho ‡
Indiana	Maryland	Missouri	Kansas ‡
Iowa	Michigan	New Mexico ‡	Louisiana ‡
Massachusetts	Nebraska ‡	Ohio	Mississippi ‡
Minnesota	New Hampshire ‡	Oklahoma ‡	Nevada ‡
Montana ‡	New York	Pennsylvania	North Dakota ‡
New Jersey	Oregon	Rhode Island ‡	South Carolina ‡
North Carolina	Utah	Tennessee	South Dakota ‡
Texas	Virginia	Vermont ‡	Wyoming ‡
West Virginia ‡	Washington	Wisconsin	

‡ EPSCoR state

SOURCE: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree Survey$^{\text{TM}}$, special tabulations. See table 8-52.

Findings

- In 2008, the size of the average venture capital investment in the United States was about $7 million per deal. This represented an increase in investment size from about $5 million per deal in 1998 but a decline from $13 million per deal in 2000 expressed in current dollars.
- The total number of venture capital deals has risen slightly, increasing from 3,632 deals in 1998 to 3,806 in 2008.
- In 2008, the state distribution on this indicator was skewed from a high value of $24 million per deal to a low of zero, with a median value of $5.03 million per deal. The value of this indicator continued to show a high level of variability from year to year and among states.

This indicator provides a measure of the average size of the venture capital investments being made in a state. The indicator is expressed as the total dollars of venture capital invested in millions divided by the number of companies receiving venture capital. The availability of venture capital may vary widely based on stage of investment, type of company, and numerous other factors.

This indicator provides some measure of the magnitude of investment that developing companies in a specific state have attracted from venture capital sources. Some states have relatively few venture capital deals taking place in a given year; thus, the value of this indicator may show large fluctuations on a year-to-year basis. Eighteen states reported fewer than 10 venture capital deals in 2008. In such states, a single large or small venture capital investment can significantly affect the value of this indicator.

Table 8-52

Venture capital disbursed per venture capital deal, by state: 1998, 2003, and 2008

	Venture capital disbursed (current $millions)			Venture capital deals			Venture capital/deal (current $millions)		
State	1998	2003	2008	1998	2003	2008	1998	2003	2008
United States	21,037	19,776	28,284	3,632	2,943	3,806	5.79	6.72	7.43
Alabama	82	30	24	15	9	8	5.49	3.32	3.01
Alaska	0	0	0	0	0	0	0.00	0.00	0.00
Arizona	210	73	208	36	16	20	5.84	4.58	10.40
Arkansas	7	1	0	2	3	0	3.45	0.37	0.00
California	7,955	8,564	14,264	1,388	1,135	1,552	5.73	7.55	9.19
Colorado	726	628	813	122	70	100	5.95	8.97	8.13
Connecticut	373	212	127	74	34	34	5.05	6.24	3.74
Delaware	0	0	63	0	1	6	0.00	0.40	10.45
District of Columbia	47	56	31	3	6	11	15.63	9.35	2.79
Florida	552	309	240	62	62	36	8.90	4.99	6.65
Georgia	431	295	426	98	58	80	4.39	5.09	5.33
Hawaii	4	13	7	3	5	6	1.40	2.56	1.20
Idaho	30	52	12	3	5	6	10.10	10.44	1.98
Illinois	429	377	444	70	56	67	6.13	6.73	6.63
Indiana	39	25	124	8	8	16	4.88	3.06	7.73
Iowa	9	0	40	7	0	5	1.26	0.00	8.04
Kansas	10	25	46	3	11	23	3.47	2.26	1.98
Kentucky	38	5	30	16	3	10	2.34	1.80	2.95
Louisiana	68	1	8	11	1	10	6.18	1.20	0.82
Maine	62	1	20	11	2	4	5.59	0.45	5.05
Maryland	328	348	477	54	87	97	6.08	4.00	4.91
Massachusetts	2,009	2,744	2,974	391	381	405	5.14	7.20	7.34
Michigan	124	80	246	32	16	43	3.88	5.01	5.71
Minnesota	361	233	491	79	58	47	4.57	4.02	10.44
Mississippi	4	1	0	2	4	0	1.75	0.20	0.00
Missouri	611	78	87	19	19	24	32.16	4.13	3.60
Montana	0	0	16	0	0	2	0.00	0.00	7.80
Nebraska	29	205	16	5	3	3	5.82	68.20	5.33
Nevada	24	40	13	10	6	6	2.42	6.70	2.10
New Hampshire	185	154	181	26	32	28	7.11	4.82	6.47
New Jersey	476	886	708	76	90	90	6.27	9.85	7.87
New Mexico	8	4	69	4	5	19	1.93	0.72	3.65
New York	1,299	660	1,299	193	118	235	6.73	5.59	5.53
North Carolina	327	387	459	82	77	51	3.98	5.02	9.00
North Dakota	1	15	0	1	2	2	0.50	7.25	0.20
Ohio	309	179	248	63	28	52	4.91	6.39	4.77
Oklahoma	101	31	17	11	2	5	9.22	15.55	3.46
Oregon	54	108	176	18	21	35	2.97	5.12	5.03
Pennsylvania	562	499	693	138	97	171	4.07	5.15	4.05
Rhode Island	26	66	39	5	10	10	5.20	6.55	3.92
South Carolina	137	14	26	16	4	11	8.56	3.58	2.38
South Dakota	0	4	1	0	1	1	0.00	3.50	0.50
Tennessee	108	84	65	24	23	21	4.48	3.67	3.10
Texas	1,171	1,250	1,283	188	168	146	6.23	7.44	8.79
Utah	117	107	194	33	22	33	3.54	4.84	5.87
Vermont	1	5	43	2	6	9	0.70	0.87	4.77
Virginia	766	413	484	102	82	81	7.51	5.04	5.97
Washington	736	464	955	109	83	164	6.75	5.58	5.82
West Virginia	2	13	24	1	5	1	2.00	2.52	24.00
Wisconsin	90	38	75	16	8	19	5.64	4.70	3.96
Wyoming	0	0	2	0	0	1	0.00	0.00	1.50
Puerto Rico	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not available

SOURCE: PricewaterhouseCoopers, Venture Economics, and National Venture Capital Association, MoneyTree™ Survey, special tabulations.

Science and Engineering Indicators 2010

Appendix
Methodology and Statistics

Introduction

Science and Engineering Indicators (SEI) contains data compiled from a variety of sources. The purpose of this appendix is to explain the methodological and statistical criteria used to assess possible data sources for inclusion in SEI and to develop statements about the data. It also provides some basic information about how statistical procedures and reasoning are applied.

The first section describes the statistical considerations that are part of the selection process for data sets to be included in SEI. The next section discusses the different types of data (e.g., sample surveys, censuses, and administrative records) used in the report and provides some information about each type. A section on data accuracy follows, discussing factors that can affect accuracy at all stages of the survey process. The last section discusses the statistical testing employed to determine whether differences between sample survey-based estimates are *statistically significant,* i.e., greater than could be expected by chance. The appendix concludes with a glossary of statistical terms commonly used or referred to in the text.

Selection of Data Sources

Four criteria guide the selection of data for SEI:

- Representativeness. Data should represent national or international populations of interest.
- Relevance. Data sources should include indicators central to the functioning of the science and technology enterprise.
- Timeliness. Data that are not part of a time series should be timely, i.e., substantial and unmeasured changes in the population under study should not have occurred since the data were collected.
- Statistical and methodological quality. Survey methods used to acquire data should provide sufficient assurance that statements based on statistical analysis of the data are valid and reliable.

Data that are collected by U.S. government agencies and that are products of the federal statistical system meet rigorous statistical and methodological criteria as described below. Unless otherwise indicated, these data are representative of the nation as a whole and of the demographic, organizational, or geographic subgroups that comprise it.

For data collected by governments in other countries and nongovernment sources, including private survey firms and academic researchers, methodological information is examined to assess conformity with the criteria U.S. federal agencies typically use. Government statistical agencies in the developed world cooperate extensively in developing data quality standards and improving international comparability for key data, and methodological information about the data generated by this international statistical system is relatively complete.

Methodological information about data from nongovernmental sources and from governmental agencies outside the international statistical system is often less well documented. These data are evaluated and must meet basic scientific standards for representative sampling of survey respondents and adequate and unbiased coverage of the population under study, and the resulting measurements must be sufficiently relevant and meaningful to warrant publication despite methodological uncertainties that remain after the documentation has been scrutinized. The most important statistical criteria are described in general terms below and in greater detail in the following sections.

Many data sources that contain pertinent information about some segment of the S&E enterprise are not cited in SEI because their coverage of the United States as a nation is partial in terms of geography, incomplete in terms of segments of the population, or otherwise not representative. For example, data may be available only for a limited number of states or studies may be based on populations not representative of the United States as a whole. Similarly, data for other countries should cover and be representative of the entire country. (In some cases, data that have limited coverage or are otherwise insufficiently representative are referenced in sidebars.)

Data included in SEI must be of high quality. Data quality can be measured in a variety of ways, some of which are described in the following sections. Some key dimensions of quality include:

- **Validity.** Data have *validity* to the degree that they accurately measure the phenomenon they are supposed to represent.
- **Reliability.** Data have *reliability* to the degree that the same results would be produced if the same measurement or procedure were performed multiple times on the same population.
- **Lack of bias.** Data are *unbiased* to the degree that estimates from the data do not deviate from the population value of a phenomenon in a systematic fashion.

Data Sources

Much of the data cited in SEI come from surveys. Surveys strive to measure characteristics of target populations. To generalize survey results correctly to the population of interest, a survey's *target population* must be rigorously defined and the criteria determining membership in the population must be applied consistently in determining which units to include in the survey.

Some surveys are censuses (also known as *universe surveys*), in which the survey attempts to obtain data for all population units. The decennial census, in which the target population is all U.S. residents, is the most familiar census survey. SEI uses data from the Survey of Earned Doctorates, an annual census of individuals who earn doctorates from accredited U.S. institutions, for information about the numbers and characteristics of new U.S. doctorate holders.

Other surveys are *sample surveys,* in which data are obtained for only a representative portion of the population units. The Survey of Recent College Graduates, which gathers data on individuals who recently received bachelor's or master's degrees in science, engineering, and health fields from U.S. institutions, is an example of a sample survey.

A sample is a *probability sample* if each unit in the sampling frame has a known, nonzero probability of being selected for the sample. Probability samples are necessary for inferences about a population to be evaluated statistically. Except for some Asian surveys referenced in chapter 7, sample surveys included in SEI use probability sampling. In *nonprobability sampling,* a sample is selected haphazardly, purposively, or conveniently, and inferences about the population cannot be evaluated statistically. Internet surveys and phone-in polls that elicit responses from self-selected individuals are examples of nonprobability sample surveys.

In sample surveys, once a survey's target population has been defined, the next step is to establish a list of all members of that target population (i.e., a *sampling frame*). Members of the population must be selected from this list in a scientific manner so that it will be possible to generalize from the sample to the population as a whole. Surveys frequently sample from lists that to varying extents omit members of the target population, because complete lists are typically unavailable.

Surveys may be conducted of individuals or of organizations, such as businesses, universities, or government agencies. Surveys of organizations are often referred to as *establishment surveys*. An example of an establishment survey used in SEI is the Survey of Research and Development Expenditures at Universities and Colleges.

Surveys may be longitudinal or cross-sectional. In a *longitudinal survey,* the same individuals (or organizations) are surveyed repeatedly. The primary purpose of longitudinal surveys is to investigate how individuals or organizations change over time. The Survey of Doctorate Recipients is a longitudinal sample survey of individuals who received research doctorates from U.S. institutions. SEI uses results from this survey to analyze the careers of doctorate holders.

Cross-sectional surveys provide a "snapshot" at a given point of time. When conducted periodically, cross-sectional surveys produce repeated snapshots of a population, enabling analysis of how the population changes over time. However, because the same individuals or organizations are not included in each survey cycle, cross-sectional surveys cannot, in general, track changes for specific individuals or organizations. National and international assessments of student achievement in K–12 education, such as those discussed in chapter 1, are examples of repeated cross-sectional surveys. Most of the surveys cited in SEI are conducted periodically, although the frequency with which they are conducted varies.

Some of the data in SEI come from *administrative records* (data previously collected for the purpose of administering various programs). Examples of data drawn directly from administrative records in SEI include patent data from the records of government patent offices; bibliometric data on publications in S&E journals, compiled from information collected and published by the journals themselves; and data on foreign S&E workers temporarily in the United States, drawn from the administrative records of immigration agencies.

Many of the establishment surveys that SEI uses depend heavily, although indirectly, on administrative records. Universities and corporations that respond to surveys about their R&D activities often use administrative records developed for internal management or income tax reporting purposes to respond to these surveys.

Surveys are conducted using a variety of modes (e.g., mail, telephone, the Internet, or in person). They can be self- or interviewer administered. Many surveys are conducted in more than one mode. For example, the Survey of Graduate Students and Postdoctorates in Science and Engineering, a census of establishments (university departments) from which students earn S&E graduate degrees, collects most of its data via a Web-based questionnaire but also allows respondents to answer a paper questionnaire. The National Survey of College Graduates, a longitudinal sample survey that collects data on individuals with S&E-related degrees and/or occupations, is initially conducted by sending a paper questionnaire by mail. Later, potential participants who did not respond to the questionnaire are contacted via telephone or in person.

Data Accuracy

Accurate information is a primary goal of censuses and sample surveys. Accuracy can be defined as the extent to which results deviate from the true values of the characteristics in the target population. Statisticians use the term "error" to refer to this deviation. Good survey design seeks to minimize survey error.

Statisticians usually classify the factors affecting the accuracy of survey data into two categories: nonsampling and sampling errors. *Nonsampling error* applies to all surveys, including censuses, whereas *sampling error* applies only to sample surveys. The sources of nonsampling error in surveys have analogues for administrative records: the processes through which such records are created affect the degree to which the records accurately indicate the characteristics of relevant populations (e.g., patents, journal articles, immigrant scientists and engineers).

Nonsampling Error

Nonsampling error refers to error related to survey design, data collection, and processing procedures. Each stage of the survey process is a potential source of nonsampling error. For most types, there is no practical method of measuring the extent of nonsampling error. A brief description of five sources of nonsampling error follows. Although for convenience the descriptions occasionally refer to samples, they apply equally to censuses.

Specification Error. Survey questions often do not perfectly measure the concept for which they are intended as indicators. For example, the number of patents is not the same as the amount of invention.

Frame Error. The sampling frame, the list of the target population members used for selecting survey respondents, is often inaccurate. If the frame has omissions or other flaws, the survey is less representative because coverage of the target population is incomplete. Frame errors often require extensive effort to correct.

Nonresponse Error. Nonresponse errors occur because not all members of the sample respond to the survey. *Response rates* indicate what proportion of sample members respond to the survey. Other things being equal, lower response rates create a greater possibility that, had nonrespondents supplied answers to the questionnaire, the survey estimates would have been different.

Nonresponse can cause *nonresponse bias*, which occurs when the people or establishments that respond to a question, or to the survey as a whole, differ in systematic ways from those who do not respond. For example, in surveys of national populations, complete or partial nonresponse is often more likely among lower-income or less-educated respondents. Evidence of nonresponse bias is an important factor in decisions about whether survey data should be included in SEI.

Managers of high-quality surveys, such as those in the U.S. federal statistical system, do research on nonresponse patterns to assess whether and how nonresponse might bias survey estimates. SEI notes instances where reported data may be subject to substantial nonresponse bias.

The response rate does not indicate whether a survey has a problem of nonresponse bias. Surveys with high response rates sometimes have substantial nonresponse bias, and surveys with relatively low response rates, if nonrespondents do not differ from respondents on important variables, may have relatively little.

Measurement Error. There are many sources of measurement error, but respondents, interviewers, and survey questionnaires are the most important. Knowingly or unintentionally, respondents may provide incorrect information. Interviewers may inappropriately influence respondents' answers or record their answers incorrectly. The questionnaire can be a source of error if there are ambiguous, poorly worded, or confusing questions, instructions, or terms, or if the questionnaire layout is confusing.

In addition, the records or systems of information that a respondent may refer to, the mode of data collection, and the setting for the survey administration may contribute to measurement error. Perceptions about whether data will be treated as confidential may affect the accuracy of survey responses to sensitive questions about business profits or personal incomes.

Processing Error. Processing errors include errors in recording, checking, coding, and preparing survey data to make them ready for analysis.

Sampling Error

Sampling error is probably the best-known source of survey error and the most commonly reported measure of a survey's precision or accuracy. Unlike nonsampling error, sampling error can be quantitatively estimated in most scientific sample surveys.

Chance is involved in selecting the members of a sample. If the same, random procedures were used repeatedly to select samples from the population, numerous samples would be selected, each containing different members of the population with different characteristics. Each sample would produce different population estimates. When there is great variation among the samples drawn from a given population, the sampling error is high and there is a large chance that the survey estimate is far from the true population value. In a census, because the entire population is surveyed, there is no sampling error.

Sampling error is reduced when samples are large, and most of the surveys used in SEI have large samples. Sampling error is not a function of the percentage of the population in the sample (when the population is large) or the population size but is a function of the sample size, the variability of the measure of interest, and the methods used to produce estimates from the sample data.

Sampling error is measured by the standard error of the estimate, sometimes called the "margin of error." The standard error of an estimate measures how closely the estimate from a particular sample approximates the average result of all possible samples. The standard error of the estimate is expressed as a range in the size of the difference (e.g., ±2%) between the sample estimate and the average result of all possible samples.

Statistical Testing for Data From Sample Surveys

Statistical tests determine whether differences observed in sample survey data could have happened by chance, i.e., as the result of random variation in which people or establishments in the population were sampled. Differences that are very unlikely to have been produced by chance variations in sample selection are termed *statistically significant.* When SEI reports statements about differences on the basis of sample surveys, the differences are statistically significant at the .05 level. This means that, if there were no true difference in the population, the chance of drawing a sample with the observed difference would be no more than 5%.

A statistically significant difference is not necessarily large, important, or significant in the usual sense of the word. It is simply a difference that cannot be attributed to chance variation in sampling. With the large samples common in SEI data, extremely small differences can be found to be statistically significant. Conversely, quite large differences may not be statistically significant if the sample or population sizes of the groups being compared are small. Occasionally, apparently large differences are noted in the text as not being statistically significant to alert the reader that these differences may have occurred by chance.

Numerous differences are apparent in every table in SEI that reports sample data. The tables permit comparisons between different groups in the survey population and in the same population in different years. It would be impractical to test and indicate the statistical significance of all possible comparisons in tables involving sample data.

As explained in “About Science and Engineering Indicators” at the beginning of this volume, SEI presents indicators. It does not model the dynamics of the S&E enterprise, although analysts could construct models using the data in SEI. Accordingly, SEI does not make use of statistical procedures suitable for causal modeling and does not compute effect sizes for models that might be constructed using these data.

Glossary

Most glossary definitions are drawn from U.S. Office of Management and Budget, Office of Statistical Policy (2006), “Standards and Guidelines for Statistical Surveys” and U.S. Bureau of the Census (2006), “Organization of Metadata, Census Bureau Standard Definitions for Surveys and Census Metadata.” In some cases, glossary definitions are somewhat more technical and precise than those in the text, where fine distinctions are omitted to improve readability.

Administrative records: Data collected for the purpose of carrying out various programs (e.g., tax collection).

Bias: Systematic deviation of the survey estimated value from the true population value. Refers to systematic errors that can occur with any sample under a specific design.

Coverage: Extent to which all elements on a frame list are members of the population and to which every element in a population appears on the frame list once and only once.

Coverage error: Discrepancy between statistics calculated on the frame population and the same statistics calculated on the target population. *Undercoverage* errors occur when target population units are missed during frame construction, and *overcoverage* errors occur when units are duplicated or enumerated in error.

Cross-sectional sample survey: Based on a representative sample of respondents drawn from a population at a particular point in time.

Estimate: A numerical value for a population parameter derived from information collected from a survey and/or other sources.

Estimation error: Difference between a survey estimate and the true value of the parameter in the target population.

Frame: A mapping of the universe elements (i.e., sampling units) onto a finite list (e.g., the population of schools on the day of the survey).

Item nonresponse: Occurs when a respondent fails to respond to one or more relevant item(s) on a survey.

Longitudinal sample survey: Follows the experiences and outcomes over time of a representative sample of respondents (i.e., a cohort).

Measurement error: Difference between observed values of a variable recorded under similar conditions and some fixed true value (e.g., errors in reporting, reading, calculating, or recording a numerical value).

Nonresponse bias: Occurs when the observed value deviates from the population parameter due to differences between respondents and nonrespondents. Nonresponse bias may occur as a result of not obtaining 100% response from the selected units.

Nonresponse error: Overall error observed in estimates caused by differences between respondents and nonrespondents. Consists of a variance component and nonresponse bias.

Nonsampling error: Includes measurement errors due to interviewers, respondents, instruments, and mode; nonresponse error; coverage error; and processing error.

Population: See “target population.”

Precision of survey results: How closely results from a sample can reproduce the results that would be obtained from a complete count (i.e., census) conducted using the same techniques. The difference between a sample result and the result from a complete census taken under the same conditions is an indication of the precision of the sample result.

Probabilistic methods: Any of a variety of methods for survey sampling that give a known, nonzero probability of selection to each member of a target population. The advantage of probabilistic sampling methods is that sampling error can be calculated. Such methods include random sampling, systematic sampling, and stratified sampling.

They do not include convenience sampling, judgment sampling, quota sampling, and snowball sampling.

Reliability: Degree to which a measurement technique would yield the same result each time it is applied. A measurement can be both reliable and inaccurate.

Response bias: Deviation of the survey estimate from the true population value due to measurement error from the data collection. Potential sources of response bias include the respondent, the instrument, and the interviewer.

Response rates: Measure the proportion of the sample frame represented by the responding units in each study.

Sample design: Sampling plan and estimation procedures.

Sampling error: Error that occurs because all members of the frame population are not measured. It is associated with the variation in samples drawn from the same frame population. The sampling error equals the square root of the variance.

Standard error: Standard deviation of the sampling distribution of a statistic. Although the standard error is used to estimate sampling error, it includes some nonsampling error.

Statistical significance: Attained when a statistical procedure applied to a set of observations yields a p value that exceeds the level of probability at which it is agreed that the null hypothesis will be rejected.

Target population: Any group of potential sample units or individuals, businesses, or other entities of interest.

Unit nonresponse: Occurs when a respondent fails to respond to all required response items (i.e., fails to fill out or return a data collection instrument).

Universe survey: Involves the collection of data covering all known units in a population (i.e., a census).

Validity: Degree to which an estimate is likely to be true and free of bias (systematic errors).

List of Appendix Tables

Detailed appendix tables are available online at http://www.nsf.gov/statistics/indicators/appendix/ and on CD.

Chapter 1. Elementary and Secondary Mathematics and Science Education

Chapter 2. Higher Education in Science and Engineering

Chapter 3. Science and Engineering Labor Force

Chapter 4. Research and Development: National Trends and International Linkages

Chapter 5. Academic Research and Development

Chapter 6. Industry, Technology, and the Global Marketplace

Chapter 7. Science and Technology: Public Attitudes and Understanding

Chapter 8. State Indicators

Index

The complete *Science and Engineering Indicators 2010* report, appendix tables, and related resources are available on the Web at www.nsf.gov/statistics/indicators/.

To obtain printed copies of *Science and Engineering Indicators 2010* (NSB 10-01), use NSF's online publication request form, http://www.nsf.gov/publications/orderpub.jsp, or call (703) 292-7827.

www.nsf.gov/statistics/indicators/

NSB 10-01