Chapter 4

Research and Development: National Trends and International Linkages

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Highlights

National R&D Trends

U.S. R&D expenditures have continued to rise steadily since 2002, reaching an estimated $340 billion in 2006.

- After having declined in nominal terms in 2002 for the first time since 1953 to $277 billion, U.S. R&D surpassed $300 billion in 2004 and is projected to increase further to $340 billion in 2006.
- In inflation-adjusted terms, this increase represents a 2.5% average annual change over the past 4 years.

The business sector accounts for the largest share of R&D performance in the United States and provides most of the nation's R&D funding.

- The business sector's share of U.S. R&D performance peaked in 2000 at 75%, but following the economic slowdown of 2001 and 2002, the business activities of many R&D-performing firms were curtailed, with the result that the industry share fell to 69% of the U.S. R&D total, until rising again to 71% in 2006.
- In terms of funding, the business sector's share peaked at 70% of total also in 2000 but has since dipped somewhat to 64% in 2004 before inching back up to 66% of the 2006 R&D total.
- The federal share of R&D funding first fell below 50% in 1979 and dropped to a low of 25% in 2000. Reflecting initially and primarily increased research spending on health and more recently development spending in the areas of defense and counterterrorism, the federal share of R&D funding is projected at 28% of the R&D funding total in 2006.

U.S. R&D is dominated by development expenditures, largely performed by the business sector, with most basic research conducted at universities and colleges.

- In 2006, the United States performed an estimated $62 billion of basic research, $75 billion of applied research, and $204 billion of development.
- Universities and colleges historically have been the largest performers of basic research in the United States and now account for more than half (56% in 2006) of the nation's basic research. Most (59%) of the nation's basic research is federally funded.
- The development of new and improved goods, services, and processes is dominated by the business sector, which funded 83% and performed 90% of all U.S. development in 2006. The federal government funded most of the remaining development performed in the United States, mostly on defense-related activities.

Location of R&D Performance

R&D is geographically concentrated, and states vary significantly in the types of research performed within their borders.

- In 2004, more than three-fifths of U.S. R&D took place in 10 states. California alone accounted for more than one-fifth of the $300 billion of R&D that could be attributed to one of the 50 states or the District of Columbia.
- Federal R&D accounts for 85% of all R&D in New Mexico, the location of the two largest federally funded research and development centers (FFRDCs) in terms of R&D performance, Los Alamos National Laboratory and Sandia National Laboratories.
- More than 70% of all R&D performed in the United States by computer and electronic products manufacturers is located in California, Massachusetts, Texas, and Illinois.
- The R&D of chemicals manufacturing companies is particularly prominent in three states, accounting for 66% of New Jersey's, 54% of Pennsylvania's, and 50% of Connecticut's business R&D. Together these states represent more than 40% of the nation's R&D in this sector.

Business R&D

Business sector R&D reached a new high in 2005.

- R&D performed by the business sector in the United States reached $226.2 billion in 2005 and is projected to have increased to $242 billion in 2006.
- Since a peak of 4.2% in 2001, the average R&D-to-sales intensity of companies performing R&D in the United States has varied between 3.5% and 3.9%; in 2005 it was 3.7%.
- Six industrial sectors account for more than three-fourths of all industrial R&D. The aggregate R&D intensity for these industries was 7.7% in 2005; for all other industries, the aggregate R&D intensity was 1.3%.

Federal R&D

In the president's 2008 budget submission, the federal government is slated to set aside $138 billion for R&D, amounting to 12.8% of its discretionary budget.

- Federal agencies are expected to obligate $113 billion for R&D support in FY 2007. The seven largest R&D-funding agencies (each with expected R&D obligations of more than $1 billion) account for 96% of total federal R&D.

Defense-related R&D dominates the federal R&D portfolio.

- The largest R&D activity in the FY 2008 budget is defense, with a proposed budget authority of more than $82 billion (mostly on development), or about 60% of the entire federal R&D budget ($138 billion).
- In FY 2008, the Department of Defense (DOD) requested a research, development, testing, and evaluation budget of $78 billion.
- Health accounts for the largest share of nondefense R&D support; 52% of the proposed FY 2008 nondefense R&D budget was for health-related programs.

Federal and State R&D Tax Credits

Both the federal and state governments use business tax credits to promote R&D.

- Federal R&D tax credit claims reached an estimated $5.5 billion in 2003, involving just under 10,400 corporate tax returns, compared with the all-time high of $7.1 billion in 2000.
- At least 32 states offered credits for company-funded R&D in 2006. The first such credit was enacted by Minnesota in 1982, only a year after the federal research and experimentation credit was enacted. Since then, the number of states offering a research credit has increased gradually.

International R&D Comparisons

R&D is performed and funded primarily by a small number of developed nations.

- In 2002 (the latest year of available data), global R&D expenditures totaled at least $813 billion, of which 45% was accounted for by the two largest countries in terms of R&D performance, the United States and Japan.
- The R&D performance of Organisation for Economic Co-operation and Development (OECD) countries, which accounted for $657 billion in 2002, grew to $726 billion in 2004. The G-7 countries performed more than 83% of OECD R&D in 2004. Outside of the G-7 countries, South Korea is the only country that accounted for a substantial share of the OECD total.
- More money was spent on R&D activities in the United States in 2004 than in the rest of the G-7 countries combined.
- In 2004, Brazil performed an estimated $14 billion of R&D, and India performed an estimated $21 billion in 2000, making it the seventh largest country in terms of R&D in that year, ahead of South Korea.
- China had the fourth largest expenditures on R&D in 2000 ($45 billion), which increased in 2005 to an estimated $115 billion. Given the lack of R&D-specific exchange rates, it is difficult to draw conclusions from these absolute R&D figures, but the country's nearly decade-long, steep ramp-up of R&D expenditures appears unprecedented in the recent past.

Industrial firms account for the largest share of total R&D performance in each of the G-8 countries and most OECD countries.

- No one industry accounted for more than 16% of total business R&D in the United States; most other countries display much higher industry concentrations.
- The pharmaceuticals industry accounts for 20% or more of business R&D in Denmark, the United Kingdom, Belgium, and Sweden. Among OECD countries, only the Netherlands and Japan report double-digit concentration of business R&D in the office, accounting, and computing machine industry.
- Service-sector R&D has risen from 9% of all business R&D in 1993 to 15% in 2003 for European Union countries.

R&D intensity indicators, such as R&D/gross domestic product (GDP) ratios, also show the developed, wealthy economies well ahead of lesser-developed economies.

- Overall, the United States ranked seventh among OECD countries in terms of reported R&D/GDP ratios. Israel (not an OECD country), devoting 4.7% of its GDP to R&D, led all countries, followed by Sweden (3.9%), Finland (3.5%), and Japan (3.2%).
- In the United States, the slowdown in GDP growth in 2001 preceded the decline of U.S. R&D in 2002. This resulted in U.S. R&D/GDP ratios of 2.7% in 2001 (a recent high) and 2.6% in 2002 and thereafter. The U.S. R&D/GDP ratio was an estimated 2.57% in 2006.
- Most non-European (non-OECD) countries invest a smaller share of their economic output in R&D than do OECD members. For example, all Latin American countries for which such data exist have R&D/GDP ratios at or below 1%.
- Despite its growing investment in R&D, China reports an R&D/GDP ratio of just 1.3% for 2005.

R&D by Multinational Corporations

R&D by affiliates of foreign companies located in the United States increased faster than overall U.S. industrial R&D.

- Affiliates of foreign companies located in the United States performed $29.9 billion in R&D expenditures in 2004, little changed from 2003. However, between 1999 and 2004, R&D by these affiliates increased faster than overall industrial R&D in the United States (2.1% on an annual average rate basis after adjusting for inflation, compared with 0.2%).

Major developed economies accounted for the majority of overseas R&D expenditures by U.S. multinational corporations (MNCs), although certain Asian emerging markets increased their share.

- Foreign affiliates of U.S. MNCs performed $27.5 billion in R&D abroad in 2004 after adjusting for inflation, up $4.7 billion, or 17.4%, from 2003. Affiliates located in Europe represented slightly more than two-thirds of the 2004 increase. Indeed, the share of this region rebounded from an all-time low of 61% in 2001 to 66% in 2004.
- Concurrently, foreign affiliates of U.S. MNCs have increasingly engaged in R&D activities in Asian emerging markets. Within the Asia-Pacific region, Japan's share decreased from 64% in 1994 to 35% in 2004, even though it remains the largest host of U.S.-owned R&D in the region. By contrast, the R&D shares of foreign affiliates located in China and Singapore increased over this period.
- R&D expenditures by affiliates located in India doubled from $81 million in 2003 to $163 million in 2004, pushing their share within this region to 3.3%.

International Trade in R&D-Related Services

Trade in research, development, and testing (RDT) services is a relatively new indicator of international knowledge and technology flows.

- In 2005, exports of RDT services reached $10.1 billion, compared with imports of $6.7 billion, resulting in a trade surplus of $3.4 billion.
- International transactions in RDT services are available for two major categories: trade among independent or unaffiliated companies and trade among affiliates of MNCs (affiliated trade). Affiliated RDT trade has been larger than unaffiliated trade since 2001, when the former became available for the first time. The prominence of affiliated trade in business services, particularly R&D-related services, may reflect advantages of internally managing, exploiting, and protecting complex or strategic transactions involving proprietary technical information.

Federal Technology Transfer

R&D performed at federal laboratories, whether run by federal agencies themselves or by contractors, represents a key source for knowledge and technologies.

- Federal technology transfer activities and metrics reflect the variety of agency missions, R&D organization and funding structures (e.g., intramural versus extramural laboratories), the character of R&D activities, and the characteristics of potential downstream technologies or industrial users.
- The Department of Energy and DOD had the largest shares of inventions disclosed and patents, whereas the National Institutes of Health/Food and Drug Administration had the largest share of new invention licenses, according to available data for FY 2005.

Introduction

Chapter Overview

As nations seek to develop knowledge-based aspects of their economies, science, engineering, and related technological activities are recognized as key drivers. Furthermore, industrial R&D has become increasingly interconnected financially, geographically, and functionally across a number of dimensions, including performing, funding, and user sectors; scientific disciplines; and business functions.

Innovation—the introduction of new goods, services, or processes in the marketplace—builds on new knowledge and technologies, contributes to national competitiveness and government agencies' missions, and furthers social welfare. A distinction is made between R&D and the implementation or commercialization of the resulting knowledge. R&D expenditures indicate the priority given to advancing science and technology (S&T) relative to other public and private goals. For example, R&D must compete for funding with other activities supported by discretionary government spending, from education to energy to national defense. In the private sector, R&D and other innovation investments are also subject to cost-benefit analyses, including productivity and organizational issues, and are increasingly linked to broader strategic business goals.

The continued policy relevance of the national innovation landscape, which includes, for example, R&D, education, tax incentives, and intellectual property protection, is reflected in the American Competitiveness Initiative (OSTP 2006) and in the recently enacted America COMPETES Act (Public Law 110–69). In support of these efforts, Dr. John H. Marburger III, the president's S&T adviser, has challenged the policy, research, and statistical community to develop better data, models, and tools for understanding the U.S. scientific and engineering enterprise in its global context by advancing the science of science policy. Concurrently, international bodies such as the Organisation for Economic Co-operation and Development's (OECD) Working Party of National Experts on Science and Technology Indicators and the United Nations Statistical Commission have engaged in several research and methodological activities to improve metrics, including work leading to new or updated statistical manuals on innovation, globalization, national economic accounts, and services trade.

Because the organizations that fund R&D shape how it is performed and what kinds of innovations nations ultimately produce, this chapter focuses on financial inputs and flows. The chapter also presents trends in R&D performance, notably R&D by industry and the federal government. Where data permit, the chapter includes comparisons with other countries. Analyses of the R&D activities of multinational corporations (MNCs) point out the importance of this growing interconnectedness. Global R&D and related international investments still are concentrated in a few developed countries or regions. However, during the past decade, certain developing markets have increased their national R&D expenditures and have become hosts of R&D by MNCs from the United States and other advanced economies.

The chapter also introduces new indicators of industrial knowledge flows in terms of U.S. international trade in R&D-related services. Transactions in these services represent the convergence of two recent trends in industrial S&T: an increase in R&D performance in the service sector and an increase in external and overseas links in innovation activities.

Chapter Organization

This chapter is organized into seven sections that examine trends in R&D domestic and international expenditures and collaborative technology activities. The first section provides an overview of national trends in R&D performance and R&D funding. The second analyzes data on the location of R&D performance in the United States. The third and fourth sections focus on the respective roles of business enterprises and the federal government in the R&D enterprise. The latter section also includes indicators on federal and state tax incentives for industrial R&D.

International R&D trends within nations and MNCs are discussed in the fifth and sixth sections, respectively. The former includes total and nondefense R&D spending; ratios of R&D to gross domestic product (GDP) in various nations; international R&D funding by performer and source; the allocation of R&D efforts among components (basic research, applied research, and development); and international comparisons of government R&D priorities. The sixth section presents data on R&D by U.S. MNCs and their overseas affiliates and by affiliates of foreign companies in the United States. Data include R&D expenditures by investing or host countries and their industrial focus, and R&D employment.

The last section summarizes available information on external technology sourcing and collaborative R&D activities across R&D-performing sectors, including domestic contract R&D, international trade in R&D services, business technology alliances, and federal technology transfer.

National R&D Trends

The National Science Foundation (NSF) estimated that expenditures for R&D conducted in the United States would grow to $340 billion in 2006, continuing a pattern of growth largely uninterrupted since 1953, when these data were first collected (see sidebar, "Definitions of R&D"). As points of reference, U.S. R&D first exceeded $100 billion in 1984, $200 billion in 1997, and $300 billion in 2004. After adjusting for inflation, total R&D increased a projected 2.3% between 2005 and 2006, following an increase of 4.5% between 2004 and 2005.[1] These recent growth rates in R&D are in line with the average annual growth rates over the past two decades and are largely driven by increases in R&D expenditures in the business sector (figure 4-1).

Official U.S. R&D data are derived by adding up the R&D expenditures for all sectors of the economy for which expenditures can be reasonably estimated. Generally these figures only include expenditures on projects that are recognized as R&D and that are separately budgeted and tracked by organizations, and therefore they do not represent the total expenditures on R&D and innovation in the economy. For example, the General Electric Company notes in its 2005 annual report that its R&D expenditures for 2005 were $3.4 billion, according to the definition of R&D required by generally accepted accounting principles in the United States. However, the report goes on to state, “For operating and management purposes, we consider amounts spent on product and services technology to include our reported R&D expenditures, but also amounts for improving our existing products and services, and the productivity of our

Definitions of R&D

R&D. According to international guidelines for conducting research and development 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, p. 30).

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.

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. R&D plant includes the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities. U.S. statistics include separate tabulations for R&D plant (NSF/SRS 2007b), which are not generally available in comparable international R&D statistics.

Budget authority. Budget authority is the authority provided by federal law to incur financial obligations that will result in outlays.

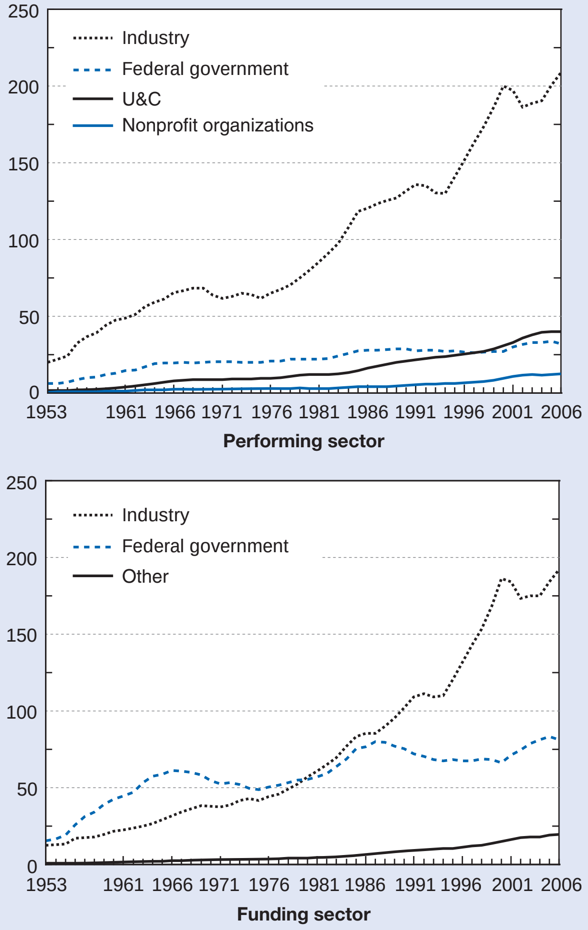
Obligations. Federal obligations represent the dollar amounts for orders placed, contracts and grants awarded, services received, and similar transactions during a given period, regardless of when funds were appropriated or payment was required.

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 (2006b).

Figure 4-1
National R&D, by performing and funding sectors, 1953–2006

Constant 2000 dollars (billions)



U&C = universities and colleges

NOTE: Federal performers of R&D include federal agencies and federally funded research and development centers. Other includes U&C, nonprofit, and state and local governments.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-4 and 4-6.

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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. However, to evaluate U.S. R&D performance over time and in comparison with other countries, it is necessary to gauge how much R&D is going unmeasured in the United States. The following are indicators 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. There are no estimates of R&D performance 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 not included in official U.S. R&D statistics.
- Social science R&D is excluded from U.S. industrial R&D statistics, and 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.
- R&D performed by state and local governments in the United States is not currently estimated for national statistics. A new survey of state R&D is currently being collected by NSF and the Census Bureau.

Although NSF estimates the R&D performance of nonprofit organizations, a nonprofit R&D survey has not been fielded since 1998.

Recent Developments in Innovation-Related Metrics

This sidebar reports on recent or ongoing initiatives aimed at advancing innovation-related measures. As noted earlier, a distinction is made between R&D and the subsequent implementation or commercialization of the resulting knowledge.

NSF Workshop: Advancing Measures of Innovation

NSF held a workshop focused on innovation metrics during the summer of 2006, “Advancing Measures of Innovation: Knowledge Flows, Business Metrics, and Measurement Strategies.” The workshop was driven by several considerations, including the challenge by Dr. John H. Marburger III, the president’s S&T adviser, for better data, models, and tools for understanding the U.S. S&E enterprise (Marburger 2005a, b). A number of strategies for data development were discussed at the workshop: survey-based methods, data linking and data integration, nonsurvey-based methods (such as mining of administrative data), and using case studies and qualitative data. The sense of the workshop was that these diverse strategies are not mutually exclusive and can be pursued productively in parallel or in combination. For workshop presentations and a summary report, see NSF/SRS (2006a).The OECD’s Blue Sky Forum, which followed the NSF workshop, discussed the development of new and better indicators of science, technology, and innovation and developed a synthesis of findings toward an agenda for the next decade. For more information about the Blue Sky Forum, see OECD (2006a).

Federal Initiatives Supporting New Metrics

Science of Science and Innovation Policy (SciSIP) is an NSF research initiative started in the fall of 2006. The initiative is expected to develop the foundations of an evidence-based platform from which policymakers and researchers may assess the nation’s S&E enterprise, improve their understanding of its dynamics, and predict its outcomes. The research, data collection, and community development components of SciSIP’s activities will: (1) develop theories of creative processes and their transformation into social and economic outcomes; (2) improve and expand science metrics, datasets, and analytical tools; and (3) develop a community of experts on SciSIP. Additional information is available at NSF/SBE (2007).

In addition to the OSTP interagency taskforce described on page 4-11, the Department of Commerce (DOC) established the Measuring Innovation in the 21st Century Economy Advisory Committee to “study metrics on effectiveness of innovation in various businesses and sectors, and work to identify which data can be used to develop a broader measure of innovation’s impact on the economy.” The committee held its first public meeting in February 2007. See DOC (2007) for further details.

Lastly, the America COMPETES Act (Public Law 110–69) enacted in the summer of 2007 establishes, among other measures, a President’s Council on Innovation and Competitiveness. In addition to policy monitoring and advice, the Council’s duties include “developing a process for using metrics to assess the impact of existing and proposed policies and rules that affect innovation capabilities in the United States” as well as “developing metrics for measuring the progress of the Federal government with respect to improving conditions for innovation, including through talent development, investment, and infrastructure development. . . .” For the complete text of the America Competes Act, see Library of Congress (2007).

plant, equipment, and processes. On this basis, our technology expenditures in 2005 were $5.2 billion" (GE 2006). For a description of other activities not captured in official U.S. R&D statistics, see sidebar, "Unmeasured R&D."

The U.S. innovation system comprises a diverse set of organizations, each with its own goals, priorities, and capabilities. These organizations include small businesses, MNCs, federal and state agencies, universities and colleges, research hospitals, and others. Because R&D often involves significant transfers of resources between organizations and sectors, the sections below analyze R&D both in the context of who is performing the R&D as well as in the context of who is funding the R&D.

Innovation—the introduction of new goods, services, or business processes in the marketplace—builds on new knowledge and technologies and contributes to national competitiveness and other social goals (NRC 2005b; OECD 2005; OSTP 2006). However, technology-based innovation activities include, but are not limited to, R&D. In response to the growing importance and complexity of these issues, the National Science and Technology Council, under the auspices of the White House Office of Science and Technology Policy (OSTP), has formed an Interagency Task Group on Science of Science Policy. The task group is analyzing federal and international efforts in science and innovation policy, identifying tools needed for new indicators and charting a strategic road map to improve theoretical frameworks, data, models, and methodologies. See also sidebar, "Recent Developments in Innovation-Related Metrics."

Performers of R&D

Expenditures on R&D reported by R&D-performing organizations reflect the level of effort, in financial terms, expended on the creation of new knowledge and the use of that knowledge to devise new and improved S&T applications. However, these data in and of themselves do not indicate how successful or effective these efforts are, only how much money is spent on them. For a methodology to measure the role of R&D in economic growth, see sidebar, "The BEA/NSF R&D Satellite Account."

Business Sector

In dollar terms, the business sector performed an estimated 71% ($242 billion of a total of $340 billion) of U.S. R&D in 2006 (figure 4-2). The business sector's share of U.S. R&D peaked in 2000 at 75%, but following the stock market decline and subsequent economic slowdown of 2001 and 2002, the business activities of many R&D-performing firms were curtailed. As a result, business R&D declined by 2% per year in real terms between 2000 and 2003, and the industry share fell to 69% of the U.S. R&D total. Subsequently, R&D expenditures in the business sector grew by more than 3% per year in real terms between 2003 and 2006 and now account for 71% of the U.S. R&D total.

Of the estimated $242 billion of business sector R&D expenditures in 2006, $23 billion was funded by the federal government (table 4-1). Before the late 1960s, the federal government was the primary source of funding for business R&D, but it now accounts for less than 10% of all R&D performed by businesses in the United States. This decline in

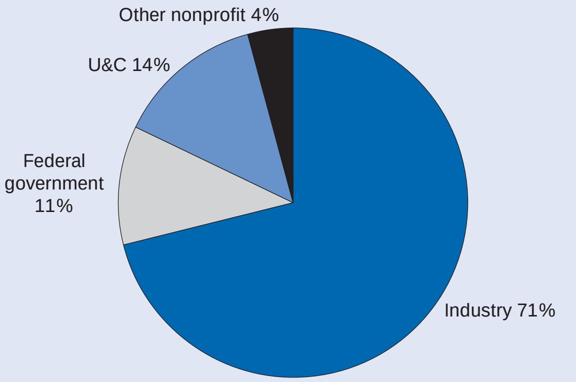
The BEA/NSF R&D Satellite Account: R&D and Economic Growth

Satellite accounts are supplementary estimates of the GDP and related measures that provide greater detail or alternative measurement concepts without changing the core accounts. In particular, the purpose of the R&D satellite account is to consider R&D as an economic investment or capital (i.e., capitalizing R&D). This is an ongoing project involving NSF's Division of Science Resources Statistics, the agency responsible for official U.S. statistics on R&D expenditures, and the Bureau of Economic Analysis (BEA), the agency responsible for the U.S. national economic accounts. This activity is one of several interagency efforts aimed at improved measures of intangibles and their economic role (Jorgensen, Landefeld, and Nordhaus [2006]; Okubo et al. [2006]). Current plans call for the incorporation of R&D capital into the National Income and Product Accounts' core accounts in 2013, based on the concepts developed in the satellite account.

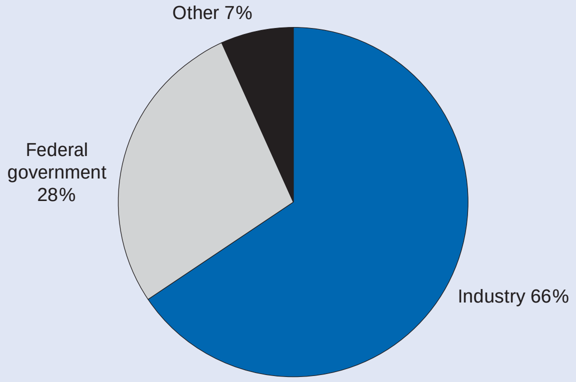
Measuring R&D as capital investment recognizes its long-term benefits much as investments in physical assets such as highways and machinery. As a newly recognized component of investment, R&D has a direct impact on GDP because business expenditures for R&D become part of economic output, instead of being treated as an expense. According to these estimates, capitalizing R&D increases the level of GDP in current dollars by an average of 2.5% per year from 1959 to 2002 (Okubo et al. 2006). In terms of GDP growth, R&D capital would account for about 4.5% of real GDP growth during that same period. During the more recent period 1995–2002, R&D investment would account for about 6.5% of growth. By comparison, according to BEA, business investment in commercial and all other types of buildings accounted for slightly more than 2% of real GDP growth between 1959 and 2002.

Further research topics include the measurement of the overall impact, both direct and indirect, of R&D activity on productivity. The indirect effects of R&D activity on productivity include spillovers that accrue when the benefits to the economy as a whole are larger than the benefits to the private owners of R&D. Additional research topics include the incorporation of international R&D flows and several methodological improvements. For more information, see BEA (2007a).

Figure 4-2
Shares of national R&D expenditures, by performing and funding sectors: 2006



Performing sector



Funding sector

U&C = universities and colleges

NOTES: National R&D expenditures projected at $340 billion in 2006. Federal performing sector includes federal agencies and federally funded research and development centers. Values rounded to nearest whole number.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3 and 4-5.

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federal R&D funding as reported by businesses differs from the trend in R&D data collected from federal agencies. (For details on this discrepancy, see sidebar, “Tracking R&D: Gap Between Performer- and Source-Reported Expenditures” later in the chapter.)

Universities and Colleges

The next largest sector in terms of R&D performance is the academic sector. Universities and colleges performed almost $47 billion of R&D in 2006, one-fifth the amount performed by businesses in the United States. However, universities and colleges perform more than half (56%) the nation’s basic research. (See the discussion of R&D by character of work that appears later in this chapter.) Universities and colleges rely much more than businesses on external sources of R&D funding. In 2006, slightly less than 20% of university and college R&D was funded by institutional funds, and more than 61% was funded by the federal government (table 4-1). In recent years, the amount of R&D performed by universities and colleges has grown faster than in any other sector of the U.S. economy. Academic R&D grew at an average annual 7.4% real rate between 2000 and 2003, but more recently this growth slowed to 1.9% per year in real terms between 2003 and 2006. See chapter 5 for a more detailed discussion of trends in academic R&D expenditures.

Federal Agencies and FFRDCs

Federal agencies and federally funded research and development centers (FFRDCs) accounted for an estimated 11% of the R&D performed in the U.S. in 2006.[2] Although the amount of R&D performed by these organizations is small compared to the U.S. business sector, the $37 billion in R&D expenditures at these organizations exceeds the total national R&D expenditures of every country in the world other than China, Germany, and Japan. These expenditures also do not include the sizable investments the U.S. government has made in R&D infrastructure and equipment. The federal government often maintains research facilities and conducts research projects that would be too costly or risky for a single company or university to undertake. Largely as a result of increased defense spending following the terrorist attacks of September 11, 2001, expenditures for R&D conducted by federal agencies and FFRDCs grew at the rapid rate of almost 6.6% per year in real terms between 2000 and 2003. In terms of total U.S. R&D, this growth helped offset the decline in business sector R&D during that period. Since 2003, the real R&D expenditures at federal agencies and FFRDCs have remained basically flat. Federal R&D is discussed in more detail later in this chapter.

R&D Funding

The funding for R&D conducted by organizations in the United States can come from a variety of sources, including the organizations’ own funds as well as contracts and grants from other organizations. Although data on the flows of R&D funding within sectors (such as between two companies) is limited, 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 2006, an estimated 20% of U.S. R&D ($67 billion) was funded by an organization in a different sector than the performing sector. Most of this intrasector R&D funding comes from the federal government, which funds significantly more R&D than it conducts in its own laboratories and FFRDCs (table 4-1). Unlike the federal government, most businesses spend their R&D budgets on either internal R&D projects or for contract R&D performed by other businesses (see the section entitled “Technology Linkages”). Less than 2% of business R&D funding flows to universities and other nonprofit organizations, although industry funded approximately 5% of all universities’ 2006 R&D.

Table 4-1
U.S. R&D expenditures, by funding and performing sectors: 2006
(Millions of current dollars)

Performing sector	Source of funds: All sources	Industry	Federal government	U&C	Other nonprofit institutions	All expenditures (% distribution)
R&D	340,429	223,370	94,217	12,354	10,488	100.0
Industry	242,129	219,569	22,560	NA	NA	71.1
Industry-administered FFRDCs	2,426	NA	2,426	NA	NA	0.7
Federal government	24,408	NA	24,408	NA	NA	7.2
U&C	46,642	2,452	28,548	12,354	3,288	13.7
U&C-administered FFRDCs	7,720	NA	7,720	NA	NA	2.3
Other nonprofit institutions	14,270	1,349	5,721	NA	7,200	4.2
Nonprofit-administered FFRDCs	2,834	NA	2,834	NA	NA	0.8
Percent distribution by source	100.0	65.6	27.7	3.6	3.1	NA

NA = not available
FFRDC = federally funded research and development center; U&C = universities and colleges

NOTES: State and local government support to industry included in industry support for industry performance. State and local government support to U&C ($3,057 million in total R&D) included in U&C support for U&C performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-3.

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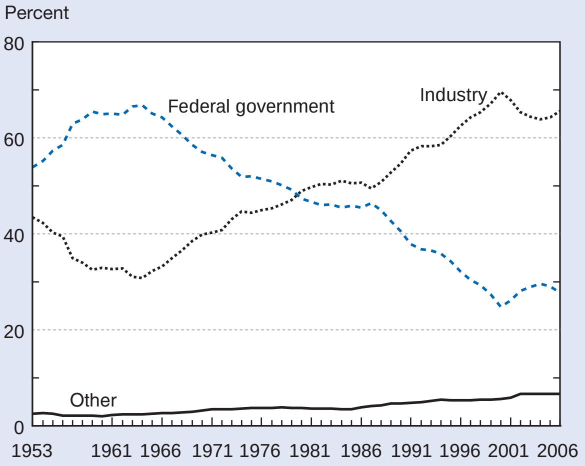
Federal R&D Funding

In 2006, the federal government is projected to have funded $94 billion of R&D as reported by performers of R&D, accounting for 28% of all R&D funding in the United States (figure 4-2). The federal government was once the foremost sponsor of the nation's R&D, funding as much as 67% of all U.S. R&D in 1964 (figure 4-3). The federal share first fell below 50% in 1979 and dropped to a low of 25% in 2000. The declining share of federal R&D funding is most 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. The decades-long trend of federal R&D funding shrinking as a share of the nation's total R&D reversed between 2000 and 2004. During this period, private investment slowed and federal spending on R&D expanded, reflecting initially and primarily increased research spending on health, and, more recently, development spending in the areas of defense and counterterrorism. By 2004, the federal share of the nation's R&D funding had increased to 30%. The federal share of R&D funding has since declined to an estimated 28% in 2006, as noted earlier.

Nonfederal R&D Funding

R&D funding from nonfederal sources reached an estimated $246 billion in 2006. Business sector funding dominates nonfederal R&D support. Besides performing the majority of U.S. R&D, the business sector also is the largest source of R&D funding in the United States, providing 66% ($223 billion) of total R&D funding in 2006 (figure 4-2). The business sector's share of national R&D funding first surpassed the federal government's share in 1980. From 1980 to 1985, industrial support for R&D, in real dollars, grew at an average annual rate of almost 8%. This growth was maintained through both the mild 1980 recession and the more severe 1982 recession (figure 4-1). Between 1985 and 1994, growth in R&D funding from industry was slower, averaging only 3% per year in real terms. However, from 1994 to 2000, industrial R&D support grew in real terms by more than 9% per year. This rapid growth rate came to a halt following the downturn in both the market valuation and economic demand for new technology during the first years of the 21st century. Between 2000 and 2002, industrial R&D support declined by more than 3% per year in real terms, but

Figure 4-3
National R&D expenditures, by funding sector: 1953–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-5.

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between 2002 and 2006, it grew by almost 3% per year in real terms.

Although R&D funding from other nonfederal sectors, namely academic and other nonprofit institutions and state and local governments, is small in comparison to federal and business R&D spending, it has grown rapidly. Between 1986 and 2006, funding from these sectors grew almost 6% per year in real terms, faster than R&D funding from either the federal or business sectors. Most of these funds went to research performed within the academic sector.

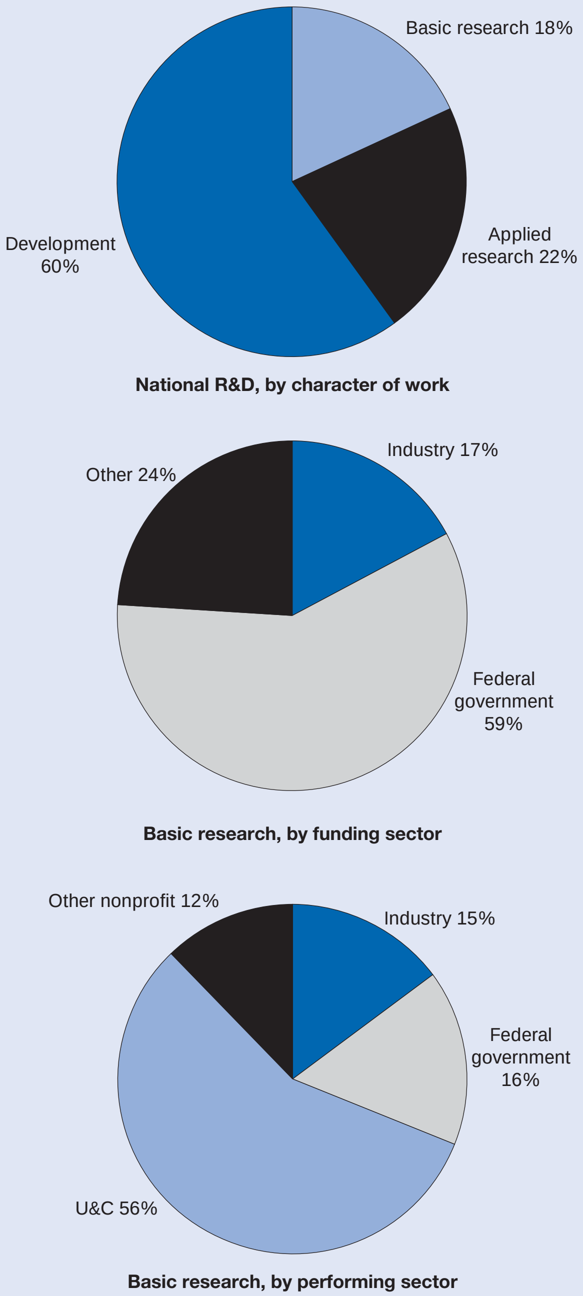
Unlike some other countries, the United States does not currently measure the amount of domestic R&D that is funded by foreign sources. However, data on investments of foreign MNCs provide some indication of this activity for the industrial sector (see the section entitled “R&D by Multinational Corporations” later in this chapter).

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 critical issues such as global climate change, energy efficiency, and disease; to the development of new and improved goods and services (from razor blades to fighter jets to business software). Because these activities are so diverse, it is helpful to group them into categories when analyzing R&D expenditures. Historically, the most common set of categories used to classify R&D are basic research, applied research, and development. The categories have been criticized by some economists and policymakers as being overly simplistic and reinforcing the idea that innovation is a linear process beginning with basic research, followed by applied research and development, and ending with the production and diffusion of technology. Although alternative models have been proposed, they have not been widely adopted by policymakers because of a lack of consensus about them and/or a lack of official data robust enough to support them.[3] Despite the difficulties in classifying specific R&D projects, the categories presented here help characterize the motivation, expected time horizons, outputs, and types of investments associated with R&D expenditures.

In 2006, the United States performed an estimated $62 billion of basic research, $75 billion of applied research, and $204 billion of development. As a share of all estimated 2006 R&D expenditures, basic research represented 18%, applied research represented 22%, and development represented 60% (figure 4-4). Historically, the federal government has been the primary source of support for basic research. In 2006, federal funding accounted for 59% of U.S. basic research (figure 4-4). Moreover, in 2006 the federal government funded 64% of the basic research performed by universities and colleges, the largest performers of basic research in the United States. Industry devoted only a projected 4% of its total R&D support to basic research in 2006 (figure 4-5). The reason for industry’s relatively small contribution to basic research is

Figure 4-4
National R&D, by character of work, and basic research, by funding and performing sectors: 2006



U&C = universities and colleges

NOTES: National R&D expenditures projected at $340 billion in 2006. Federal performers include federal agencies and federally funded research and development centers. Figures rounded to nearest whole number. Due to rounding, detail may not sum to totals.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3, 4-7, 4-11, and 4-15.

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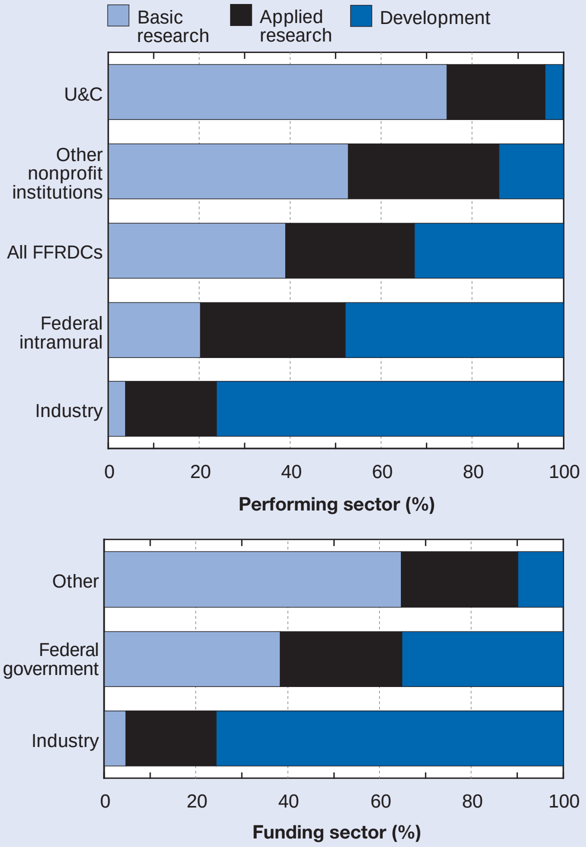
Figure 4-5
R&D performing and funding sectors, by character of work: 2006



FFRDCs = federally funded research and development centers; U&C = universities and colleges

NOTES: State and local government support to industry included in industry support for industry performance. State and local government support to U&C ($3,057 million in total R&D) included in U&C support for U&C performance.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-3, 4-7, 4-11, and 4-15.

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that basic research generally involves a high degree of uncertainty with respect to the near-term commercial value of any discovery and the ability of the firm to enforce property rights over the discovery. However, firms may have other reasons for performing basic research above and beyond immediate commercial demands. For example, a company that supports basic research could boost its human capital (by attracting and retaining academically motivated scientists and engineers) and strengthen its innovative capacity (i.e., its ability to absorb external scientific and technological knowledge). The industries that invest the most in basic research are those whose new products are most directly tied to recent advances in S&T, such as the pharmaceuticals industry and the scientific R&D services industry.

The business sector spends more than four times as much on applied research as on basic research and accounts for more than half of U.S. applied research funding. In 2006, industry invested an estimated $44 billion in applied research funding, 59% of the U.S. total. Examples of industries that perform a relatively large amount of applied research are the chemicals industry, the aerospace industry (largely financed by the Department of Defense (DOD)), and the R&D services industry (encompassing many companies whose business is licensing technology). Although most of the federal investment in basic research supports research at universities and colleges, the majority of federally funded applied research is performed by federal agencies and FFRDCs.

Development expenditures totaled an estimated $204 billion in 2006, representing the majority of U.S. R&D expenditures. The development of new and improved goods, services, and processes is dominated by industry, which funded 83% of all U.S. development in 2006 ($169 billion). The federal government funded most of the remaining development performed in the United States, totaling 16% or $33 billion. Most federal development spending is defense related. The federal government generally invests in the development of such products as military aircraft, for which it is the only consumer. The business sector conducts even more development than it funds, accounting for 90% of all development conducted in the United States in 2006. Universities, colleges, and other nonprofit institutions conducted less than 2% of U.S. development. The balance of development is conducted by federal agencies and FFRDCs.

The OECD notes that in measuring R&D, possibly the greatest source of error "is the difficulty of locating the cut-off point between experimental development and the related activities required to realize an innovation" (OECD 2002). Most definitions of R&D set the cut-off point to be when a particular product or process reaches the point of "market readiness." At this point, the defining characteristics of the product or process (at least for manufacturers, if not also for services) are substantially set, and further work is primarily aimed at developing markets, doing preproduction planning, or getting a production or control system working smoothly.

Location of R&D Performance

R&D performance is geographically concentrated in the United States. More than 50% of U.S. R&D is performed in only seven states.[4] Although R&D expenditures are concentrated in relatively few states, patterns of R&D activity vary considerably among the top R&D-performing locations (appendix table 4-23). (For a broader range of indicators of state-level S&E activities, see chapter 8.)

Distribution of R&D Expenditures Among States

In 2004, the 20 highest-ranking states in R&D expenditures accounted for 85% of U.S. R&D expenditures, whereas the 20 lowest-ranking states accounted for 5%. (A complete list of state rankings is provided in appendix table 4-24.) The top 10 states accounted for more than three-fifths of U.S. R&D expenditures in 2004 (table 4-2). California alone accounted for approximately one-fifth of the $300 billion U.S. R&D total, exceeding the next highest state (Michigan) by more than a factor of three.[5] States vary significantly in the size of their economies because of differences in population, land area, infrastructure, natural resources, and history. Consequently, state variations in R&D expenditure levels may simply reflect differences in economic size or the nature of R&D efforts. One way to control for the size of each state's economy is to measure each state's R&D level as a percentage of its share of GDP. Like the ratio of national R&D to GDP discussed later in this chapter, the proportion of a state's GDP devoted to R&D is an indicator of R&D intensity. Some of the states with the highest R&D to GDP ratios include New Mexico and Maryland, home to major government research facilities; Massachusetts, home to a number of large research universities and a thriving high-technology industry; and Michigan, home to the major auto manufacturers. A list of states and corresponding R&D intensities can be found in appendix table 4-24.

Sector Distribution of R&D Performance by State

Although leading states in total R&D tend to be well represented in each of the major R&D-performing sectors, the proportion of R&D performed in each of these sectors varies across states. Because business sector R&D accounts for 71% of the U.S. R&D total that can be distributed among states, it is not surprising that 9 of the top 10 states in terms of total R&D performance are also in the top 10 in terms of industry R&D (table 4-2). Connecticut, 10th in terms of business sector R&D, replaced Maryland among the leading 10 states for total R&D. University-performed R&D accounts for only 15% of the U.S. total, but it is also highly correlated with the total R&D performance in a state. Only New Jersey and Washington, among the top 10 total R&D state locations, were not among the top 10 locations for university R&D performance. North Carolina and Ohio rounded out the academic R&D top 10.

There is less of a relationship between federal R&D performance (both intramural and FFRDC) and total R&D, as federal R&D is more geographically concentrated than the R&D performed by other sectors.[6] The top four states in terms of federal R&D (Maryland, California, New Mexico, and Virginia), along with the District of Columbia, account for two-thirds of all federal R&D performance. Federal R&D accounts for 85% of all R&D in New Mexico, the location of the two largest FFRDCs in terms of R&D performance, Los Alamos National Laboratory and Sandia National Laboratories. Federal R&D accounts for about 50% of all R&D performed in Maryland, Virginia, and the District of Columbia, reflecting the concentration of federal facilities and adminis-

Table 4-2
Top 10 states in R&D performance, by sector and intensity: 2004

	All R&D[a]		Sector ranking			R&D intensity (R&D/GDP ratio)		
Rank	State	Amount (current $millions)	Industry	U&C	Federal intramural and FFRDC[b]	State	R&D/ GDP (%)	GDP (current $billions)
1	California	59,607	California	California	Maryland	New Mexico	8.01	63.9
2	Michigan	16,722	Michigan	New York	California	Maryland	6.26	229.2
3	Massachusetts	15,987	Massachusetts	Texas	New Mexico	Massachusetts	5.17	309.5
4	Maryland	14,341	New Jersey	Maryland	Virginia	Michigan	4.60	363.4
5	Texas	14,266	Texas	Pennsylvania	District of Columbia	Rhode Island	4.36	42.2
6	New York	13,113	Washington	Massachusetts	Massachusetts	Washington	4.33	252.4
7	New Jersey	12,460	New York	Illinois	Illinois	Connecticut	4.29	183.9
8	Illinois	11,300	Illinois	North Carolina	Washington	California	3.93	1,515.5
9	Washington	10,936	Pennsylvania	Michigan	Alabama	New Hampshire	3.22	51.7
10	Pennsylvania	10,813	Connecticut	Ohio	Tennessee	District of Columbia	3.06	77.8

FFRDC = federally funded research and development center; GDP = gross domestic product; U&C = universities and colleges

[a] Includes in-state total R&D performance of industry, 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: Rankings do not account for margin of error of estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Bureau of Economic Analysis, Gross Domestic Product by State (2006), http://www.bea.gov/regional/gsp, accessed 25 August 2007.

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trative offices within the national capital area. Federal R&D also represents 33% of the R&D performed in Alabama and West Virginia. The Departments of Energy (DOE) and Agriculture (USDA) account for the largest shares of federal intramural R&D performance in West Virginia, whereas DOD's Redstone Arsenal laboratories and the National Aeronautics and Space Administration's (NASA) George C. Marshall Space Flight Center, both in Huntsville, account for most of Alabama's federal R&D activity. Looking across all states, federal R&D represents 12% of the distributed U.S. total.

Industrial R&D in Top States

The types of companies that carry out R&D vary considerably among the 10 leading states in industry-performed R&D (table 4-3). This reflects regional specialization or clusters of industrial activity. For example, in Michigan, the motor vehicles industry accounted for 74% of industrial R&D in 2005, whereas it accounted for only 7% of the nation's total industrial R&D.

The computer and electronic products manufacturing industries perform 19% of the nation's total industrial R&D, but they perform a larger share of the industrial R&D in Massachusetts (41%), Texas (38%), Illinois (38%), and California (33%). These states have clearly defined regional centers of high-technology research and manufacturing: Cambridge and Route 128 in Massachusetts; the Silicon Hills of Austin, Texas; Champaign County in Illinois; and Silicon Valley in California. More than 70% of R&D performed in the United States by computer and electronic products companies in 2005 was located in these four states, representing 14% of all business R&D nationwide.

The R&D of chemicals manufacturing companies is particularly prominent in New Jersey, Pennsylvania, and Connecticut, all of which host robust pharmaceutical and chemical industries. According to the American Chemistry Council, together these states host more than 1,600 chemical manufacturing establishments and rank among the top 20 in chemical industry employment (American Chemistry 2007). These companies accounted for 66% of New Jersey's, 54% of Pennsylvania's, and 50% of Connecticut's business R&D in 2005. Together these three states represented more than 40% of the nation's R&D in this sector.

The R&D services sector, which consists largely of biotechnology companies, contract research organizations, and early-stage technology firms, is even more concentrated geographically, with California and Massachusetts accounting for more than 40% of R&D in this sector. The companies in this sector maintain strong ties to the academic sector and often are located near large research universities (Stuart and Sorenson 2003).

The R&D performance of small companies (defined as having from 5 to 499 employees) is also concentrated geographically.[7] Nationally, small companies perform 18% of the nation's total business R&D, but in California, Massachusetts, and New York these companies perform between 19% and 22% of the states' business R&D. About 39% of the R&D performed in the United States by companies in this category is performed in these three states. Overall, these companies performed 7% of the nation's R&D in 2005.

Table 4-3
Top 10 states in industry R&D performance and share of R&D, by selected industry: 2005
(Percent)

State	Industry-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	226,159	19.0	19.2 L	13.5	7.5	7.1 L	17.9
California	50,683	11.2	33.2	15.0	10.7	D	21.8
Michigan	16,752	9.5	2.3	D	1.5	74.3	6.2
Massachusetts	13,342	13.2	41.1	D	11.1	D	22.3
New Jersey	13,214	65.7	5.7	3.5	5.6	0.2	13.1
Texas	12,438	4.7	37.4	18.3	6.3	0.5	16.1
Washington	9,736	5.5	5.6	D	6.3	0.7	11.7
Illinois	9,712	18.9	37.4	5.1	1.7	2.4	12.4
New York	9,474	28.4	6.6	18.8	3.7	D	18.5
Pennsylvania	8,846	54.2	6.9	6.0	8.3	0.4	15.4
Connecticut	7,885	50.3	3.5	2.4	4.0	0.1	11.5

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.

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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. For most firms, R&D is a discretionary expense. R&D does not directly generate revenue in the same way that production expenses do, so it can be trimmed with little impact on revenue in the short term. Firms attempt to invest in R&D at a level that maximizes future profits while maintaining current market share and increasing operating efficiency. R&D expenditures, therefore, indicate the level of effort dedicated to producing future products and process improvements in the business sector. By extension, they may reflect firms' perceptions of the market's demand for new and improved technology.

R&D performed by the business sector reached $226 billion in 2005. The federal government funded 9.7% ($22 billion) of this total, and company funds and other private sources financed the remainder (appendix tables 4-19, 4-20, and 4-21). These estimates are 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. business R&D estimates (see sidebar, "Industry Classification").

In addition to absolute levels of R&D expenditures, another key company S&T indicator in the business sector is R&D intensity, a measure of R&D relative to production in a company, industry, or sector. Many ways exist to measure R&D intensity, including the ratio of R&D to GDP discussed earlier. The measure used most frequently is the ratio of company-funded R&D to net sales.[8] This statistic provides a way to gauge the relative importance of R&D across industries and among firms in the same industry. The average R&D intensity of companies performing R&D in the United States reached its highest reported level of 4.2% in 2001; R&D performance remained steady compared with the previous year, while sales of R&D-performing companies declined. Since then, R&D intensity has varied between 3.5% and 3.9%; in 2005, it was 3.7%.

Largest R&D Industries

Although all industries benefit from advances in S&T, industries perform different amounts of R&D.[9] Some industries have relatively low R&D intensities (0.5% or less), such as the utilities industry[10] and the finance, insurance, and real estate industries. Appendix table 4-22 provides data on company-funded R&D to net sales ratios for an array of industries.[11] Six industries, four manufacturing and two services industries, account for 75% of company-funded business R&D and 95% of federally funded business R&D (table 4-4).[12]

Computer and Electronic Products

The computer and electronic products manufacturing sector accounts for the largest amount of business R&D performed in the United States (table 4-4). Industries in this sector include companies that manufacture computers, computer peripherals, communications equipment, and similar electronic products, and companies that manufacture components for such products. The design and use of integrated circuits and the application of highly specialized miniatur-

Industry Classification

As a result of classification conventions, interpretation of industry-level R&D data is not always straightforward. Initially, each company sampled in NSF's Survey of Industrial Research and Development is assigned to a single industry according to payroll data for the company,* and each is requested to report its R&D expenditures for the entire company. These expenditures are assigned to the previously classified single industry. This classification scheme reasonably categorizes most companies into industries closely aligned with their primary business activities. However, for diversified companies that perform R&D in support of a variety of industries, any single assigned industry is only partly correct. And in some cases, the industry assigned based on payroll data is not directly related to a company's R&D activities.

It is important to assess the relationships between industries as well as the business structure within industries when analyzing R&D data. For example, most of the federally funded R&D reported in the navigational, measuring, electromedical, and control instruments industry is performed by large defense contractors that also produce aerospace products. And investigations of survey microdata revealed that most of the R&D classified into the trade industry represents the activities of manufacturing firms that have integrated their supply chains and brought their warehousing, sales, and marketing efforts in-house. Consequently, beginning with the 2004 cycle of the survey, the assigned industry classification of companies in selected industries (such as wholesale trade) and also companies that most influence the overall R&D performance estimates is subjected to manual review and potential reclassification. Wherever possible, this report includes industry-level data that results from this new method of industry classification.[†]

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[*] Details on how companies are assigned initial industry codes based on payroll in the NSF Survey of Industrial Research and Development can be found at NSF/SRS (2002b). For information on the current industry classification process, see NSF/SRS (2004b).

[†] The impact of the new industry classification methodology is detailed in NSF/SRS (2007d).

ization technologies are common elements in the production processes of the computer and electronic products sector.

In 2005, these industries performed at least $43.5 billion of R&D, or 19% of all business R&D.[13] Companies and other nonfederal sources funded almost this entire R&D. The focus of the R&D in this sector is on development, with less than 25% of company-funded R&D devoted to basic and applied research. Two of the more R&D-intensive industries, communications equipment and semiconductor manufacturing, are included in this group. Both devoted more than 11% of sales to R&D in 2005.

Chemicals

The chemicals industry performed an estimated $43.0 billion of R&D in 2005. Like the computer and electronic products industries, relatively little of the R&D in the chemicals industry is federally funded. In terms of R&D performance, the largest industry within the chemicals subsector is pharmaceuticals and medicines. In 2005, pharmaceutical companies performed $34.8 billion of company-funded R&D, representing 81% of nonfederal R&D funding of the chemicals sector.

The Pharmaceutical Research and Manufacturers of America (PhRMA), an industry association that represents the country's leading research-based pharmaceutical and biotechnology companies, annually surveys its members for information about their R&D. In 2005, PhRMA estimated that its members invested $31.4 billion in R&D performed in the United States, which was 19.2% of domestic sales and 15.8% of global sales (PhRMA 2006a).[14] According to PhRMA, members' domestic R&D investment supports continuing R&D on projects that originated in their own laboratories, but 25% supports R&D on products licensed from other companies (notably biotechnology companies), universities, or the government (PhRMA 2006b). 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 services industry. Therefore, a sizable amount of biotechnology R&D that serves the pharmaceutical industry is reported in the R&D services sector (see the section entitled "R&D Services").

Computer-Related Services

Industries associated with software and computer-related services (such as data processing and systems design) performed approximately $30.5 billion of company-funded R&D in 2005. The R&D of these industries, combined with that of the computer and electronic products manufacturers discussed earlier, accounted for 33% of all industrial

Table 4-4
R&D and domestic net sales, by selected business sector: 2004 and 2005
(Millions of current dollars)

	All R&D		Federal R&D		Company R&D		Domestic net sales		All R&D/sales ratio (%)	
Sector	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
All industries	208,301	226,159	20,266	21,909	188,035	204,250	5,601,729	6,119,133	3.7	3.7
Highlighted sectors	163,102 L	174,970 L	19,122 L	20,867 L	143,980	154,102	2,205,651	2,268,642	7.4	7.7
Computer and electronic products[a]	40,964	43,520 L	273	1,057 L	40,691	42,463	506,103	472,330	8.1	9.2
Chemicals	39,224 L	42,995	154 L	169	39,070	42,826	595,292	624,344	6.6	6.9
Computer-related services[b]	28,117 L	30,518	410 L	578	27,707	29,939	166,545	213,574	16.9	14.3
Aerospace and defense manufacturing[c]	23,567 L	24,926 L	14,343 L	13,998 L	9,224	10,928	228,018	227,271	10.3	11.0
R&D services[d]	15,620	16,986	3,942	5,065	11,678	11,921	66,614	84,637	23.4	20.1
Automotive manufacturing[e]	15,610 L	16,025	NA	NA	15,610	16,025	643,079	646,486	2.4	2.5
All other industries	45,199 L	51,189 L	1,144 L	1,042 L	44,055	50,148	3,396,078	3,850,491	1.3	1.3

L = lower-bound estimate; NA = not available

[a] Includes all nonfederal R&D and domestic net sales for the navigational, measuring, electromedical, and control instruments industry. All federal R&D for navigational, measuring, electromedical, and control instruments industry included in aerospace and defense manufacturing sector.

[b] Includes R&D and domestic net sales for software and computer systems development industries.

[c] Includes all R&D for aerospace products and parts, plus all federal R&D for navigational, measuring, electromedical, and control instruments and automotive and other transportation manufacturing industries. Domestic net sales not included for automotive and other transportation manufacturing industries.

[d] Includes R&D and domestic net sales for architectural, engineering, and related services and scientific R&D services industries.

[e] Federal R&D for all transportation manufacturing industries (including automotive manufacturing) 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.

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R&D in 2005. As computing and information technology became more integrated with every sector of the economy, the demand for services associated with these technologies boomed.

Between 1987 and 2005, the R&D of companies providing these services grew dramatically. In 1987, when an upper-bound 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 2005, the company-funded R&D of these industries (excluding engineering and architectural services) accounted for 14.7% of all company-funded industrial R&D, and these companies accounted for 3.5% of domestic sales of R&D-performing companies (table 4-5).[15] Although the R&D activities of computer-related services companies have grown dramatically, this group is not the sole performer of software development R&D in the United States. In fact, companies in almost every industry report expenditures for software development R&D.

Aerospace and Defense Manufacturing

Although it is common to refer to the "defense industry," there is no such category in the industry classification system used by the federal government. Companies performing the majority of DOD's extramural R&D are classified in the aerospace products and parts industry; other transportation equipment industries; and the navigational, measuring, electromedical, and control instruments manufacturing industry. To approximate the cost of defense-related R&D, one can focus on the federally supported R&D performed by these industries. In 2005, these industries reported performing $14.0 billion of federal R&D, about two-thirds of all federal industrial R&D expenditures (table 4-4).[16] This accounts for more than half of the $25.0 billion the "defense industry" as a whole spent on R&D, including both federal and nonfederal sources of funds. (See the section entitled "Federal R&D" later in this chapter for further discussion of defense R&D.)

R&D Services

Companies in the business of selling S&E R&D services to other companies or licensing the results of their R&D are generally classified in the architectural, engineering, and related services industry, or the scientific R&D services industry. Companies in this sector perform the majority of the federal R&D that is not performed by aerospace and defense manufacturing firms; $5.1 billion in 2005. Despite the significant amount of government-sponsored R&D performed by this sector, R&D services companies increasingly rely on nonfederal sources of R&D financing. The R&D performed by companies in the R&D services sector and funded by company and other nonfederal sources has grown from $5.8 billion in 1997 to $11.9 billion in 2005.[17] Because much of the R&D reported by these companies also appears in their reported sales figures, the R&D intensity of the R&D services sector is particularly high (20% in 2005).

Although the companies in this sector and their R&D activities are classified as nonmanufacturing, many of the industries they serve are manufacturing industries. For example, many biotechnology companies in the R&D services sector license their technology to companies in the pharmaceutical manufacturing industry. If a research firm was a subsidiary of a manufacturing company rather than an independent contractor, its R&D 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" (Jankowski 2001). (For more information, see the section entitled "Technology Linkages.")

Table 4-5
Estimated share of computer-related services in company-funded R&D and domestic net sales of R&D-performing companies: 1987–2005
(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

NOTES: Before 1998 companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). 1998–2005 companies classified in North American Industry Classification System (NAICS) industries 5112 (software), 51 minus (511, 513; other information), 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 1987–2005); and special tabulations.

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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 industrial 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 from these surveys help identify broad trends in corporate R&D strategies. Dr. Jules J. Duga, a senior analyst at the Battelle Memorial Institute in Columbus, Ohio, notes (in a personal communication) that the IRI survey

> . . . provides a reasonable overview of the actions that are being taken by industry. Although the internal analysis of IRI survey results does not delve deeply into the driving forces for the stated planning, the overall results are certainly a reflection of industrial response to markets, federal actions, and approaches for the most effective means for acquiring technological assets. Although there have been changes in the type of membership pattern that is represented within IRI, and there are similar changes in the character of the respondents, the IRI survey provides a long-term envelope of planning and practices as applied to R&D, and results in there being the raw material for qualitative and semi-quantitative longitudinal studies that well serve the objectives of industrial science policy analyses. One of the major characteristics of the IRI survey is that for all intents and purposes the questionnaire has maintained the same format for many years, thus permitting the development of a long-term analytical framework with a minimum of disruptions. The analysis of the responses to individual questions, as well as the introduction of a so-called "sea change" indicator, provides a series of snapshots of postures. Over the past few years, efforts have been directed toward viewing clusters of responses to questions that have internal conceptual linkages. Such an approach has provided a means for developing broader pictures of the driving forces and action items that are influencing industrial R&D strategy.

The most recent survey, administered during the summer of 2006, 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 2007). This reported shift in R&D priorities also is reflected in how responding companies intend to spend their R&D budgets. IRI survey respondents reported the following plans for 2007:

- Increase total company expenditures on R&D
- Increase hiring of new graduates
- Increase outsourcing of R&D to other companies
- Increase outsourcing for university R&D and federal laboratories
- Increase participation in alliances and joint R&D ventures
- Increase licensing of technology to and from other companies
- Increase acquisition of technological capabilities through mergers and acquisitions

Overall, these strategic moves are consistent with responses suggesting increased R&D budgets. Responding companies are increasing R&D spending to support existing lines of business as well as new business projects and are leveraging their R&D spending through joint R&D ventures and grants/contracts for university R&D. (For more information, see the section entitled "Technology Linkages.")

Automotive Manufacturing

The sixth largest business sector in terms of R&D is automotive manufacturing. Companies in this industry reported performing $16.0 billion of company-funded R&D in 2005, accounting for 7.1% of all such R&D performed by businesses in the United States. At one time, this industry played a larger role in U.S. business R&D; for example, in 1959, automotive manufacturing accounted for as much as 16.2% of all company-funded and -performed R&D.

In 2004, nine companies in the automotive manufacturing industry reported R&D expenditures of more than $100 million, representing more than 80% of the industry's R&D. 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 reported R&D expenses of $21.1 billion in 2004 (see sidebars, "Trends in R&D for Industrial Research Institute Members" and "R&D Expenses of Public Corporations").[18]

Federal R&D

In the president's 2008 budget submission, the federal government is slated to invest $138 billion in R&D, amounting to 12.8% of its discretionary budget (i.e., that part of the annual federal budget that the president proposes and Congress debates and sets). The government supports S&T

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. In 2004, the 25 public corporations with the largest reported worldwide R&D expenses spent $127.3 billion on R&D. The three companies that topped the list were automobile manufacturers. Ford Motor Company, DaimlerChrysler, and Toyota, together with the other four automobile manufacturers on the list, reported spending $41.0 billion on R&D (32.5% of the total for the top 25) (table 4-6). There are 10 companies in the information and communications technologies (ICT) sector that spent a total of $49.4 billion (38.8% of the total). The remaining eight companies include six pharmaceutical manufacturers and two diversified consumer product-oriented manufacturers. As Hira and Goldstein (2005) point out, although four of the five top leaders in R&D in 2004 were automobile manufacturers, which is a marked difference compared with 2000, when the top four spenders were the telecommunications giants Ericsson, Lucent, Motorola, and Nortel, “automakers face an uncertain near-term outlook because of pressures from an increasing cost structure and the need to achieve shorter product life cycles to meet rapidly changing consumer preferences.”

The top 25 companies are headquartered in seven different countries, with nine headquartered in the United States. However, the location of a company’s headquarters 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 around the world. (For more information, see the section entitled “R&D by Multinational Corporations.”)

Overall, R&D spending for the top 25 increased 4.0% in 2004 compared with 2003. Sales for the group as a whole increased 6.8%; sales increased in the 6%–8% range for the automobile and pharmaceutical manufacturers and ICT companies in the group, and more than 11% for the consumer product manufacturers. R&D expenditures increased for the manufacturers (pharmaceutical, 6.9%; automobile, 6.3%; and consumer products, 10.4%). However, the ICT companies, representing the sector with traditionally the highest R&D intensity, reported only a 0.1% increase.

It should be noted that a recent change in accounting standards by the Financial Accounting Standards Board (FASB) may result in discontinuities in companies’ reported R&D expenses, making it more difficult to evaluate R&D spending trends from publicly available financial data. By 2004, most large companies began following the guidelines of FASB’s Statement of Financial Accounting Standards, “Accounting for Stock-Based Compensation,” which requires companies to expense the fair value of all stock-based compensation.* Many high-technology companies have historically compensated their R&D employees with stock options and stock awards. This stock-based compensation may not have been reported as company expenses before these new guidelines. For example, according to Hira and Goldstein (2005), “Microsoft’s R&D spending decreased 20.5% in 2004 despite an increase in R&D employees. According to its U.S. Securities and Exchange Commission filings, the decrease was “‘due to lower stock-based compensation expense’ [because] in 2003 the company began offering its employees stock-based compensation in lieu of options. This affected its R&D accounting significantly. . . .” For information on how many of the largest U.S.-based corporations intended to adjust their R&D strategies and spending, see sidebar, “Trends in R&D for Industrial Research Institute Members.”

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* See FASB (2004); Hira and Goldstein (2005). For information about how FASB standards as they apply to U.S. firms compare and converge with the standards of the International Accounting Standards Board, see FASB (2007).

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 such R&D activities, on the government’s contribution to the U.S. R&D infrastructure, and on federal and state R&D tax credits (an indirect means of stimulating R&D in the private sector).

R&D by Federal Agency

Federal agencies are expected to obligate $113 billion for R&D support in FY 2007 (table 4-7). Although more than 25 agencies report R&D obligations, only 7 report expected R&D obligations of more than $1 billion in FY 2007. Together, these agencies account for 96% of total federal R&D. These agencies vary considerably in terms of their R&D funding, reflecting the unique mission, history, and culture of each.

Table 4-6
Top 25 R&D-spending corporations: 2004

	R&D rank		R&D expense ($millions)			Sales ($millions)		R&D intensity (%)	
Company (country)	2004	2003	2004	2003	Change (%)	2004	2003	2004	2003
Ford Motor (U.S.)	1	2	7,400	7,500	–1.3	171,652	164,196	4.3	4.6
DaimlerChrysler (Germany)	2	4	7,187	7,076	1.6	180,448	173,307	4.0	4.1
Toyota Motor (Japan)	3	6	7,052	6,372	10.7	173,254	161,517	4.1	3.9
Pfizer (U.S.)	4	3	6,613	7,131	–7.3	52,516	45,188	12.6	15.8
General Motors (U.S.)	5	7	6,500	5,700	14.0	190,812	182,005	3.4	3.1
Siemens (Germany)	6	5	6,431	6,436	–0.1	95,480	94,293	6.7	6.8
Microsoft (U.S.)	7	1	6,184	7,779	–20.5	39,788	36,835	15.5	21.1
Matsushita Electric Industrial (Japan)	8	8	5,748	5,409	6.3	81,377	69,854	7.1	7.7
GlaxoSmithKline (UK)	9	9	5,251	5,162	1.7	37,655	39,656	13.9	13.0
Johnson & Johnson (U.S.)	10	13	5,203	4,684	11.1	47,348	41,862	11.0	11.2
International Business Machines (U.S.)	11	10	5,167	5,068	2.0	96,293	89,131	5.4	5.7
Volkswagen (Germany)	12	14	4,823	4,479	7.7	113,004	110,705	4.3	4.0
Intel (U.S.)	13	15	4,778	4,360	9.6	34,209	30,141	14.0	14.5
Nokia (Finland)	14	12	4,742	4,776	-0.7	37,176	37,415	12.8	12.8
Sony (Japan)	15	11	4,688	4,805	-2.4	66,864	70,009	7.0	6.9
Samsung Electronics (South Korea)	16	25	4,529	3,337	35.7	77,494	61,284	5.8	5.4
Honda Motor (Japan)	17	16	4,368	4,193	4.2	80,784	76,231	5.4	5.5
Novartis (Switzerland)	18	20	4,207	3,756	12.0	28,247	24,864	14.9	15.1
Roche Holding (Switzerland)	19	17	4,192	3,925	6.8	25,742	25,698	16.3	15.3
Merck (U.S.)	20	29	3,885	3,178	22.2	23,430	22,486	16.6	14.1
AstraZeneca (UK)	21	23	3,803	3,451	10.2	21,426	18,849	17.7	18.3
Nissan Motor (Japan)	22	28	3,718	3,309	12.4	80,094	69,382	4.6	4.8
Robert Bosch (Germany)	23	24	3,681	3,366	9.4	50,818	46,182	7.2	7.3
Hitachi (Japan)	24	22	3,630	3,472	4.5	84,304	80,619	4.3	4.3
Hewlett-Packard (U.S.)	25	21	3,506	3,652	–4.0	79,905	73,061	4.4	5.0

UK = United Kingdom

SOURCE: Institute of Electronics and Electronics Engineers (IEEE), IEEE Spectrum Top 100 R&D Spenders, Standard & Poor's data (2005), http://www.spectrum.ieee.org/dec05/2395, accessed 24 April 2007.

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Department of Defense

According to preliminary data, DOD will obligate $56 billion for R&D support in FY 2007. DOD funds more R&D than any other federal agency, representing half of all federal R&D obligations. Of these funds, 89% ($50 billion) will be spent on development (figure 4-6). Most of the development funded by DOD is classified as "major systems development" ($44 billion), representing the cost of developing, testing, and evaluating combat systems. Industrial firms are expected to perform 74% of DOD-funded R&D in FY 2007. DOD accounts for more than 84% of all federal R&D obligations to industry in FY 2007. Federal intramural R&D and R&D performed by FFRDCs account for most of DOD's remaining R&D activity and represent 25% of its FY 2007 total.

Department of Health and Human Services

The Department of Health and Human Services (HHS), the primary source of federal health-related R&D funding (largely through its National Institutes of Health [NIH]), will obligate the second largest amount for R&D in FY 2007 at $29 billion, representing 26% of all federal R&D obligations. In contrast to DOD, HHS will allocate most of its R&D funding ($16 billion) for basic research. In FY 2007, HHS is expected to provide universities and colleges, the primary recipients of HHS funding, with $16 billion, which represents 65% of all federal R&D funds obligated to universities and colleges (table 4-8). HHS will provide 75% ($4 billion) of all federal R&D funds obligated to nonprofit institutions. Most of these institutions are large research hospitals such as Massachusetts General Hospital and the Dana-Farber Cancer Institute (NSF/SRS 2007c).

National Aeronautics and Space Administration

The third largest agency in terms of R&D support is NASA, with R&D obligations expected to reach more than $8 billion in FY 2007. Almost half ($4 billion) of NASA's R&D activity is in development, much of which relies on industrial performers similar to those funded by DOD. However, unlike the industrial R&D funded by DOD, the majority (55%) of that funded by NASA supports research projects (basic and applied) as opposed to development. NASA is also the primary sponsor of R&D projects at nine federal facilities (including the Ames Research Center in California's Silicon Valley and the Marshall Space Flight Center in Huntsville, Alabama) and one FFRDC, the Jet Propulsion Laboratory, administered by the California Institute of Technology.

Table 4-7
Estimated federal R&D obligations, by performing sector and agency funding source: FY 2007

		Primary funding source		Secondary funding source	
Character of work/performer	All obligations ($millions)	Agency	Percent	Agency	Percent
All R&D	112,829.7	DOD	50	HHS	26
Federal intramural	24,741.5	DOD	53	HHS	23
Industrial firms	46,502.1	DOD	85	NASA	7
Industry-administered FFRDCs	1,477.8	DOE	58	HHS	24
U&C	24,968.5	HHS	65	NSF	13
U&C FFRDCs	6,136.3	DOE	54	NASA	29
Other nonprofit organizations	5,751.6	HHS	75	DOD	7
Nonprofit-administered FFRDCs	1,949.2	DOE	60	DOD	34
Basic research	28,264.4	HHS	57	NSF	13
Federal intramural	4,846.4	HHS	62	USDA	12
Industrial firms	2,211.1	HHS	44	NASA	39
Industry-administered FFRDCs	269.1	HHS	76	DOE	21
U&C	14,272.5	HHS	64	NSF	21
U&C FFRDCs	2,364.3	DOE	63	NASA	25
Other nonprofit organizations	2,927.9	HHS	82	NSF	10
Nonprofit-administered FFRDCs	897.7	DOE	98	HHS	1
Applied research	26,824.8	HHS	48	DOD	19
Federal intramural	7,828.1	HHS	33	DOD	27
Industrial firms	4,575.3	DOD	46	NASA	20
Industry-administered FFRDCs	708.5	DOE	73	HHS	21
U&C	9,088.9	HHS	78	DOD	6
U&C FFRDCs	1,701.5	DOE	87	DOD	4
Other nonprofit organizations	2,413.3	HHS	78	DOD	6
Nonprofit-administered FFRDCs	256.4	DOE	54	DOD	25
Development	57,740.5	DOD	86	NASA	7
Federal intramural	12,067.0	DOD	88	NASA	4
Industrial firms	39,715.7	DOD	93	NASA	4
Industry-administered FFRDCs	500.1	DOE	56	DOD	38
U&C	1,607.1	DOD	43	NASA	35
U&C FFRDCs	2,070.5	NASA	56	DOD	19
Other nonprofit organizations	410.4	DOD	37	NASA	19
Nonprofit-administered FFRDCs	795.1	DOD	74	DOE	20

DOD = Department of Defense; DOE = Department of Energy; FFRDC = federally funded research and development center; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; U&C = universities and colleges

NOTE: Subtotal by performer may not add to total because state and local governments and foreign performers of R&D not detailed.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming).

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Department of Energy

Of the large R&D-funding agencies, DOE invests the most resources in FFRDCs. In FY 2007, DOE obligated 67% of its estimated $8 billion in R&D funding to these organizations. Of the 37 FFRDCs, DOE sponsored 16 and accounted for more than half of all federal R&D obligations to FFRDCs in FY 2007. Much of DOE's research requires specialized equipment and facilities that are only available at its intramural laboratories and FFRDCs. (See the section on FFRDCs later in this chapter.)

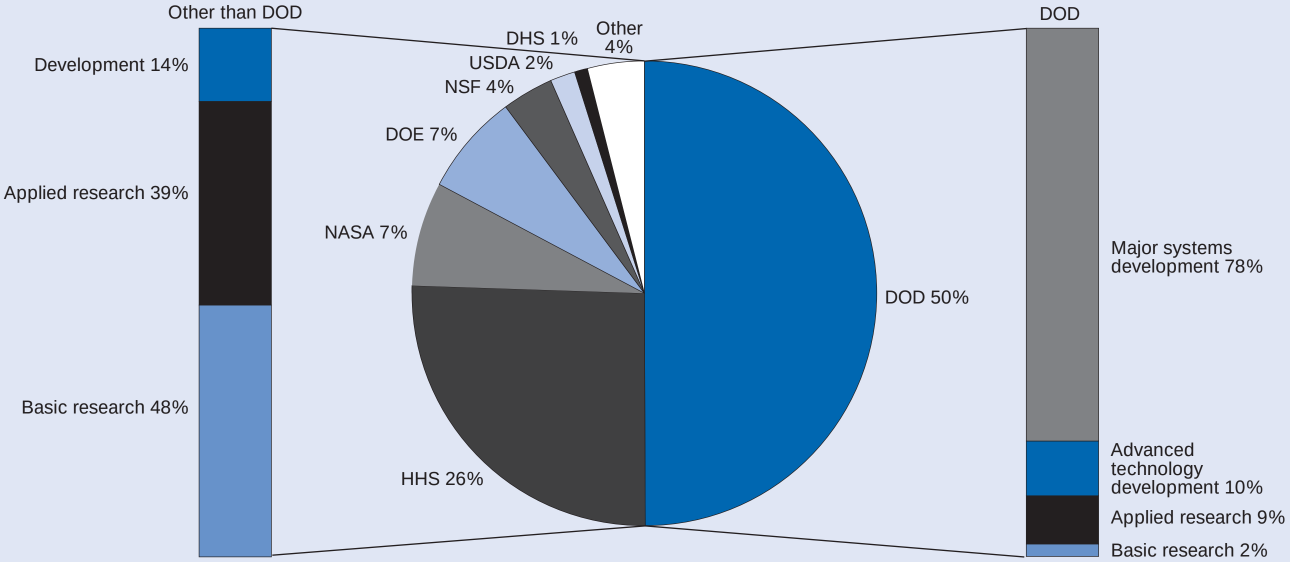
National Science Foundation

NSF is the federal government's primary source of funding for general S&E research and is expected to fund $4 billion of R&D in FY 2007. Of these funds, 91% are for basic research. Unlike many other federal agencies, NSF does not operate any of its own laboratories, but instead supports scientists and engineers through their home institutions. For the most part, these home institutions are universities and colleges; NSF is the second largest federal source of R&D funds to universities and colleges and is expected to invest more than $3 billion in academic research in FY 2007.

Department of Agriculture

USDA is expected to fund almost $2 billion of R&D in FY 2007, with most of this (69%) supporting USDA intramural R&D. Although USDA focuses most of its R&D in the life sciences, it is also one of the largest funding agencies for research in the social sciences, predominantly agricultural economics.

Figure 4-6
Projected federal obligations for R&D, by agency and character of work: FY 2007



DOD = Department of Defense; DOE = Department of Energy; DHS = Department of Homeland Security; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture

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

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming). See appendix table 4-30.

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Department of Homeland Security

In FY 2007, the Department of Homeland Security (DHS) is expected to fund approximately $1 billion in R&D. DHS conducts and funds research in various areas but focuses significant resources on countering threats of catastrophic terrorism such as weapons of mass destruction. Most of this R&D is either conducted in DHS laboratories or under contract by industrial firms and FFRDCs. DHS also has established a grant-giving agency, Homeland Security Advanced Research Project Agency, modeled in part on the Defense Advanced Research Project Agency.

Other Agencies

Of the remaining R&D-funding federal agencies, 10 are expected to fund between $100 million and $1 billion of R&D in FY 2007. The largest of these agencies in terms of R&D funding are the Department of Commerce (DOC), the Department of the Interior (DOI), and the Environmental Protection Agency (EPA). Unlike most of the larger R&D-funding agencies, DOC, DOI, and EPA direct most of their R&D funds to their own laboratories, which are run by the National Institute of Standards and Technology (NIST), the U.S. Geological Survey, and the EPA Office of Research and Development, respectively.

Federally Funded R&D by Performer

Federal Funding to Academia

The federal government has historically been the primary source of R&D funding to universities and colleges, accounting for as much as two-thirds of all academic R&D funding in the early 1980s. (For more detailed information on academic R&D, see chapter 5.) In FY 1955, obligations for academic R&D accounted for 7% of all federal R&D funding, or $0.8 billion in constant 2000 dollars. In FY 2007, R&D funding to academia represents an estimated 22% of all federal R&D obligations, or $21 billion in constant 2000 dollars. As figure 4-7 illustrates, funding to academia grew rapidly after FY 1998, the result of a successful bipartisan effort to double the budget of NIH from its FY 1998 level over 5 years. After FY 2004 however, federal R&D obligations to universities and colleges failed to keep pace with inflation.

Federal Funding to Industry

Since FY 1956, the federal government has obligated the largest share of its R&D funding to industry. Federal funding for this sector, largely for development projects, has experienced more variability over the past 50 years than for any other sector (figure 4-7). R&D obligations to industry grew rapidly in the 1960s and peaked at $42 billion in constant 2000 dollars as the government invested heavily in its space program. Following the successful Apollo 11 mission

Table 4-8
Federal total, intramural, and FFRDC R&D obligations, by U.S. agency: FY 2007
(Millions of dollars)

Agency	All R&D obligations	Intramural	FFRDC	Intramural plus FFRDC (%)
All federal government	112,830	24,742	9,563	30
DOD	56,348	13,015	1,340	25
HHS	28,902	5,623	454	21
NASA	8,153	1,272	1,782	37
DOE	7,957	540	5,365	74
NSF	4,049	20	227	6
USDA	1,966	1,351	0	69
DHS	1,028	288	329	60
DOC	940	723	4	77
DOI	570	484	0	85
EPA	557	434	0	78
DOT	502	162	17	36
VA	412	412	0	100
ED	339	18	0	5
DOL	271	26	0	10
AID	255	30	0	12
DOJ	158	88	4	58
Smithsonian Institution	130	130	0	100
Other agencies	293	125	42	57

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; DOJ = Department of Justice; DOL = Department of Labor; 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: Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by federal personnel. Only agencies with >$100 million in R&D obligations shown.

SOURCE: NSF, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming).

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to the moon, R&D obligations to industry declined and did not experience another surge until more than a decade later, when Cold War investments in military technology resulted in another period of growth. Similarly, military investments following the events of September 11, 2001, resulted in an influx of federal R&D funding to industry. After adjusting for inflation, federal R&D obligations to industry increased by more than 48% between FY 2001 and 2005. Beginning in FY 1989, the amount of federally funded R&D reported by industry began to diverge from the amount reported by the federal government. For details on this discrepancy, see sidebar, “Tracking R&D: Gap Between Performer- and Source-Reported Expenditures.”

Federal Intramural R&D

In FY 2007, obligations for federal intramural R&D totaled almost $25 billion. These funds supported R&D performed at federal laboratories as well as costs associated with the planning and administration of both intramural and extramural R&D projects. Among individual agencies, DOD continued to fund the most intramural R&D and is expected to account for almost half of all federal obligations for intramural R&D in FY 2007 (table 4-8). DOD’s intramural R&D obligations are more than twice that of the second largest R&D-performing agency, HHS, which performs most of its intramural R&D at NIH in Maryland. Only two other agencies report intramural R&D obligations of more than $1 billion in FY 2007, NASA and USDA.

Federally Funded Research and Development Centers

FFRDCs are unique organizations that help the U.S. government meet “special long-term research or development needs that cannot be met as effectively by existing in-house or contractor resources.” According to the Federal Acquisition Regulations (35.017), an FFRDC is required “to operate in the public interest with objectivity and independence, to be free from organizational conflicts of interest, and to have full disclosure of its affairs to the sponsoring agency.” First established during World War II to assist DOD and DOE with R&D on nuclear weapons, FFRDCs today perform R&D with both defense and civilian applications across a broad range of S&E fields.

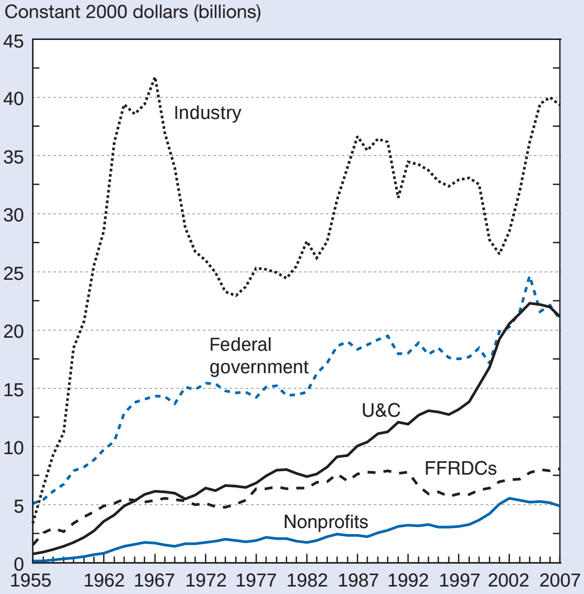
Of the 37 FFRDCs active in 2005, DOE sponsors 16, more than any other agency. These 16 organizations performed almost $10 billion of R&D in FY 2005, three-quarters of that performed by all FFRDCs combined (appendix table 4-25).

Four reported R&D expenditures of more than $1 billion in FY 2005: Los Alamos National Laboratory, Sandia National Laboratory, Jet Propulsion Laboratory, and Lawrence Livermore National Laboratory. Together, these four laboratories account for more than half of all FFRDC R&D expenditures. Los Alamos National Laboratory and the Lawrence Livermore National Laboratory are the only two laboratories in the United States where research on the nation's nuclear stockpile is conducted. See sidebar, "Federal R&D Infrastructure," for more information on FFRDCs' and other federal facilities' contributions to the U.S. R&D system.

Federal Research Funding by Field

Federal agencies fund research in a wide range of S&E fields, from aeronautical engineering to sociology. The relative amount of (basic plus applied) research funding differs by field, as do trends in funding over time. According to preliminary estimates, federal obligations for research (excluding development) will total $55 billion in FY 2007 (see "Definitions of R&D" sidebar earlier in this chapter). Half of this funding, almost $28 billion, supports research in the life sciences. The next largest fields in terms of their share of expected federal research obligations in FY 2007 are engineering (17%), physical sciences (10%), environmental sciences (7%), and mathematics and computer sciences (6%) (figure 4-8). The balance of federal research obligations ($5 billion) supports the social sciences, psychology, and all other sciences.

Figure 4-7
Federal obligations for R&D, by performing sector: FY 1955–2007



FFRDCs = federally funded research and development centers; U&C = universities and colleges

NOTE: Preliminary 2006 and 2007 data.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming).

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HHS, primarily through NIH, provides the largest share (52%) of all federal research obligations in FY 2007, with most of its obligations funding medical and other related life sciences. The next four largest federal agencies in terms of research funding in FY 2007 are DOD (12%), DOE (11%), NASA (7%), and NSF (7%). DOD's research funding is focused on engineering ($3.6 billion) and on mathematics and computer sciences ($1.0 billion). DOE provides substantial funding for research in the physical sciences ($2.4 billion) and engineering ($2.0 billion). NASA's research funding also emphasizes engineering ($1.5 billion), followed by physical sciences ($1.1 billion) and environmental sciences ($1.0 billion). NSF, whose mission is to "promote the progress of science," has a relatively balanced research portfolio, contributing between $0.5 and $0.9 billion to researchers in each of the following fields: mathematics and computer sciences, physical sciences, engineering environmental sciences, and life sciences.

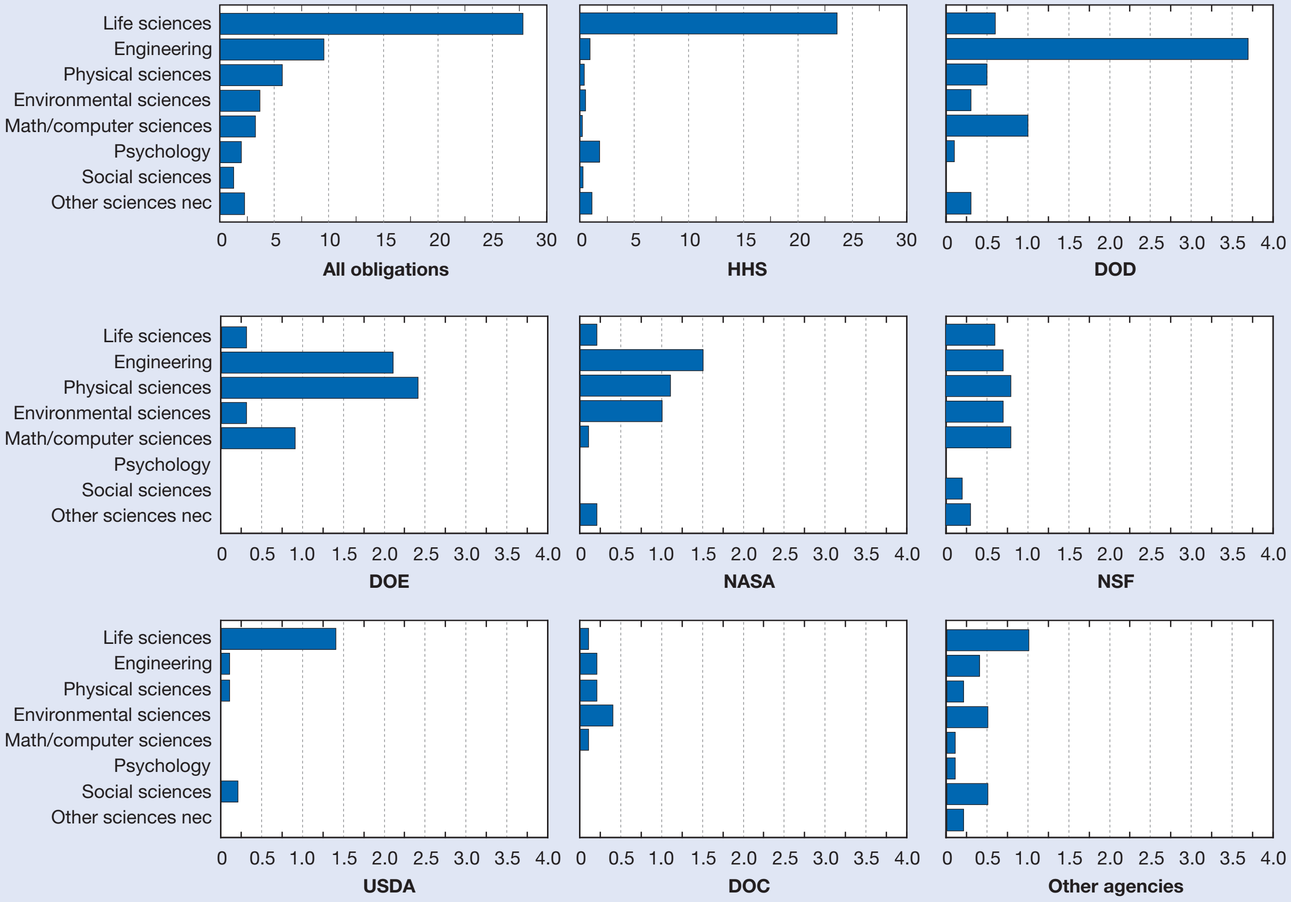
Federal obligations for research have grown at different rates for different S&E fields, reflecting changes in perceived public needs in those fields, changes in the national resources (e.g., scientists, equipment, and facilities) that have been built up in those fields over time, and differences in scientific opportunities across fields. Over the period 1986–2007, total federal research obligations grew on average 3.4% per year in real terms, from $23 billion in 2000 dollars to $47 billion in 2000 dollars. The fields that experienced higher-than-average growth during this period were mathematics and computer sciences (5.6% per year in real terms), life sciences (4.6%), and psychology (6.1%) (appendix table 4-32). Funding for the remaining fields also grew at a faster rate than inflation over this period: social sciences (2.7%), engineering (2.0%), environmental sciences (1.9%), and physical sciences (0.5%).

Caution should be used when examining trends in federal support for more detailed S&E fields than those presented above because federal agencies classify a significant amount of R&D only by major S&E field, such as life sciences, physical sciences, or social sciences. In FY 2005, for example, 1% of the federal research obligations classified by major S&E field were not subdivided into detailed fields. This was less pronounced in physical sciences and mathematics and computer sciences, in which all but 6% of the research dollars were subdivided. It was most pronounced in social sciences and psychology, in which, respectively, 69% and 97% of federal research obligations were not subdivided into detailed fields (appendix table 4-32).

Figure 4-8

Estimated federal obligations for research, by agency and major S&E field: FY 2007

(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 = U.S. Department of Agriculture

NOTE: Scale differs for All obligations and HHS versus all other agencies.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal Funds for Research and Development: Fiscal Years 2005, 2006, and 2007 (forthcoming). See appendix table 4-31.

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Federal R&D Budget by National Objective

Before any agency can obligate funds for R&D, it must first have budget authority from Congress for such activity. In the president's FY 2008 budget submission to Congress, the proposed total federal budget authority for R&D is $138 billion. Adjusting for inflation, this amount is a 1% decline from the previous year's budget. This decline follows a 5-year period of increasing inflation-adjusted federal R&D budgets. Although R&D tends to be a popular budgetary item, the growing federal debt may hamper future growth in federal R&D.

To assist Congress and the president in evaluating and adjusting the federal budget, the Office of Management and Budget (OMB) requests agencies to allocate their budget requests into specific categories called budget functions. These budget functions represent a wide range of national objectives the government aims to advance, from national defense to health to transportation (see sidebar, "Federal R&D Initiatives").

Defense-Related R&D

The largest R&D budget function in the FY 2008 budget is defense, with a proposed budget authority of $82 billion, or 60% of the entire federal R&D budget. (DOD requested $78 billion for its research, development, testing, and evaluation budget; the remainder of defense-related R&D is funded by DOE and HHS.) In 1980, the federal budget authority for defense-related R&D was roughly equal to that for nondefense R&D, but by 1985, defense R&D had grown to more than double nondefense R&D (figure 4-11). The gap between the

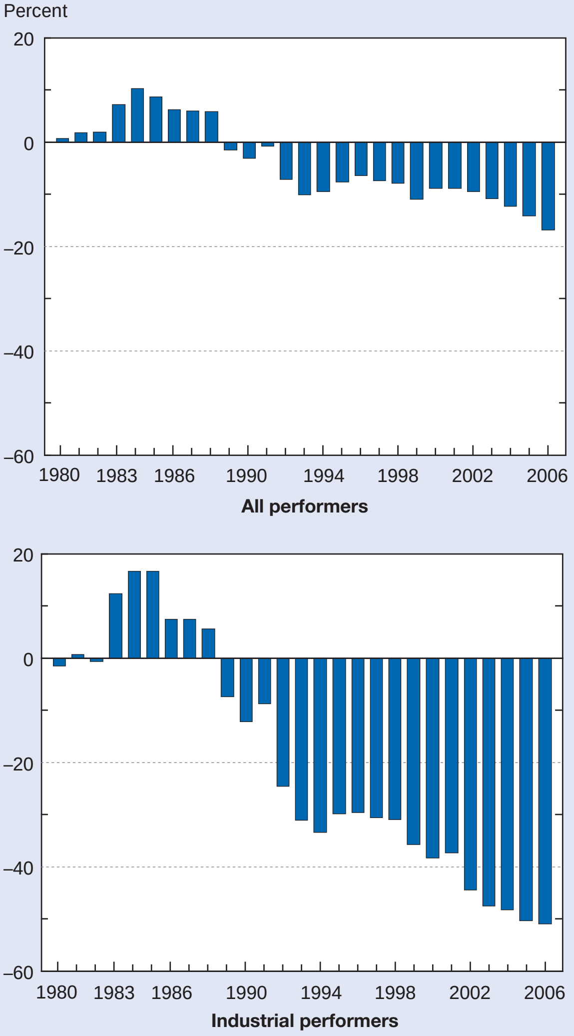
Tracking R&D: Gap Between Performer- and Source-Reported Expenditures

In some OECD countries, including the United States, total government R&D support figures reported by government agencies differ from those reported by performers of R&D work. Consistent 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). Although funding and performing series may be expected to differ for many reasons, such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year), the gap between the two U.S. R&D series has widened during 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–$4 billion annually (5%–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 2005, federal agencies reported obligating $109 billion in total R&D to all R&D performers ($44 billion to the business sector), compared with $94 billion in federal funding reported by the performers of R&D ($23 billion by businesses). Hence, overall industrywide estimates equal approximately a 50% paper "loss" of federally reported 2005 R&D support (figure 4-9). The difference in federal R&D totals was primarily in DOD development funding of industry.

Several investigations into the possible causes for the data gap produced insights into the issue, but a conclusive explanation has been elusive. According to a General Accounting Office (GAO 2001) investigation, "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) notes that comparing federal outlays for R&D (as opposed to obligations) to performer expenditures results in a smaller discrepancy. In FY 2005, federal agencies reported total R&D outlays of $103 billion.

Figure 4-9
Difference in U.S. performer- and agency-reported federal R&D: 1980–2006



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 2005, 2006, and 2007 (forthcoming). See appendix table 4-29.

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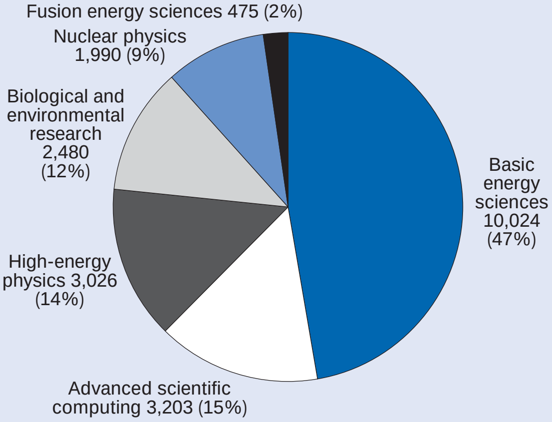
Federal R&D Infrastructure

The U.S. government invests substantial resources not only in R&D, but also in the facilities and instrumentation required by researchers to tackle problems at the frontier of S&T. In FY 2007, federal agencies are expected to obligate more than $3.5 billion for R&D plant, capital equipment, and facilities for use in R&D. Two agencies, NASA and DOE, account for more than two-thirds of all federal R&D plant obligations in FY 2007. Some examples of research infrastructure made possible through federal funding include:

- **Supercomputing resources.** As of November 2006, 6 of the top 10 supercomputers in the world were located in U.S. FFRDCs or government laboratories (TOP500 Supercomputer Sites 2007). The Terascale Simulation Facility at Lawrence Livermore National Laboratory houses two of the world's fastest supercomputers: BlueGene/L, ranked fastest in the world, and ASC Purple, ranked number four. These powerful computers support DOE's research on the safety and reliability of the nation's nuclear arsenal. The federal supercomputing resources are also used for nondefense purposes such as research on climate change and bioinformatics. For example, the DOE Joint Genome Institute leveraged the computing resources and research capabilities of multiple federal laboratories to contribute to the sequencing of the human genome. For more information, see DOE (2007).
- **Hubble Space Telescope.** Launched in 1990 and upgraded during four subsequent servicing missions, NASA's Hubble Space Telescope revolutionized astronomy by providing deep, clear views of the universe without the distorting effects of the Earth's atmosphere. Among its many highlights, Hubble was the first optical telescope to provide convincing proof of a black hole. More than 6,300 published scientific papers have been based on its data. At the time of its launch, the Hubble Space Telescope cost $1.5 billion. More details are available at NASA (2007).
- **Antarctic research stations.** NSF funds and manages the U.S. Antarctic Program, which coordinates almost all U.S. science on the continent, including research carried out by other federal agencies. The unique Antarctic environment has proven to be a boon to many fields of study. For example, astronomers and astrophysicists have benefited from the excellent optical properties of the atmosphere at the South Pole (resulting from its high elevation, low temperature, and low humidity) and from the extremely clear, thick, and homogeneous ice that makes neutrino detection possible. For additional information, see NSF/OPP (2007).
- **Highly Infectious Diseases Laboratories.** DOD and HHS (through both NIH and the Centers for Disease Control and Prevention) currently operate several laboratories that facilitate research on pathogens that require the highest levels of safety precaution, such as Ebola, viral hemorrhagic fevers, monkeypox, and avian influenza. DHS also plans to operate two such labs.

Many of the laboratories funded by the federal government provide scientists and engineers with tools and facilities that otherwise would not exist. For example, capabilities in DOE user facilities include particle and nuclear physics accelerators, synchrotron light sources, neutron scattering facilities, genome sequencing, supercomputers, and high-speed computer networks. By itself, DOE's Office of Science oversees facilities used by more than 20,000 non-DOE researchers each year in a range of scientific disciplines (figure 4-10). User facilities are one channel for collaborating and diffusing knowledge and technologies (see "Technology Transfer Metrics" later in this chapter).

Figure 4-10
External users at Department of Energy facilities, by science program: FY 2006



NOTES: External users are non-Department of Energy (DOE) researchers. One facility user may represent an individual researcher or a research team. Total external users = 21,198.

SOURCE: DOE, special tabulations, 1 June 2007. See appendix table 4-34.

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Federal R&D Initiatives

The 2008 budget targets R&D priority areas often involving the expertise of multiple federal agencies (OMB 2007). To improve the efficiency and effectiveness of federal R&D investments in these areas, the administration continues to encourage strategic coordination among stakeholder agencies. Priorities detailed in the Administration's FY 2008 budget include:

- **American Competitive Initiative (ACI).** The ACI invests in basic research areas that advance knowledge and technologies used by scientists in nearly every field through DOC's National Institute of Standards and Technology, DOE's Office of Science, and NSF. For FY 2008, the second year of ACI, President Bush proposes $11.4 billion for these three agencies. For an overview of the initiative, see OSTP (2006).
- **Climate Change.** The Climate Change Science Program (CCSP) is focused on improving decisionmaking on climate change science issues. This program has an FY 2008 R&D budget of $1.5 billion, of which the National Aeronautics and Space Administration accounts for 56%. More information is available at CCSP (2007) and Climate Change Technology Program (2007).
- **Combating Terrorism.** This area supports the president's strategy for homeland security by harnessing federal R&D programs that could help to deter, prevent, or mitigate terrorist acts. The FY 2008 budget provides support for capabilities in several areas including detection and imaging, cargo screening, biometric systems, and critical medical countermeasures. For an overview of homeland-security related R&D, see Knezo (2006).
- **Hydrogen Fuel.** The Hydrogen Fuel Initiative seeks to support R&D aimed at developing and improving technologies for producing, distributing, and using hydrogen to power automobiles. DOE will continue to lead this initiative. The 2008 budget completes the president's 5-year, $1.2 billion commitment announced in his 2003 State of the Union address, but work will continue on the many technical challenges that remain. For more details, see Interagency Working Group on Hydrogen and Fuel Cells (2007).
- **Nanotechnology.** The National Nanotechnology Initiative (NNI) supports basic and applied research on materials, devices, and systems that exploit the fundamentally distinct properties of matter at the atomic and molecular levels. The FY 2008 budget provides $1.4 billion for NNI R&D, three-fourths of which is allocated to NSF, DOD, and DOE. For more information, see NNI (2007).
- **Networking and Information Technology.** The multiagency Networking and Information Technology Research and Development (NITRD) program aims to leverage agency research efforts in advanced networking and information technologies. The FY 2008 budget provides $3.1 billion for NITRD R&D, including about $1 billion each to DOD and NSF. Additional information is available at NITRD (2007).

defense and nondefense R&D budgets shrank almost every year after 1986 until 2001, when the defense budget function represented 53% of the federal R&D budget. The terrorist attacks of September 11, 2001, reversed this trend, and the annual federal defense R&D budget grew by an estimated $36 billion over the next 7 years.

Civilian-Related R&D

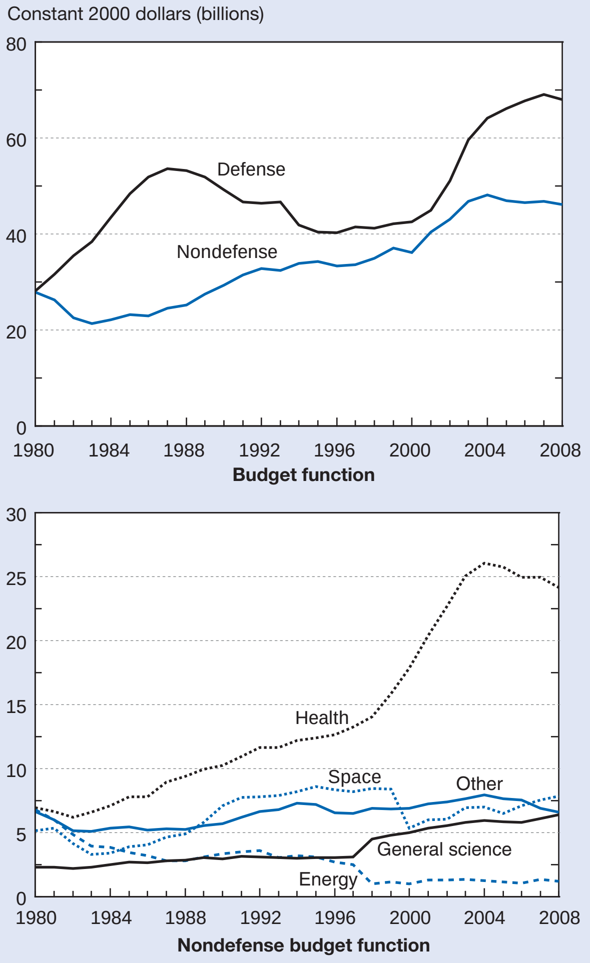
R&D accounts for 13.1% ($56 billion) of the FY 2008 federal nondefense discretionary budget authority of $428 billion, or slightly more than the R&D share reserved for defense activities (12.7% of the $647 billion discretionary defense budget authority in FY 2008). Almost 95% of federal basic research funding is for nondefense budget functions, accounting for a large part of the budgets of agencies with nondefense missions such as general science (NSF), health (NIH), and space research and technology (NASA) (table 4-9; appendix table 4-27). Over the last several years, however, the budget authority for basic research has been rather flat. In FY 2002 that budget authority was approximately $23 billion (in constant 2000 dollars), and the same amount has been proposed for FY 2008.

The most dramatic change in national R&D priorities during the past 25 years has been the large rise in health-related R&D. As illustrated in figure 4-11, health-related R&D rose from representing 25% of the federal nondefense R&D budget allocation in FY 1980 to a high of 55% in FY 2005. Most of this growth occurred after 1998, when NIH's budget was set on a pace to double by 2003 (NSF/SRS 2002a). Growth in health-related R&D has since slowed considerably and accounted for 52% of the proposed FY 2008 nondefense R&D budget.

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. Since the loss of the Space Shuttle Columbia and its crew of seven on 1 February 2003, manned space missions were curtailed. Nonetheless, the proportion of the proposed federal nondefense R&D budget for space research was higher in FY 2008 (17%) than in FY 2003 (15%). In the president's FY 2008 budget, 58% of NASA's $17 billion discretionary budget was allocated for R&D. This space R&D total is higher (in constant dollars) than at any time since FY 1999.

Compared with that of health-related R&D, the budget allocation for general science R&D has grown relatively little

Figure 4-11
Federal R&D budget authority, by budget function: FY 1980–2008



NOTES: 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 results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Federal R&D Funding by Budget Function: Fiscal Years 2006–08 (forthcoming). See appendix table 4-26.

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during the past 25 years. The growth that has occurred in general science R&D is more the result of a reclassification of several DOE programs from energy to general science in FY 1998 than it is the result of increased budget allocations (figure 4-11).

Federal and State R&D Tax Credits

Background

Governments have used multiple policy tools to foster R&D in diverse industries, technologies, and innovation environments (Martin and Scott 2000; Tassey 1996). Fiscal policy tools include direct funding (as discussed earlier in this chapter) and indirect incentives such as tax relief.[19] Tax relief may take the form of a tax allowance, exemption or deduction (a reduction in taxable income), or a tax credit (a reduction in tax liability). The United States offers both types of incentives, namely a deduction for qualified R&D under U.S. Internal Revenue Code (C.F.R. Title 26) Section 174 and a tax credit under Section 41 (Guenther 2006; Hall 2001). R&D tax incentives in advanced economies vary in terms of how they are structured or targeted, their effect on public budgets, and their effectiveness in stimulating innovation (Bloom, Griffith, and Van Reenen 2002; OECD 2003). This section focuses on business R&D tax credits at the federal and state levels.

The federal research and experimentation (R&E) tax credit was established by the Economic Recovery Tax Act of 1981. Given its temporary status, it is subject to periodic extensions, and it was last renewed by the Tax Relief and Health Care Act of 2006 (Public Law 109–432) through 31 December 2007.[20] The Bush administration has proposed making the R&E tax credit permanent (OMB 2007).

Under the federal R&E tax credit, companies can take a 20% credit for qualified research above a base amount for activities undertaken in the United States.[21] For most companies, the base amount is determined by multiplying R&D-to-sales ratio by the average gross receipts for the previous 4 years. Currently, the reference period for R&D-to-sales ratio is fixed as the average from 1984 to 1988 (start-up companies follow different provisions). Thus, the credit is characterized as a fixed-base incremental credit (Hall 2001; Wilson 2007). Companies, however, benefit by less than the statutory credit rate of 20%, since benefits from the credit are taxable.[22]

An alternative R&E tax credit has been available since 1996 (Small Business Protection Act, Public Law 104–188). The 2006 Act (Public Law 109–432), signed into law in December 2006, not only extended the research credit for 2 years—2006 (retroactively) and 2007—but also increased the rates for the alternative credit for 2007. In addition, it created a new, simplified alternative credit beginning in 2007. Companies may select only one of these credit configurations on a permanent basis, unless the Internal Revenue Service (IRS) authorizes a change. A 20% credit with a separate threshold is provided for payments to universities for basic research.

Federal Corporate Tax Credit Claims

R&E tax credit claims reached an estimated $5.5 billion in 2003 ($5.2 billion in constant, or inflation-adjusted, dollars), involving just under 10,400 corporate tax returns, compared with the all-time high of $7.1 billion in 2000 (table 4-10), according to IRS Statistics of Income Division (SOI) estimates.[23] Even at their 2000 peak, R&E tax credit claims accounted for less than 4% of industry-funded R&D expenditures (figure 4-12). Since 1998, corporate tax returns classified in five North American Industry Classification System (NAICS) industries accounted for approximately 80% of

Table 4-9

Budget authority for R&D, by federal agency and character of work (proposed levels): FY 2008

(Millions of current dollars)

Agency	All discretionary budget authority	All R&D	Basic research	Applied research	Development	R&D share of discretionary budget (%)
All federal government	1,074,966	137,912	28,371	26,638	82,903	12.8
DOD	627,718	78,658	1,428	4,357	72,873	12.5
HHS	69,330	28,874	15,615	13,237	22	41.6
NASA	17,310	10,060	2,226	1,127	6,707	58.1
DOE	24,310	8,169	3,409	2,869	1,891	33.6
NSF	6,430	4,373	3,993	380	0	68.0
USDA	20,226	1,911	771	984	156	9.4
DHS	34,511	934	132	533	269	2.7
DOC	6,554	932	164	696	72	14.2
VA	39,418	822	330	444	48	2.1
DOT	12,110	793	0	541	252	6.5
DOI	10,610	619	39	525	55	5.8
EPA	7,200	562	94	364	104	7.8
Other	199,239	1,205	170	581	454	0.6

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; 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

SOURCE: Office of Management and Budget, Budget of the United States Government, Fiscal Year 2008 (2007).

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Table 4-10

Federal research and experimentation tax credit claims and corporate tax returns claiming credit: 1990–2003

Year	Tax credit claims ($millions) Current	Tax credit claims ($millions) Constant	Tax returns
1990	1,547	1,896	8,699
1991	1,585	1,877	9,001
1992	1,515	1,754	7,750
1993	1,857	2,101	9,933
1994	2,423	2,684	9,150
1995	1,422	1,544	7,877
1996	2,134	2,274	9,709
1997	4,398	4,609	10,668
1998	5,208	5,399	9,849
1999	5,281	5,396	10,019
2000	7,079	7,079	10,495
2001	6,356	6,207	10,389
2002	5,656	5,428	10,254
2003	5,488	5,158	10,369

NOTES: Data exclude Internal Revenue Service (IRS) forms 1120S (S corporations), 1120-REIT (Real Estate Investment Trusts), and 1120-RIC (Regulated Investment Companies). Constant dollars based on calendar year 2000 gross domestic product price deflator.

SOURCE: IRS, Statistics of Income program, special tabulations. See appendix table 4-33.

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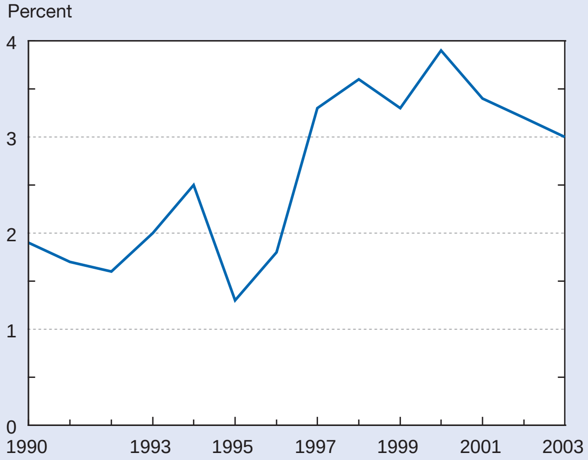
Figure 4-12

Research and experimentation credit claims as percentage of industry-funded R&D: 1990–2003



SOURCES: Internal Revenue Service, Statistics of Income, special tabulations; and National Science Foundation, Survey of Industrial R&D (annual series).

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R&E credit claims. In 2003, the top five industries accounted for a total of $4.2 billion or 77% of credit claims:

- Computer and electronic products (21%)
- Chemicals, including pharmaceuticals and medicines (18%)
- Transportation equipment, including motor vehicles and aerospace (16%)
- Information, including software (12%)
- Professional, scientific, and technical services, including computer services and R&D services (10%)

In 2003, companies classified in the professional, scientific, and technical services industry represented one-third of all corporate returns claiming the R&E tax credit, followed by computer and electronic products and information, each with about 15%. Consequently, among the top five industries listed above, professional, scientific, and technical services had the lowest average claims per return ($15.9 million) in 2003, compared with an average of $52.9 million per return overall.[24]

State Tax Credits

At least 32 states offered credits for company-funded R&D (table 4-11) in 2006, according to Wilson (2007). The first such credit was enacted by Minnesota in 1982 only a year after the federal R&E credit was enacted. Since then, the number of states offering a research credit has increased gradually (figure 4-13).

More than half of these states' research credits (19 of 32) mimic the structure of the federal credit, namely, an incremental credit with a fixed base (table 4-11). Another 10 states offer an incremental credit with a moving average

Table 4-11
Summary of state-level R&D tax credits: 2006

State	Year enacted	Top-tier statutory credit rate (%)	Base definition for credit
Arizona	1994	11.0	Federal (fixed-period)
California	1987	15.0	Federal (fixed-period)
Connecticut	1993	6.0	Nonincremental
Delaware	2000	10.0	Average of previous 4 years
Georgia	1998	10.0	Federal (fixed-period)
Hawaii	2000	20.0	Nonincremental
Idaho	2001	5.0	Federal (fixed-period)
Illinois	1990	6.5	Average of previous 3 years
Indiana	1985	10.0	Federal (fixed-period)
Iowa	1985	6.5	Federal (fixed-period)
Kansas	1988	6.5	Average of previous 2 years
Louisiana	2003	8.0	Federal (fixed-period)
Maine	1996	5.0	Average of previous 3 years
Maryland	2000	10.0	Average of previous 4 years
Massachusetts	1991	10.0	Federal (fixed-period)
Minnesota	1982	2.5	Federal (fixed-period)
Missouri	1994	6.5	Average of previous 3 years
Montana	1999	5.0	Federal (fixed-period)
Nebraska	2005	3.0	Average of previous 2 years
New Jersey	1994	10.0	Federal (fixed-period)
North Carolina	1996	5.0	Federal (fixed-period)
North Dakota	1988	4.0	Federal (fixed-period)
Ohio	2004	7.0	Average of previous 3 years
Oregon	1989	5.0	Federal (fixed-period)
Pennsylvania	1997	10.0	Average of previous 4 years
Rhode Island	1994	16.9	Federal (fixed-period)
South Carolina	2001	5.0	Federal (fixed-period)
Texas	2001	5.0	Federal (fixed-period)
Utah	1999	6.0	Federal (fixed-period)
Vermont	2003	10.0	Average of previous 4 years
West Virginia	1986	3.0	Nonincremental
Wisconsin	1986	5.0	Federal (fixed-period)
Median	na	6.5	na

na = not applicable

NOTES: Top-tier credit rate applies to highest tier of expenditure levels for states having multiple credit rates.

SOURCE: Dr. Daniel Wilson, Federal Reserve Bank of San Francisco, special tabulations (February 2007).

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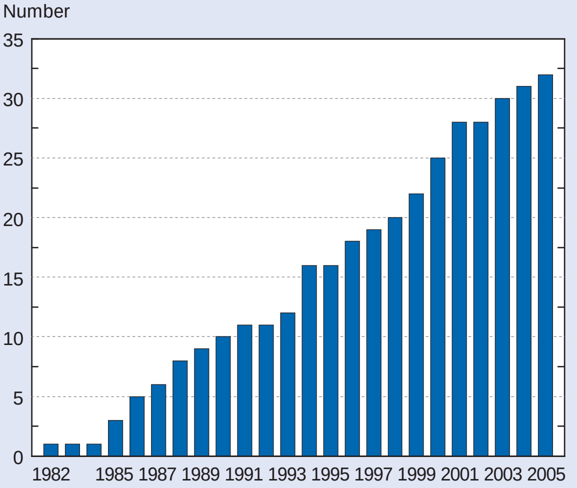
Figure 4-13
U.S. states with credits for company-funded R&D: 1982–2005



SOURCE: Dr. Daniel Wilson, Federal Reserve Bank of San Francisco, special tabulations (February 2007).

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(much like the earlier version of the federal credit). Three states (Connecticut, Hawaii, and West Virginia) have a nonincremental credit, that is, the credit applies to all qualified research. These counts do not include narrowly targeted credits (either by technology or geographically within the state) or credits with a cap.[25]

In a study attempting to measure the impact of states' research credits, Wilson (2007) was able to estimate increases in within-state R&D. At the same time, however, estimated effects appear to come from shifts in other states' R&D, raising questions about the aggregate effect of these state R&D incentives. Further empirical research on these issues is warranted given the recent enactment of some of these credits.

International R&D Comparisons

Data on R&D expenditures are often used to make international comparisons, in part because of the relative ease of comparing monetary data across countries. But although it is possible to compare the cost of R&D in two countries, differences in their national systems of innovation may make one country more effective than the other in translating investments in S&T into economic growth or other social benefits. Although it can be difficult to assess the qualitative differences in the R&D and innovation systems in different countries, it is important to keep these differences in mind when analyzing data presented in this section on international R&D spending patterns.

Most of the R&D data presented in this section are from the OECD, the most reliable source for such international comparisons. However, an increasing number of non-OECD countries and organizations now collect and publish R&D statistics (with variable levels of international comparability), which are cited at various points in this section. No R&D-specific currency exchange rates exist, but for comparison purposes, international R&D data have been converted to U.S. dollars with purchasing power parity (PPP) exchange rates (see sidebar, "Comparing International R&D Expenditures").

Global R&D Expenditures

Worldwide R&D performance is concentrated in a few developed nations. In 2002, global R&D expenditures totaled at least $813 billion; one-third of this world total was accounted for by the United States, the largest country in terms of domestic R&D expenditures, and 45% of this total was accounted for by the two largest countries in terms of R&D performance, the United States and Japan.

As figure 4-14 illustrates, more than 95% of global R&D is performed in North America, Asia, and Europe. Within each of these regions, a small number of countries dominate in terms of expenditures on R&D: the United States in North America; Japan and China in Asia; and Germany, France, and the United Kingdom in Europe.[26]

Wealthy, well-developed nations, generally represented by OECD countries, perform most of the world's R&D, but R&D expenditures have grown rapidly in several lesser-developed nations. In 2004, Brazil performed an estimated $14 billion of R&D (RICYT 2007), although the compilations of its R&D statistics do not yet fully conform to OECD guidelines. India performed an estimated $21 billion in 2000, making it the seventh largest country in terms of R&D in that year, ahead of South Korea (UNESCO/Institute for Statistics 2007). China had the fourth largest expenditures on R&D in 2000 ($45 billion), behind Germany's $52 billion (OECD 2006b). In 2005, it is estimated that $115 billion of R&D was performed in China, making it the third largest country in terms of R&D expenditures. Given the lack of R&D-specific exchange rates (see sidebar, "Comparing International R&D Expenditures"), it is difficult to draw conclusions from these absolute R&D figures, but China's nearly decade-long ramp-up of R&D expenditures appears unprecedented in recent years.

OECD and G-7 R&D Expenditures

The 30 OECD countries represented 81% of global R&D, or $657 billion, in 2002. Although global R&D estimates are not available for later years, the R&D performance of OECD countries grew to $726 billion in 2004. The G-7 countries performed two-thirds of the world's R&D in 2002 and 83% of OECD's R&D in 2004. Outside of the G-7 countries, South Korea is the only country that accounted for a substantial share of the OECD total (4% in 2004).

More money was spent on R&D activities in the United States in 2004 than in the rest of the G-7 countries combined (figure 4-15). In terms of relative shares, the U.S. share of the G-7's R&D expenditures has fluctuated between 48%

Figure 4-14
Estimated R&D expenditures and share of world total, by region: 2002

NOTE: R&D estimates from 91 countries in billions of purchasing power parity dollars. Percentages may not add to 100 because of rounding.

SOURCES: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006); Ibero-American Network of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 5 March 2007; and United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org.

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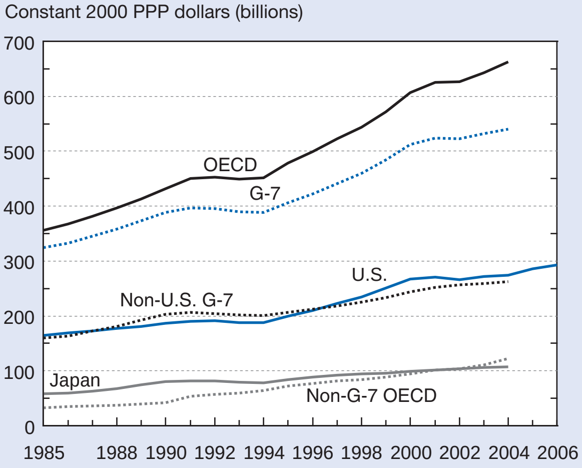
Figure 4-15
R&D expenditures of United States and G-7 and OECD countries: 1985–2006



OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity

NOTE: Data not available for all countries for all years.

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-35.

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and 52% during the past 25 years. As a proportion of the G-7 total, U.S. R&D expenditures reached a low of 48% in 1990. After the early 1990s, the U.S. percentage of total G-7 R&D expenditures grew as a result of a worldwide slowing in R&D performance that was more pronounced in other countries. R&D spending rebounded in the late 1990s in several G-7 countries, but the recovery was most robust in the United States, and the U.S. share of total G-7 R&D has exceeded 50% since 1997, peaking at 52% in 2000, before dropping slightly to 51% of total in 2004.

Indicators of R&D Intensity

International comparisons of absolute R&D expenditures are complicated by the fact that countries vary widely in terms of the size of their population and economy. For example, although Germany and China had similar R&D expenditures in 2000, China's population was more than 15 times larger, and its economy more than twice as large, as Germany's in that year. Policy analysts commonly use various measures of R&D intensity to account for these size differences when making international comparisons.

One of the first (Steelman 1947) and now one of the more widely used indicators of a country's R&D intensity is the ratio of R&D spending to GDP, the main measure of a na-

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, which circumvents the problem of currency conversion; and (2) convert all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation that 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. However, 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, which have little or nothing to do with changes in the relative prices of internationally traded goods, greatly reduce their statistical utility.

PPPs. PPPs were developed because of the shortcomings of MERs described above (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 therefore 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 OECD.*

Because MERs tend to understate the domestic purchasing power of developing countries' currencies, PPPs can produce substantially larger R&D estimates than MERs do for these countries. For example, China's 2005 R&D expenditures are $30 billion using MERs but are $115 billion using PPPs. Appendix table 4-2 shows the relative difference between MERs and PPPs for a number of countries.

Although PPPs are available for developing countries such as India and China, there are several reasons why they may be less useful for converting R&D expenditures than in more developed countries:

- 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 the market basket 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.

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*Recent research calls into question the use of GDP PPPs for deflating R&D expenditures. Analyzing manufacturing R&D inputs and outputs in 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."

tion's total economic activity. Policymakers often use this ratio for international benchmarking and goal setting.

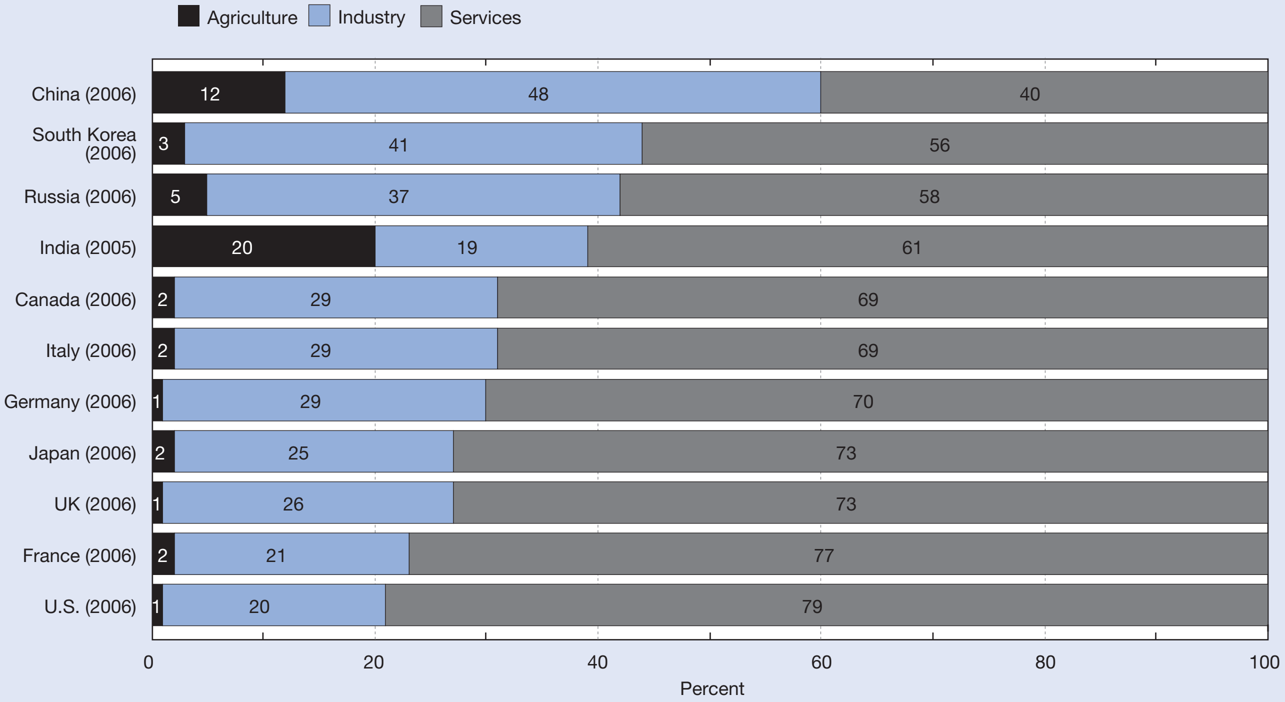
Normalized indicators, such as R&D/GDP ratios, are useful for international comparisons because they not only account for size differences between countries, but they also obviate the need for exchange rates. However, even normalized indicators are not always comparable from one country to another. This occurs most often when the variable being used to normalize the indicator differs across countries. For example, the structure of national economies, and hence GDP, varies greatly. As figure 4-16 shows, the agricultural and industrial sectors account for less than one-third of GDP in the United States and the other G-7 countries. These sectors represent similarly small shares of the labor force in the G-7 countries. This contrasts with less-developed nations such as China, where the agricultural and industrial sectors account for more than half of GDP and an even larger share of the labor force (estimated to be 69%) (CIA 2007). In recent years, the service sector has grown substantially in India in terms of its contribution to GDP (61% in 2005), but more than half of India's labor force works in the agricultural sector. Differences such as these in the structure of economies can result in significant country-to-country differences in terms of various R&D indicators.

Total R&D/GDP Ratios

The ratio of R&D expenditures to GDP can indicate the intensity of R&D activity in relation to other economic activity and can be used to gauge a nation's commitment to R&D at different points in time. For example, since 1953, R&D expenditures as a percentage of GDP in the United States have ranged from a minimum of 1.4% (in 1953) to a maximum of 2.9% (in 1964). Most of the growth over time in the R&D/GDP ratio can be attributed to increases in nonfederal R&D spending, the majority of which is company financed. Nonfederally financed R&D increased from 0.6% of GDP in 1953 to a projected 1.9% of GDP in 2006 (down from a high of 2.0% of GDP in 2000). The increase in nonfederally financed R&D as a percentage of GDP illustrated in figure 4-17 is indicative of the growing role of S&T in the U.S. economy.

Historically, most of the peaks and valleys in the U.S. R&D/GDP ratio can be attributed to changing priorities in federal R&D spending. The initial drop in the R&D/GDP ratio from its peak in 1964 largely reflects federal cutbacks in defense and space R&D programs. Gains in energy R&D activities between 1975 and 1979 resulted in a relative stabilization of the ratio. Beginning in the late 1980s, cuts in defense-related R&D kept federal R&D spending from keeping pace with GDP growth, while growth in nonfederal sources of R&D spending generally kept pace with or exceeded GDP growth. Since 2000, defense-related R&D

Figure 4-16
Composition of gross domestic product for selected countries, by sector: 2005 or 2006



UK = United Kingdom

SOURCE: Central Intelligence Agency, *The World Factbook 2007*, http://www.cia.gov/cia/publications/factbook/index.html, accessed 2 March 2007.

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spending has surged, and federal R&D spending growth has outpaced GDP growth. (See the discussion of defense-related R&D earlier in this chapter.)

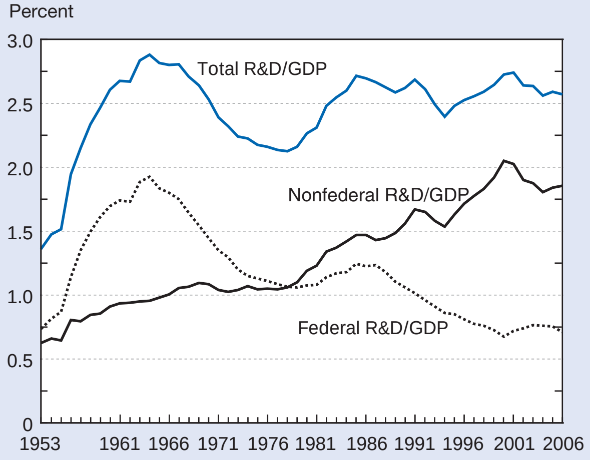
For many of the G-8 countries (i.e., the G-7 countries plus Russia), the latest R&D/GDP ratio is no higher now than it was at the start of the 1990s, which ushered in a period of slow growth or decline in their overall R&D efforts (figure 4-18). The two exceptions, Japan and Canada, both exhibited substantial increases on this indicator between 1990 and 2004. In Japan this indicator declined in the early 1990s as a result of reduced or level R&D spending by industry and government, a pattern similar to that exhibited by the United States. Japan's R&D/GDP ratio subsequently rose to 3.2% in 2004, the result of both a resurgence of industrial R&D in the mid-1990s coupled with slow GDP growth. By contrast, over the same period, GDP grew more robustly in Canada; therefore the rise in its R&D/GDP ratio is more indicative of R&D growth.

Because of the business sector's dominant role in global R&D funding and performance, R&D/GDP ratios are most useful when comparing countries with national S&T systems of comparable maturity and development. Geopolitical events also affect R&D intensity indicators, as evidenced by Germany and Russia. [West] Germany's R&D/GDP ratio fell from 2.8% at the end of the 1980s, before reunification, to 2.2% in 1994 for all of Germany. Its R&D/GDP has since risen to 2.5% in 2005. The end of the Cold War and collapse of the Soviet Union had a drastic effect on Russia's R&D intensity. R&D performance in Russia was estimated at 2.0% of GDP in 1990; that figure dropped to 1.4% in 1991 and then dropped further to 0.7% in 1992. The severity of this decline is compounded by the fact that Russian GDP contracted in each of these years. Both Russia's R&D and GDP exhibited strong growth after 1998. Between 1998 and 2003, Russia's R&D doubled, and its R&D/GDP ratio rose from 1.0% to 1.3%. This growth was not maintained in the subsequent 2 years, and Russia's R&D/GDP ratio dropped to 1.1% in 2005.

Overall, the United States ranked seventh among OECD countries in terms of reported R&D/GDP ratios (table 4-12), but several of its states have R&D intensities of more than 4%. Massachusetts, a state with an economy larger than Sweden's and approximately twice the size of Israel's, has reported an R&D intensity at or above 5% since 2001 (see the section entitled "Location of R&D Performance"). Israel (not an OECD country), devoting 4.7% of its GDP to R&D, currently leads all countries, followed by Sweden (3.9%), Finland (3.5%), Japan (3.2%), and South Korea (3.0%). In

Figure 4-17

U.S. R&D share of gross domestic product: 1953–2006



GDP = gross domestic product

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix tables 4-1 and 4-3.

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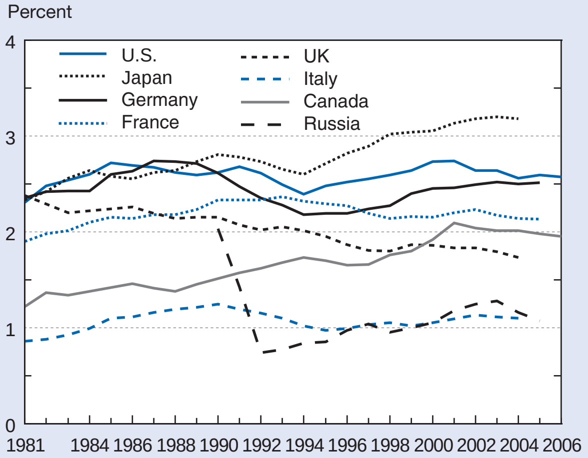
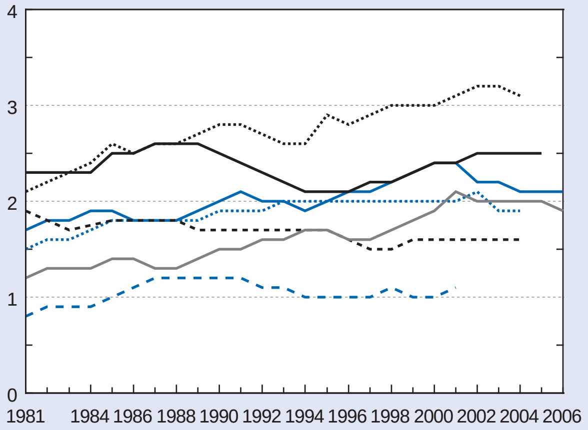
Figure 4-18

R&D share of gross domestic product, by selected countries: 1981–2006



All R&D/GDP



Nondefense R&D/GDP

GDP = gross domestic product; UK = United Kingdom

NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006). See appendix tables 4-35 and 4-36.

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Table 4-12
R&D share of gross domestic product, by country/economy: Most recent year
(Percent)

Country/economy	Share	Country/economy	Share
All OECD (2004)	2.25	Luxembourg (2005)	1.56
EU-25 (2005)	1.77	Norway (2005)	1.51
Israel (2005)	4.71	Czech Republic (2005)	1.42
Sweden (2005)	3.86	China (2005)	1.34
Finland (2006)	3.51	Ireland (2005)	1.25
Japan (2004)	3.18	Slovenia (2005)	1.22
South Korea (2005)	2.99	New Zealand (2003)	1.14
Switzerland (2004)	2.93	Spain (2005)	1.12
Iceland (2003)	2.86	Italy (2004)	1.10
United States (2006)	2.57	Russian Federation (2005)	1.07
Germany (2005)	2.51	Hungary (2005)	0.94
Austria (2006)	2.44	South Africa (2004)	0.87
Denmark (2005)	2.44	Portugal (2005)	0.81
Taiwan (2004)	2.42	Turkey (2004)	0.67
Singapore (2005)	2.36	Greece (2005)	0.61
France (2005)	2.13	Poland (2005)	0.57
Canada (2006)	1.95	Slovak Republic (2005)	0.51
Belgium (2005)	1.82	Argentina (2005)	0.46
Netherlands (2004)	1.78	Mexico (2003)	0.43
Australia (2004)	1.77	Romania (2004)	0.39
United Kingdom (2004)	1.73		

EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: Civilian R&D only for Israel and Taiwan.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006).

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general, nations in Southern and Eastern Europe tend to have R&D/GDP ratios of 1.5% or lower, whereas Nordic nations and those in Western Europe report R&D spending shares greater than 1.5%. This pattern broadly reflects the wealth and level of economic development for these regions. A strong link exists between countries with high incomes that emphasize the production of high-technology goods and services and those that invest heavily in R&D activities (OECD 1999). The private sector in low-income countries often has a low concentration of high-technology industries, resulting in low overall R&D spending and therefore low R&D/GDP ratios.

Outside the European region, R&D spending has intensified considerably since the early 1990s. Several Asian countries, most notably South Korea and China, have been particularly aggressive in expanding their support for R&D and S&T-based development. In Latin America and the Pacific region, other non-OECD countries also have attempted to increase R&D substantially during the past several years. Even with recent gains, however, most non-European (non-OECD) countries invest a smaller share of their economic output in R&D than do OECD members (with the exception of Israel). All Latin American countries for which such data are available report R&D/GDP ratios at or below 1% (RICYT 2007). This distribution is consistent with broader indicators of economic growth and wealth.

Nondefense R&D Expenditures and R&D/GDP Ratios

Another indicator of R&D intensity, the ratio of nondefense R&D to GDP, is useful when comparing nations with different financial investments in national defense. Although defense-related R&D does result in spillovers that produce commercial and social benefits, nondefense R&D is more directly oriented toward national scientific progress, economic competitiveness, and standard-of-living improvements. Using this indicator, the relative position of the United States falls below that of Germany and just above Canada among the G-7 nations (figure 4-18). This is because the United States devotes more of its R&D, primarily for development rather than research, to defense-related activities than do most other countries. In 2006, approximately 16% of U.S. R&D was defense related, whereas for historical reasons, less than 1% of the R&D performed in Germany and Japan is defense related. Approximately 10% of the United Kingdom’s total R&D was defense related in 2004.

Basic Research/GDP Ratios

R&D involves a wide range of activities, ranging from basic research to the development of marketable goods and services. Because it is motivated primarily by curiosity, basic research generally has low short-term returns, but it builds intellectual capital and lays the groundwork for future advances in S&T. (See sidebar, “Definitions of R&D.”) The relative investment in basic research as a share of GDP indicates differences in national priorities, traditions, and incentive structures with respect to S&T. Estimates of basic research often involve a greater element of subjective assessment than other R&D indicators; thus, approximately 40% of the OECD countries do not report these data at the national level. Nonetheless, where these data exist, they help differentiate national innovation systems in terms of how their R&D resources contribute to advancing scientific knowledge and developing new technologies.

High basic research/GDP ratios generally reflect the presence of robust academic research centers in the country and/or a concentration of high-technology industries (such as biotechnology) with patterns of strong investment in basic research (see the section entitled “International R&D by Performer and Source of Funds”). Of the OECD countries for which data are available, Switzerland has the highest basic research/GDP ratio at 0.8% (figure 4-19). This is significantly higher than either the U.S. ratio of 0.5% or the Japanese ratio of 0.4%. Switzerland, a small, high-income country boasting the highest number of Nobel prizes, patents, and science citations per capita worldwide, devoted almost 30% of its R&D to basic research in 2004 despite having an industrial R&D share comparable with the United States and Japan. The differences among the Swiss, U.S., and Japanese character-of-work shares reflect both the high concentration of chemical and pharmaceutical R&D in Swiss industrial R&D, as well as the “niche strategy” of focusing on specialty products adopted by many Swiss high-technology industries.

China, despite its growing investment in R&D, reports among the lowest basic research/GDP ratios (0.07%), below Romania (0.08%) and Mexico (0.11%). With its emphasis on applied research and development aimed at short-term economic development, China follows the pattern set by Taiwan, South Korea, and Japan. In each of these economies, basic research accounts for 15% or less of total R&D (figure 4-20). Singapore also followed this pattern, but since 2000, its expenditures on basic research have grown faster than its total R&D. In 2000, 12% of Singapore’s R&D was basic research, but in 2004 this share was 19%, on par with the United States.

Figure 4-19
Basic research share of gross domestic product, by country/economy: 2003 or 2004

GDP = gross domestic product

NOTE: Countries with same values sorted alphabetically.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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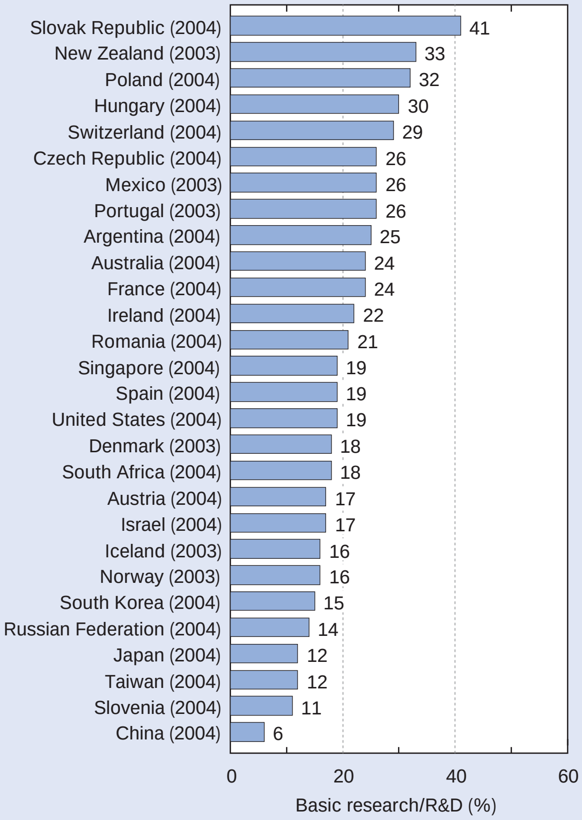
Figure 4-20
Basic research share of R&D, by country/economy: 2003 or 2004



NOTE: Countries with same values sorted alphabetically.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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International R&D by Performer and Source of Funds

R&D performance patterns by sector are broadly similar across countries, but national sources of support differ considerably. In each of the G-8 countries, the industrial sector is the largest performer of R&D (table 4-13). Industry's share of R&D performance ranged from 48% in Italy to more than 75% in Japan and South Korea; it was 71% in the United States. In China, much of the recent growth in R&D expenditures has occurred in the business sector, which performed 68% of China's R&D in 2005, up from 60% in 2000. In most countries, industrial R&D is financed primarily by the business sector. A notable exception is the Russian Federation, where government was the largest source of industrial R&D funding in 2005 (appendix table 4-37).

In all of the G-8 countries except Russia, the academic sector was the second largest performer of R&D (representing from 13% to 38% of R&D performance in each country). In Russia, government is the second largest R&D performer, accounting for 26% of its R&D performance in 2005. Government-performed R&D accounted for 22% of China's R&D in 2005, down from 32% in 2000.

Government and industry together account for more than three-quarters of the R&D funding in each of the G-8 countries, although their respective contributions vary (table 4-14). The industrial sector provided as much as 75% of R&D fund-

Table 4-13

R&D expenditures for selected countries, by performing sector: Most recent year

(Percent)

Country	Industry	Higher education	Government	Other nonprofit
South Korea (2005)	76.9	9.9	11.9	1.4
Japan (2004)	75.2	13.4	9.5	1.9
Germany (2005)	69.9	16.5	13.6	NA
United States (2006)	71.1	13.7	11.0	4.2
China (2005)	68.3	9.9	21.8	NA
Russian Federation (2005)	68.0	5.8	26.1	0.2
United Kingdom (2004)	63.0	23.4	10.3	3.3
France (2005)	61.9	19.5	17.3	1.2
Canada (2006)	52.4	38.4	8.8	0.5
Italy (2004)	47.8	32.8	17.9	1.5

NA = not available

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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Table 4-14

R&D expenditures for selected countries, by source of funds: Most recent year

(Percent)

Country	Industry	Government	Other domestic	Abroad
Canada (2006)	46.7	33.7	11.0	8.5
China (2005)	67.0	26.3	NA	0.9
France (2004)	51.7	37.6	1.9	8.8
Germany (2004)	66.8	30.4	0.4	2.5
Japan (2004)	74.8	18.1	6.8	0.3
Russian Federation (2005)	30.0	62.0	0.5	7.6
South Korea (2005)	75.0	23.0	1.3	0.7
United Kingdom (2004)	44.2	32.8	5.8	17.3
United States (2006)	65.6	28.6	5.8	NA

NA = not available

NOTES: Separate data on foreign sources of R&D funding unavailable for United States but included in sector totals. In most other countries, "foreign sources of funding" is a distinct and separate funding category. For some countries (such as Canada), foreign firms are the source for a large amount of foreign R&D funding, reported as funding from abroad. In United States, industrial R&D funding from foreign firms reported as industry. Data unavailable for Italy.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006).

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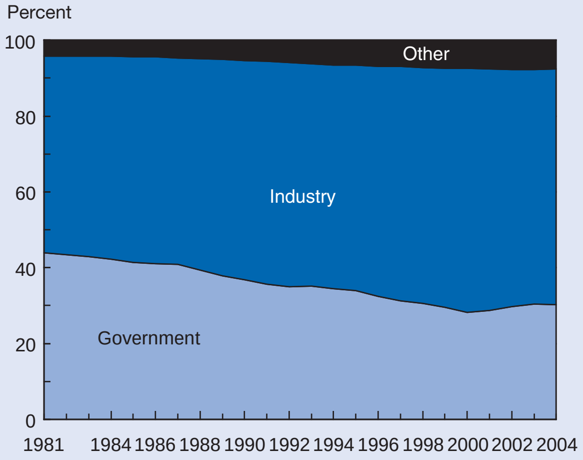
ing in Japan to as little as 30% in Russia. Government provided the largest share of Russia's R&D (62%), and although recent data for Italy are not available, its government funded 50% of Italy's R&D in 1999. In the remaining six G-8 nations, government was the second largest source of R&D funding, ranging from 18% of total R&D funding in Japan to 38% in France.

In nearly all OECD countries, the government's share of total R&D funding declined during the 1980s and 1990s as the role of the private sector in R&D grew considerably (figure 4-21). In 2000, 28% of all OECD R&D was funded from government sources, down from 44% in 1981. The relative decline of government R&D funding was the result of budgetary constraints, economic pressures, and changing priorities in government funding (especially the relative reduction in defense R&D in several of the major R&D-performing countries, notably France, the United Kingdom, and, until rather recently, the United States). This trend also reflected the growth in business R&D spending during this period, irrespective of government R&D spending patterns. However, since 2000, government funding of R&D has grown in the OECD relative to funding from the business sector. In 2004, governments funded 30% of all OECD R&D.

Not all countries track the amount of domestic R&D that is funded by foreign sources, but of those that do, the United Kingdom reports a relatively large amount of R&D funding from abroad (17% in 2004) (table 4-14). Businesses in the United States also receive foreign R&D funding; however, these data are not separately reported in U.S. R&D statistics and are included in the figures reported for industry. Therefore, the industry share of R&D funding for the United States is overstated compared with the industry shares for countries where foreign sources of R&D funding are reported separately from domestic sources.

Figure 4-21
Total OECD R&D, by funding sector: 1981–2004



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-39.

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Industrial Sector

The structure of industrial R&D varies substantially among countries in terms of both sector concentration and sources of funding. Because industrial firms account for the largest share of total R&D performance in each of the G-8 countries and most OECD countries, differences in industrial 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 communications equipment manufacturing) are likely to also have higher R&D/GDP ratios than countries whose industrial structures are weighted more heavily toward less R&D-intensive industries.

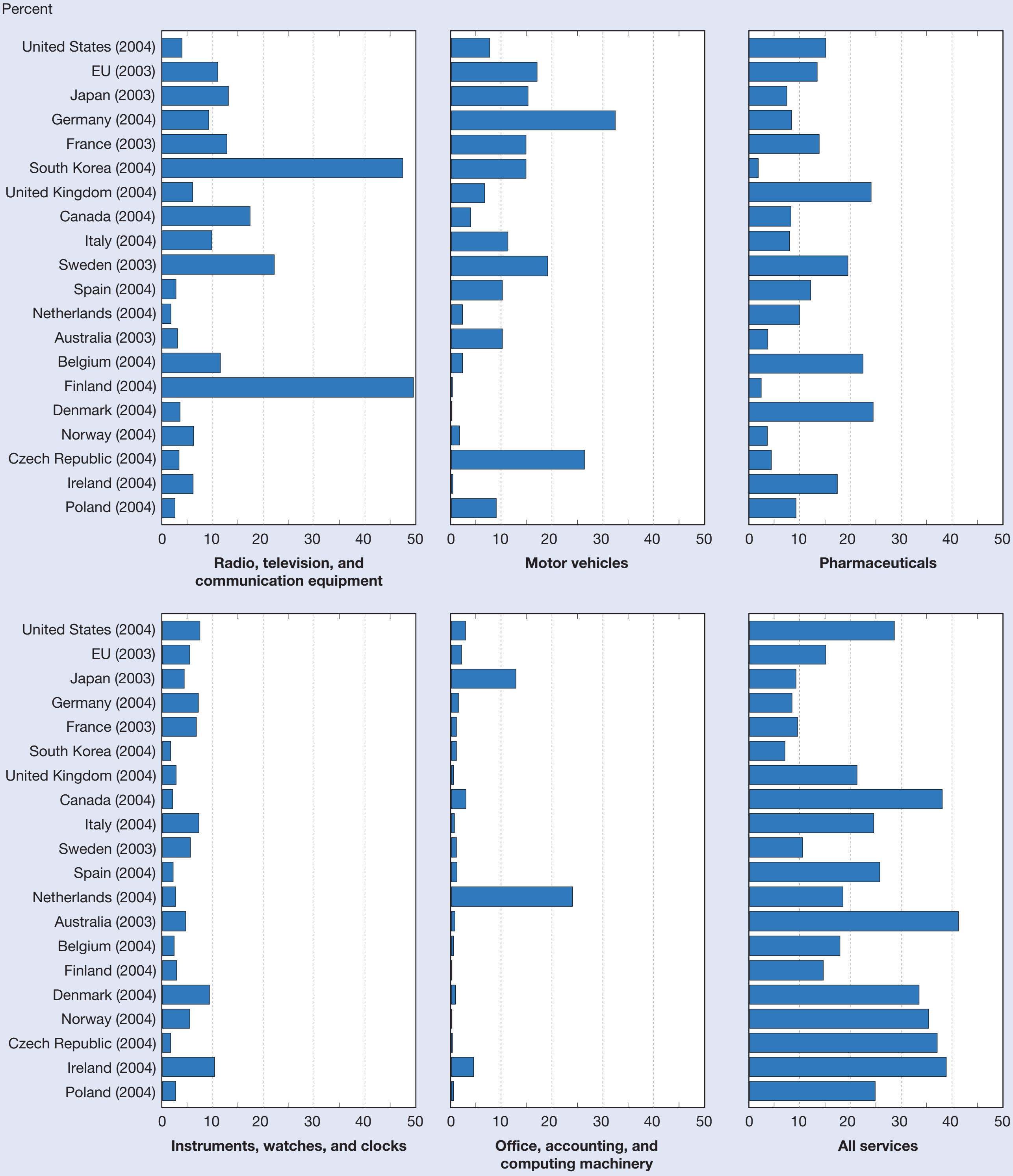
Sector Focus

Using internationally comparable data, no one industry accounted for more than 16% of total business R&D in the United States in 2004 (figure 4-22; appendix table 4-42) (OECD 2006d). This is largely a result of the size of business R&D expenditures in the United States, which makes it 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 in a broad range of industries.[27]

Compared with the United States, many of the other countries shown in figure 4-22 display much higher industry and 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 radio, television, and communications equipment industry accounted for almost half of business R&D in 2004. This high concentration most likely reflects the activities of one company, Nokia, the world's largest manufacturer of cellular phones (see also table 4-6 in sidebar, "R&D Expenses of Public Corporations"). By contrast, South Korea's high concentration (47% of business R&D in 2004) of R&D 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 (see sidebar, "R&D in the ICT Sector").

Other industries also exhibit relatively high concentrations of R&D by country. Automotive manufacturers rank among the largest R&D-performing companies in the world (see sidebar, "R&D Expenses of Public Corporations"). Because of this, the countries that are home to the world's major automakers also boast the highest concentration of R&D in the motor vehicles industry. This industry accounts for 32% of Germany's business R&D, 26% of the Czech Republic's, and 19% of Sweden's, reflecting the operations of automakers such as DaimlerChrysler and Volkswagen in Germany, Skoda in the Czech Republic, and Volvo and Saab

Figure 4-22
Share of industrial R&D for selected countries and European Union, by industry sector: 2003 or 2004



EU = European Union

NOTE: Countries listed in descending order by amount of total industrial R&D.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm, accessed 1 March 2007. See appendix table 4-42.

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in Sweden. Japan, France, South Korea, and Italy are also home to large R&D-performing firms in this industry.

The pharmaceuticals industry is less geographically concentrated than the automotive industry but is still prominent in several countries. The pharmaceuticals industry accounts for 20% or more of business R&D in Denmark, the United Kingdom, Belgium, and Sweden. 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 industrial enzymes, 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, the second largest pharmaceutical company in the world in terms of R&D expenditures in 2003 and 2004 (table 4-6).

The office, accounting, and computing machinery industry represents only a small share of business R&D in most countries. Among OECD countries (appendix table 4-42), only the Netherlands and Japan report double-digit concentration of business R&D in this industry, 24% (2004) and 13% (2003), respectively. The Netherlands is the home of Royal Philips Electronics, the largest electronics company in Europe.

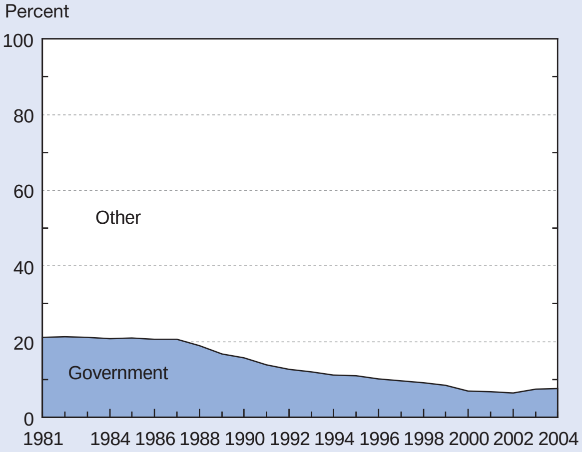
One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of R&D in the service sector. In the European Union (EU), service-sector R&D has grown from representing 9% of business R&D in 1993 to 15% in 2003. In 2003, the EU's service-sector R&D nearly equaled that of its motor vehicles industry and more than doubled that of its aerospace industry. According to national statistics for recent years, the service sector accounted for less than 10% of total industrial R&D performance in only four of the countries shown in figure 4-22 (Japan, Germany, France, and South Korea). Among the countries listed in this figure, the service sector accounted for as little as 7% of business R&D in South Korea to as much as 41% in Australia, and it accounted for 29% of total business R&D in the United States. Information and communications technologies (ICT) services account for a substantial share of the service R&D totals (see sidebar, "R&D in the ICT Sector").

Sources of Industrial R&D Funding

Most of the funding for industrial R&D in each of the G-8 countries is provided by the business sector, and in most OECD countries, government financing accounted for a small and declining share of total industrial R&D performance during the 1980s and 1990s (figure 4-23). In 1981, government provided 21% of the funds used by industry in conducting R&D within OECD countries. By 2000, government's funding share of industrial R&D had fallen to 7% but rose slightly to 8% in 2004. Among G-8 countries, government financing of industrial R&D performance shares ranged from as little as 1% in Japan in 2004 to 54% in Russia in 2005 (appendix table 4-37). In the United States in 2006, the federal government provided about 9% of the R&D funds used by industry, and the majority of that funding came from DOD contracts.

Foreign sources of funding for business R&D increased in many countries in the 1990s (figure 4-24). The role of foreign funding varies by country, accounting for less than 1% of industrial R&D in Japan to as much as 23% in the United Kingdom in 2004. The countries that exhibited the largest

Figure 4-23
OECD industry R&D, by funding sector: 1981–2004



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, Main Science and Technology Indicators (2006). See appendix table 4-39.

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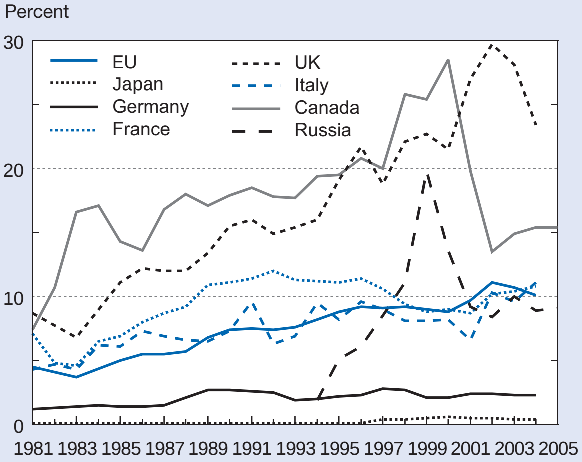
Figure 4-24
Industrial R&D financed, by foreign sources: 1981–2005



EU = European Union; UK = United Kingdom

NOTE: Data not available for all countries for all years.

SOURCE: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2006). See appendix table 4-38.

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growth in this indicator during the 1990s (United Kingdom, Russia, and Canada), also experienced sharp drops in more recent years as shown by figure 4-25. Year-to-year variations in this measure can reflect changes in ownership of businesses conducting R&D in a country as well as changes in the level of foreign investment in the country.

This funding predominantly comes from foreign corporations and can be viewed as an indicator of the globalization of industrial R&D. However, some of this funding also comes from foreign governments and other foreign organizations. For European countries, growth in foreign sources of R&D funds may reflect the expansion of coordinated European Community (EC) efforts to foster cooperative shared-cost research through its European Framework Programmes.[28]

There are no data on foreign funding sources of U.S. R&D performance. However, data on investments by foreign MNCs provide some indication of this activity for the

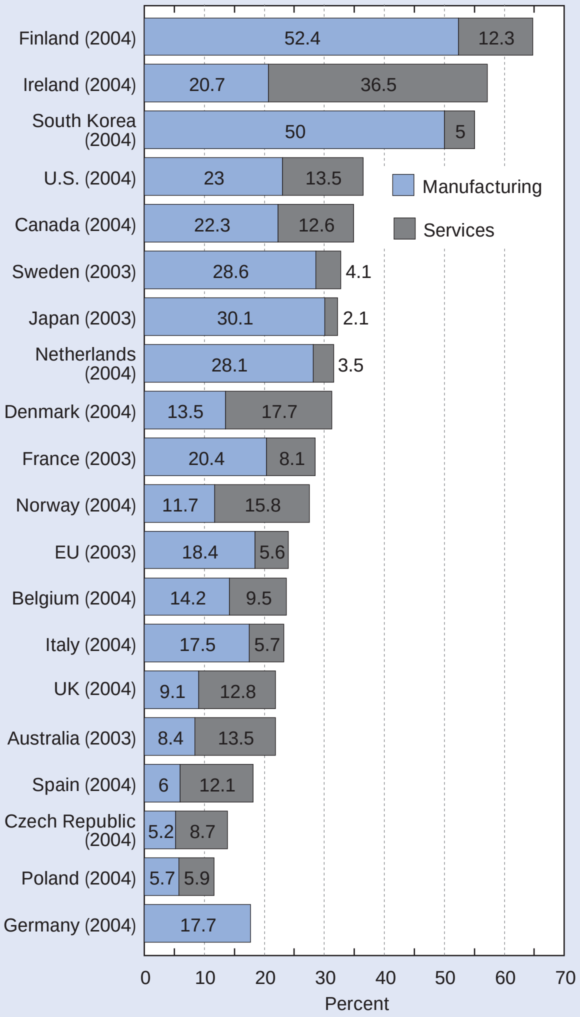
R&D in the ICT Sector

Information and communications technologies (ICTs) play an increasingly important role in the economies of OECD member countries. Both the production and use of these technologies contribute to output and productivity growth. Compared with other industries, ICT industries are among the most R&D intensive, with their products and services embodying increasingly complex technology. Because R&D data are often unavailable for detailed industries, for the purpose of this analysis, ICT industries include the following International Standard Industrial Classification categories:

- Manufacturing industries: 30 (office, accounting, and computer machinery), 32 (radio, television, and communications equipment), and 33 (instruments, watches, and clocks)
- Services industries: 64 (post and communications) and 72 (computer software and related activities) (OECD 2002)

The ICT sector accounted for more than one-quarter of total business R&D in 11 of the 19 OECD countries shown in figure 4-25, and more than half of total business R&D in Finland, Ireland, and South Korea. ICT industries accounted for 37% of the business R&D in the United States and 32% of Japanese business R&D. Of the other G-7 countries, Canada comes closest to matching the ICT R&D concentration of the United States and Japan.

Figure 4-25
Industrial R&D by information and communications technologies sector for selected countries and European Union: 2003 or 2004



EU = European Union; UK = United Kingdom

NOTE: Information and communications technologies service-sector R&D data not available for Germany.

SOURCE: Organisation for Economic Co-operation and Development, ANBERD database, http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm, accessed 22 May 2007.

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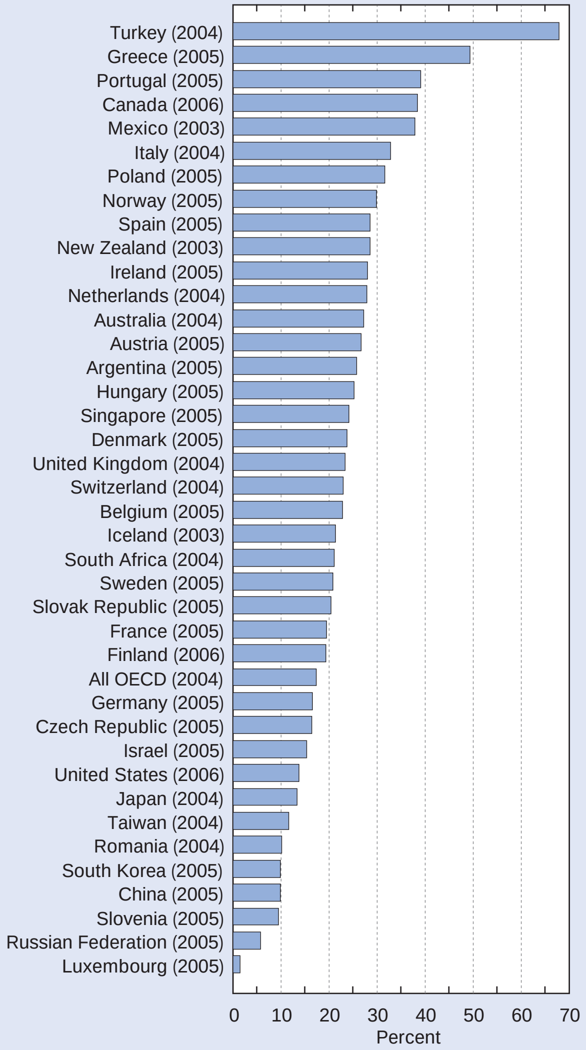
industrial sector (see the section entitled “R&D by Multinational Corporations” later in this chapter).

Academic Sector

In most OECD countries, the academic sector is a distant second to industry in terms of national R&D performance. Among G-8 countries, universities accounted for as little as 6% of total R&D in Russia to as much as 38% in Canada, and they accounted for 14% of U.S. total R&D (figure 4-26). In Asia, the academic sector generally performs a small share of national R&D in financial terms, accounting for 13% or less of total R&D expenditures in Japan, China, South Korea, and Taiwan.

Figure 4-26
Academic R&D share of all R&D for selected countries/economies and all OECD: Most recent year



OECD = Organisation for Economic Co-operation and Development

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006).

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Each of these countries also reports relatively low amounts of basic research as a share of total R&D (figure 4-20).

Source of Funds

For most countries, the government is now, and historically has been, the largest source of academic research funding (see sidebar, “Government Funding Mechanisms for Academic Research”). However, in each of the G-7 countries for

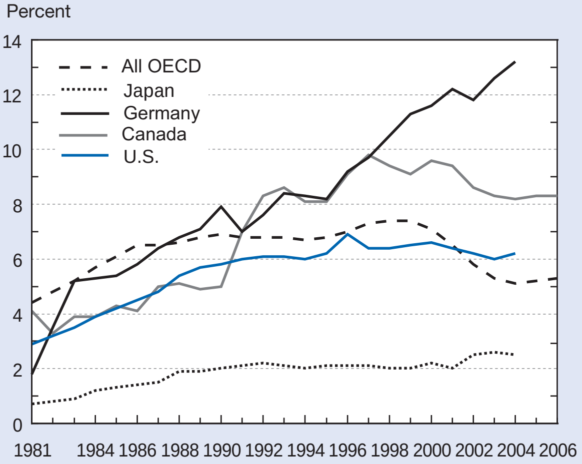
Government Funding Mechanisms for Academic Research

Because U.S. universities generally do not maintain data on departmental research, U.S. 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 public universities in the United States.

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 individual 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. Government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds for which can be assigned to specific socioeconomic categories). In the United States, the federal government (although not necessarily state governments) is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere. In each of the European G-7 countries, GUF accounts for 50% or more of total government R&D to universities, and in Canada it accounts for roughly 45% of government academic R&D support. These data indicate not only relative international funding priorities, but also funding mechanisms and philosophies regarding the best methods for financing academic research.

which historical data exist, the government's share declined and industry's share increased during the 1980s and 1990s. Business funding of academic R&D for all OECD countries combined peaked in 2000 at 7% but declined to 6% in 2004. In the United States, it slipped to 5% in 2003, where it has since remained. Among OECD countries, the business sector's role in funding academic R&D is most prominent in Germany where the industry-funded share of academic R&D is twice that of all OECD members combined (figure 4-27). The business sector plays an even greater role in other countries, however. In 2004, the business sector funded 37% of China's academic R&D and 33% of Russia's. With the launching in early 2007 of the European Research Council, a pan-European funding agency established as part of the EU's Seventh Research Framework Programme, the EU hopes to provide additional support to academic research. The European Research Council, with a 7-year budget of 7.5 billion (approximately $10 billion), will employ a competitive peer-review process similar to that employed by various government agencies in the United States to select grant recipients.

Figure 4-27
Academic R&D financed by industry for selected countries and all OECD: 1981–2006



OECD = Organisation for Economic Co-operation and Development

NOTE: Data not available for all countries for all years.

SOURCES: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series); and OECD, Main Science and Technology Indicators (2006). See appendix table 4-40.

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S&E Fields

Most countries supporting a substantial level of academic R&D devote a larger proportion of their R&D to engineering and social sciences than does the United States (table 4-15).

Table 4-15
Share of academic R&D expenditures, by country and S&E field: 2002 or 2003
(Percent distribution)

Field	U.S (2003)	Japan (2003)	Germany (2002)	Spain (2003)	Australia (2002)	Netherlands (2002)	Sweden (2003)	Switzerland (2002)
Academic R&D expenditure (PPP $billions)	41.4	15.4	9.7	3.4	2.6	2.6	2.3	1.5
Academic R&D	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NS&E	91.0	67.8	77.0	62.8	73.2	72.8	79.6	47.6
Natural sciences	39.5	12.1	28.5	22.6	29.7	17.9	19.5	19.9
Engineering	14.5	24.7	19.8	23.5	11.5	21.0	26.1	9.8
Medical sciences	30.9	26.7	24.6	14.2	25.2	28.3	29.3	17.9
Agricultural sciences	6.2	4.3	4.0	2.5	6.9	5.5	4.7	NA
Social sciences and humanities	7.3	32.2	20.2	37.2	26.8	24.8	19.6	14.7
Social sciences	6.2	NA	8.2	21.8	20.6	NA	13.2	NA
Humanities	0.4	NA	12.1	15.4	6.2	NA	6.4	NA
Academic NS&E								
NS&E	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Natural sciences	43.4	17.8	37.0	36.0	40.5	24.7	24.5	41.8
Engineering	15.9	36.5	25.8	37.5	15.7	28.8	32.7	20.5
Medical sciences	33.9	39.4	32.0	22.6	34.4	38.9	36.8	37.6
Agricultural sciences	6.8	6.3	5.2	3.9	9.4	7.6	5.9	NA

NA = detail not available but included in totals

NS&E = natural sciences and engineering; PPP = purchasing power parity

NOTES: Detail may not add to total because of rounding or because some R&D could not be allocated to specific fields. For United States, $0.7 billion could not be allocated between NS&E and social sciences. Data for years in parentheses.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2003 (2005); and Organisation for Economic Co-operation and Development, R&D Statistics database (November 2005).

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Conversely, the U.S. academic R&D effort emphasizes the natural sciences and medical sciences more than do many other OECD countries. This is consistent with the emphases in health and biomedical sciences for which the United States is known. Japan, the country with the second largest amount of academic R&D ($16 billion in 2004, approximately one-third of the U.S. amount) places a roughly equal emphasis on engineering and medical sciences. Together, these two fields account for half of Japan's academic R&D expenditures.

Government R&D Priorities

Analyzing public expenditures for R&D by major socioeconomic objectives shows how government priorities differ between countries and change over time. Within the OECD, the defense share of governments' R&D financing declined from 43% in 1986 to 28% in 2001 (table 4-16). Much of this decline was driven by the United States, where the defense share of the government's R&D budget dropped from 69% in 1986 to 50% in 2001. The defense share of the U.S. government's R&D budget is projected to have grown to 58% in 2006 (appendix table 4-41).

Notable shifts also occurred in the composition of OECD countries' governmental nondefense R&D support over the past two decades. In terms of broad socioeconomic objectives, government R&D shares increased most for health and the environment. Growth in health-related R&D financing was particularly strong in the United States, whereas many of the other OECD countries reported relatively higher growth in environmental research programs. In the United States, health-related R&D has accounted for more than half of the government's nondefense R&D budget since 2000. Throughout the OECD, the relative share of government R&D support for economic development programs declined from 25% in 1981 to 15% in 2005. Economic development programs include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy.

Differing R&D activities are emphasized in each country's governmental R&D support statistics (figure 4-28). As noted above, defense accounts for a relatively smaller

Table 4-16

Government R&D support for defense and nondefense purposes, all OECD countries: 1981–2005

(Percent)

			Nondefense R&D budget shares			
Year	Defense	Nondefense	Health and environment	Economic development programs	Civil space	Other purposes
1981	34.6	65.4	19.2	37.6	9.6	31.9
1982	36.9	63.1	18.9	37.8	8.3	33.2
1983	38.7	61.3	18.8	36.9	7.5	36.1
1984	40.8	59.2	19.7	36.0	7.8	34.7
1985	42.4	57.6	20.0	35.8	8.4	35.0
1986	43.4	56.6	20.0	34.7	8.6	35.9
1987	43.2	56.8	20.8	32.5	9.6	36.2
1988	42.6	57.4	21.2	30.8	10.0	37.2
1989	41.2	58.8	21.4	29.9	10.8	37.2
1990	39.3	60.8	21.8	28.8	11.7	36.8
1991	36.4	63.6	21.7	28.1	11.8	37.3
1992	35.3	64.8	22.0	27.0	11.9	37.7
1993	35.2	64.8	22.0	26.1	12.1	38.4
1994	32.9	67.2	22.2	25.1	12.3	38.7
1995	31.2	68.8	22.5	24.4	12.1	38.2
1996	30.9	69.1	22.6	24.4	11.9	38.7
1997	30.8	69.2	22.8	24.6	11.4	38.8
1998	30.0	70.0	23.6	22.8	11.4	39.8
1999	29.4	70.6	24.5	23.3	10.7	39.2
2000	28.1	71.9	25.0	23.4	9.9	39.3
2001	28.1	71.9	26.1	23.1	9.8	39.0
2002	29.5	70.5	27.1	22.7	9.4	39.2
2003	31.5	68.5	28.0	22.2	9.5	38.7
2004	31.9	68.1	29.1	22.0	9.2	38.4
2005	33.2	66.8	29.2	22.2	9.4	38.5

OECD = Organisation for Economic Co-operation and Development

NOTE: Nondefense R&D classified as Other purposes consists primarily of university funds and nonoriented research programs.

SOURCE: OECD, Main Science and Technology Indicators (2006).

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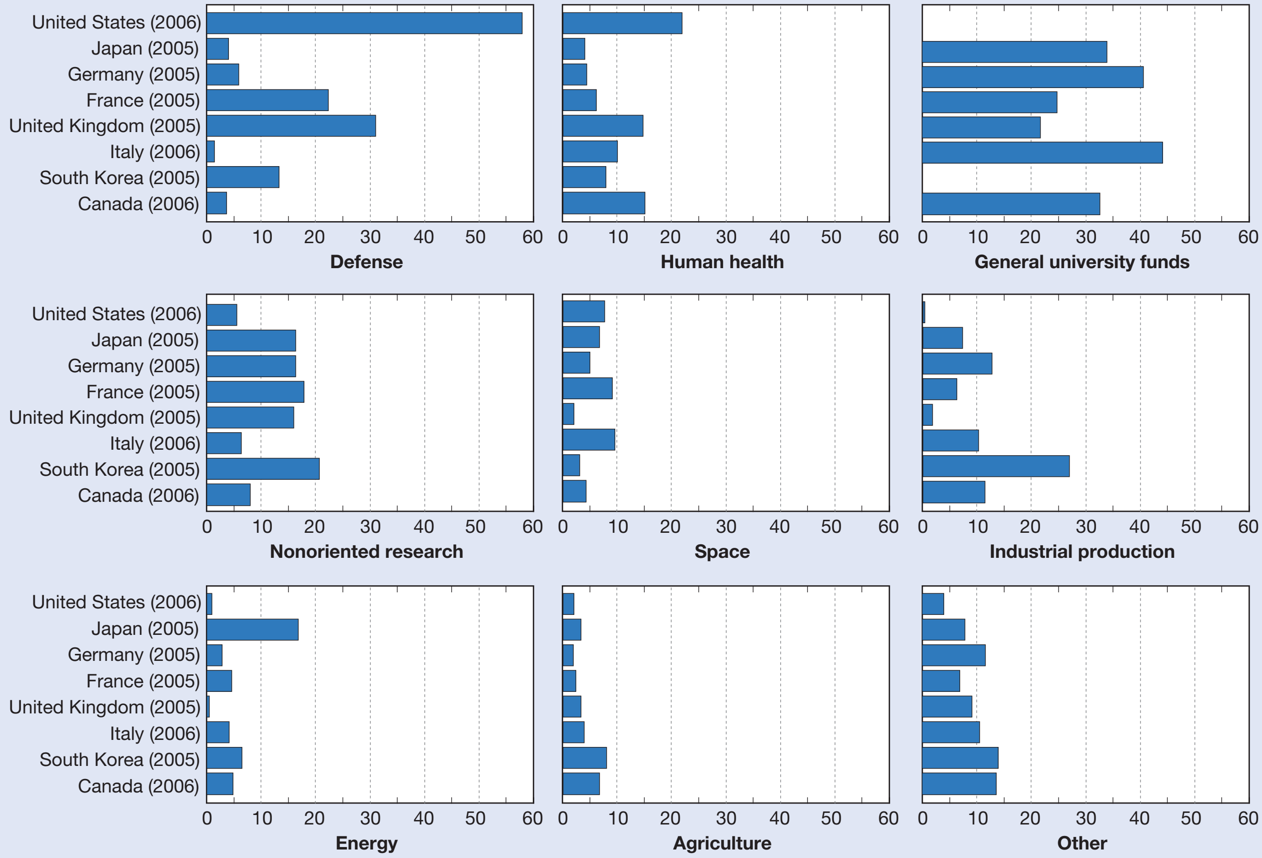
Figure 4-28

Government R&D support for selected countries, by socioeconomic objective: 2005 or 2006

(Percent)



NOTE: Countries listed in descending order by amount of total goverment R&D. R&D classified according to its primary government objective, although may support several complementary goals, e.g., defense R&D with commercial spinoffs classified as supporting defense, not industrial development.

SOURCE: Organisation for Economic Co-operation and Development, special tabulations (2007). See appendix table 4-41.

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government R&D share in most countries outside the United States. In recent years, the defense share was relatively high in the United Kingdom and France at 31% and 22%, respectively, but was 6% or less in Germany, Italy, Canada, and Japan. In 2005, South Korea allocated 13% of its government R&D budget for defense-related activities.

Japan committed 17% of its governmental R&D support to energy-related activities, reflecting the country's historical concern over its high dependence on foreign sources of energy. Industrial production and technology is the leading socioeconomic objective for R&D in South Korea, accounting for 27% of its government's R&D budget. This funding is primarily oriented toward the development of science-intensive industries and is aimed at increasing economic efficiency and technological development. Industrial technology programs accounted for less than 1% of the U.S. total. This figure, which includes mostly R&D funding by NIST, is understated relative to most other countries as a result of data compilation differences. In part, the low U.S. industrial development share reflects the expectation that firms will finance industrial R&D activities with their own funds; in part, government R&D that may be indirectly useful to industry is often funded with other purposes in mind such as defense and space (and is therefore classified under other socioeconomic objectives).

Compared with other countries, France and South Korea invested relatively heavily in nonoriented research at 18% and 21% of government R&D appropriations, respectively. The U.S. government invested 6% of its R&D budget in nonoriented research, largely through the activities of NSF and DOE. However, differences in countries' classification practices affect the size of this apparent gap.

R&D by Multinational Corporations

The internationalization of R&D through foreign direct investment (FDI) by MNCs is one indicator of increasing globalization of innovation activities (Carlsson 2006; OECD 2006c). Related indicators include international trade and cross-country business alliances, which are discussed later

Foreign Direct Investment in R&D

Foreign direct investment (FDI) refers to the ownership of productive assets outside the home country by multinational corporations (MNCs). More specifically, the Bureau of Economic Analysis (BEA) defines direct investment as ownership or control of 10% or more of the voting securities of a business in another country (BEA 1995). A company located in one country but owned or controlled by a parent company in another country is known as an affiliate. Affiliate data used in this section are for majority-owned affiliates, i.e., those in which the ownership stake of parent companies is more than 50%. Statistics on R&D by affiliates of foreign companies in the United States and by foreign affiliates of U.S. MNCs and their parent companies are part of operations data 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), respectively. Operations data exclude depository institutions and are on a fiscal-year basis.

Global R&D supports a range of objectives, from technology adaptation to the development of new products or services (Kumar 2001; Niosi 1999). The location decision for global R&D sites is driven by market- and science-based factors, including cost considerations, the investment climate, the pull of large markets, and the search for location-specific expertise (von Zedtwitz and Gassmann 2002). Furthermore, the relative importance of these factors is likely to vary depending on the industry, the technology objectives of the overseas activity, and host country characteristics relative to those of home countries. For example, in a recent study examining motives to locate R&D overseas, Thursby and Thursby (2006) report that the size of output markets and the quality of R&D personnel are the top "attractors" for FDI R&D in emerging markets, whereas the activities associated with strong research universities remain a key factor for R&D in the home market or in overseas developed economies. Barriers or challenges include managing and coordinating knowledge on a global scale and intellectual property protection.

in this chapter. International R&D links are particularly strong between U.S. and European companies, especially in pharmaceutical, computer, and transportation equipment manufacturing. More recently, certain developing or newly industrialized economies are emerging as hosts of U.S.-owned R&D, including China, Singapore, and India. For general information about R&D by MNCs, see sidebar, "Foreign Direct Investment in R&D."

U.S. Affiliates of Foreign Companies

Majority-owned affiliates of foreign companies located in the United States performed $29.9 billion in U.S. R&D expenditures in 2004, little changed from 2003.[29] However, between 1999 and 2004, R&D by these affiliates increased faster than overall industrial R&D in the United States (2.1% on an annual average rate basis after adjusting for inflation, compared with 0.2%). Currently, there are no data on the R&D character of work for MNCs separate from the national trends discussed earlier in this chapter. However, an interagency project involving NSF, the Census Bureau, and BEA is aimed, in part, at developing these data, not only for affiliates of foreign MNCs in the United States, but also for parents of U.S. MNCs discussed below. (See sidebar, "Linking MNC Data From International Investment and Industrial R&D Surveys.")

In 2004, manufacturing accounted for 70% of U.S. affiliates' R&D, including 34% in chemicals (of which 86% were in pharmaceuticals), 13% in transportation equipment, and 11% in computer and electronic products (table 4-17; appendix table 4-44). U.S. affiliates owned by European parent companies accounted for three-fourths ($22.6 of $29.9 bil-

Linking MNC Data From International Investment and Industrial R&D Surveys

An ongoing data development project aims to integrate the statistical information from the BEA's international investment surveys with the NSF/Census Survey of Industrial Research and Development. Such data sharing among federal statistical agencies has been facilitated by the Confidential Information Protection and Statistical Efficiency Act of 2002. Combining technological and investment data from these separate but complementary sources will facilitate a better assessment of globalization trends in R&D and technological innovation. The initial methodological study (completed in 2005) demonstrated not only the feasibility of such a linkage, but also its utility.

A combined preliminary dataset provided information for the first time on R&D expenditures by U.S. and foreign MNCs by character of work (basic research, applied research, development). The study also has produced tangible benefits for the participating agencies, including improvements in survey sampling and the quality of reported data. As a result of these promising initial results, the three participating agencies are considering future work in this area. For more information, see NSF/SRS (2007e) and Census Bureau et al. (2005).

Table 4-17
R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and country/region: 2004
(Millions of current U.S. dollars)

Country/region	All industries	Manufacturing						Nonmanufacturing	
		Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Transportation equipment	Information	Professional, technical, scientific services
All countries	29,900	20,891	10,045	1,547	3,279	238	3,728	898	1,442
Canada	1,458	940	38	3	D	D	D	D	40
Europe	22,648	17,710	9,606	1,382	1,999	164	3,282	549	560
France	3,738	3,050	2,064	D	D	D	D	261	28
Germany	5,929	5,345	1,375	987	246	18	2,553	D	D
Netherlands	1,316	579	353	D	0	2	4	3	D
Switzerland	4,004	3,462	3,201	112	25	5	5	3	411
United Kingdom	5,924	4,273	2,225	50	1,248	10	445	D	73
Asia/Pacific	3,725	1,403	291	D	422	17	D	46	D
Japan	3,413	1,232	281	72	354	16	334	D	699
Latin America/OWH	D	645	3	D	D	D	2	1	D
Middle East	D	134	80	*	D	0	7	D	D
Africa	36	D	D	0	0	0	0	D	0

D = suppressed to avoid disclosure of confidential information; * = ≤$500,000

NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2004 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/bea/di/di1fdiop.htm, accessed 24 April 2007. See appendix tables 4-43 and 4-44.

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lion) of U.S. affiliates' R&D (figure 4-29), compared with their 66% share in value-added by U.S. affiliates.

Affiliates from some investing countries are particularly notable in some industries. German-owned affiliates classified in transportation equipment performed $2.6 billion of R&D, or 68% of all U.S. affiliates' R&D in this industry and 43% of total R&D performed by German-owned U.S. affiliates (table 4-17). On the other hand, affiliates owned by Swiss, British, and French parent companies performed about three-fourths of U.S. affiliates' R&D in chemicals (which includes pharmaceuticals). British-owned affiliates performed 38% of U.S. affiliates' R&D in computers and electronic products, whereas Japanese-owned affiliates accounted for just under half of R&D expenditures in professional, scientific, and technical services.

U.S. MNCs and Their Overseas R&D

Majority-owned foreign affiliates of U.S. MNCs (henceforth, foreign affiliates) performed $27.5 billion in R&D abroad in 2004 after adjusting for inflation, up $4.7 billion or 17.4% from 2003, which was the largest annual increase since a 22% rise in 1999.[30] In general, changes in FDI R&D reflect a combination of activities in existing facilities, the acquisition of R&D-performing companies, and the establishment of new industrial laboratories or other facilities engaged in technical activities. However, available data do not allow for distinguishing between these FDI alternatives.

U.S. MNCs comprise U.S. parent companies and their foreign affiliates.[31] Since 1994, at least 85% of the combined global R&D expenditures by U.S. MNCs were performed at home (table 4-18).

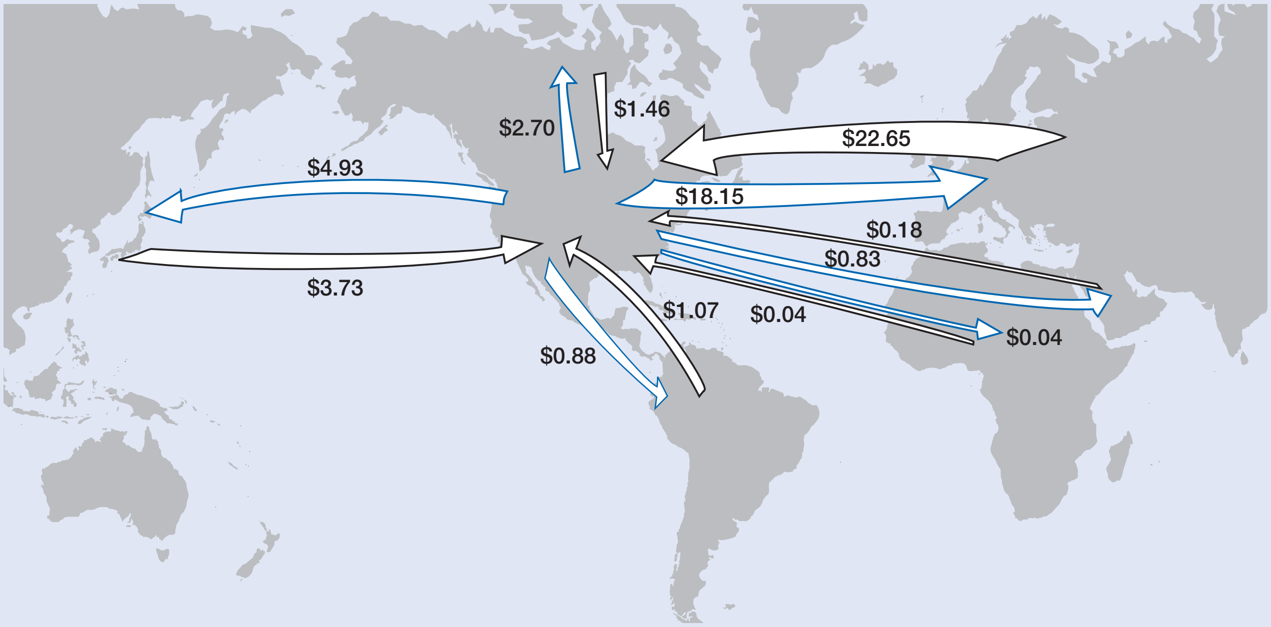
At the same time, however, foreign affiliates' R&D expenditures and value-added by foreign affiliates grew at a faster rate than U.S. parents' after adjusting for inflation. Consequently, the share of foreign affiliates' R&D expenditures within U.S. MNCs increased from 11.5% in 1994 to 15.3% in 2004, comparable with the increase in their value-added share from 23.5% to 27.1% over the same period.

Perhaps more revealing than aggregate figures are changes in the geographic distribution of these expenditures, reflecting the changing dynamics of international R&D (figure 4-30). In 1994, major developed economies or regions (Canada, Europe, and Japan) accounted for 90% of overseas R&D expenditures by U.S. MNCs. By 2001, this combined share was down to 80%. However, Europe's share rebounded from an all-time low of 61% in 2001 to 66% in 2004, representing slightly more than two-thirds of the $4.7 billion increase in 2004, driven by affiliates in the United Kingdom, Germany, and Switzerland. At the same time, however, foreign affiliates of U.S. MNCs have increasingly engaged in R&D activities in Asian emerging markets (figure 4-30; appendix table 4-45).

Figure 4-29

R&D performed by U.S. affiliates of foreign companies in U.S., by investing region, and performed by foreign affiliates of U.S. multinational corporations, by host region: 2004 or latest year

Current U.S. dollars (billions)



NOTES: Preliminary estimates for 2004. 2002 data for U.S. affiliates of foreign companies from Latin America and Middle East.

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 4-43 and 4-45.

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Table 4-18

R&D performed by parent companies of U.S. multinational corporations and their majority-owned foreign affiliates: 1994–2004

	R&D performed (current US$millions)			Shares of MNC (%)	
Year	U.S. parents	MOFAs	Total MNCs	U.S. parents	MOFAs
1994	91,574	11,877	103,451	88.5	11.5
1995	97,667	12,582	110,249	88.6	11.4
1996	100,551	14,039	114,590	87.7	12.3
1997	106,800	14,593	121,393	88.0	12.0
1998	113,777	14,664	128,441	88.6	11.4
1999	126,291	18,144	144,435	87.4	12.6
2000	135,467	20,457	155,924	86.9	13.1
2001	143,017	19,702	162,719	87.9	12.1
2002	136,977	21,063	158,040	86.7	13.3
2003	139,884	22,793	162,677	86.0	14.0
2004	152,384	27,529	179,913	84.7	15.3

MNC = multinational corporation; MOFA = majority-owned foreign affiliate

NOTES: MOFAs are affiliates in which combined ownership of all U.S. parents is >50%. Detail may not add to total because of rounding.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm, accessed 24 April 2007.

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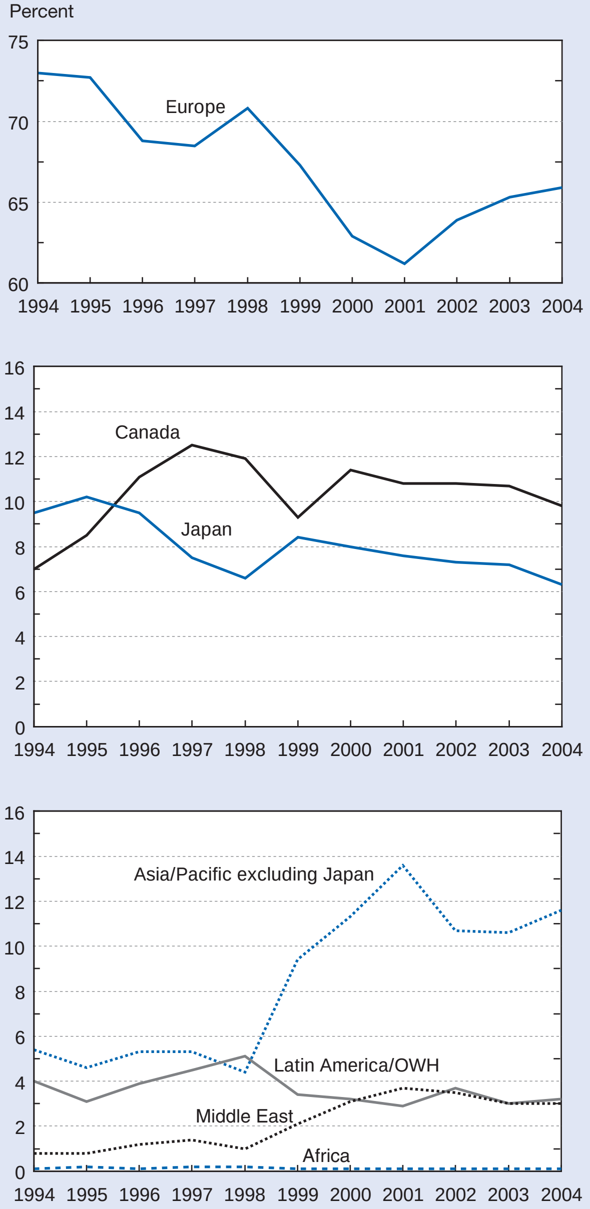
Figure 4-30
Regional shares of R&D performed abroad by foreign affiliates of U.S. MNCs: 1994–2004



MNC = multinational corporation; OWH = other Western Hemisphere

NOTES: Data for majority-owned affiliates. Preliminary estimates for 2004.

SOURCE: Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series). See appendix table 4-45.

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Within the Asia-Pacific region (which also includes Australia and New Zealand), the share for Japan decreased from 64% in 1994 to 35% in 2004, even though this country remains the largest host of U.S.-owned R&D in the region. In contrast, the shares of foreign affiliates located in China and Singapore increased from 0.4% and 9.4%, respectively, to 12.6% and 14.4%. Other countries with sizable 2004 shares within this region include Australia (9.5%), Taiwan (7.4%), Malaysia (6.1%), and South Korea (5.0%). Notably, R&D by affiliates located in India doubled from $81 million in 2003 to $163 million in 2004, increasing the share within this region to 3.3%.

Brazil and Mexico have represented around 80% or more of R&D expenditures by U.S. MNCs in Latin America since 1994. Finally, Israel and South Africa represent virtually all of the R&D expenditures by U.S. MNCs in their respective regions over the same period (appendix table 4-45).

In 2004, three manufacturing industries accounted for most foreign-affiliate R&D: transportation equipment (28.1%), chemicals (including pharmaceuticals) (22.7%), and computer and electronic products (19.2%) (table 4-19; appendix table 4-46). Within the nonmanufacturing sector, the professional, technical, and scientific services industry (which includes R&D and computer services) accounted for 7.7%. The industry distribution in European locations is similar to the average across all host countries, whereas at least half of affiliates' R&D expenditures in Canada and Japan are performed by affiliates classified in transportation equipment and chemicals, respectively. Affiliates classified in computer and electronic products performed 63.1% of U.S.-owned R&D in Israel and 42.7% of U.S.-owned R&D in the Asia-Pacific region, excluding Japan.

Technology Linkages: Contract R&D, Trade in R&D Services, Business Alliances, and Federal Technology Transfer

Collaboration with external technology sources, including universities and federal laboratories, has long played a key role in U.S. industrial innovation (Bozeman 2000; Mowery 1983; Rosenberg and Nelson 1994). Increasingly, however, industrial innovation requires partners, resources, and ideas outside company and national boundaries (Chesbrough, Vanhaverbeke, and West 2006; EIU 2006; IBM 2006; IRI 2007). (See sidebar, "A Window Into Open or Collaborative Innovation.") Factors behind this trend include the complex and multidisciplinary nature of scientific research, coupled with the increased relevance of science for industrial technology in a globally competitive environment. Several terms in the academic and business literature capture diverse but related dimensions of this new environment, including open or collaborative innovation, networked R&D, innovation sourcing, and technology markets.[32] The resulting exchanges or joint activities involve customers, suppliers, competitors, and public institutions such as universities and government agencies.

Table 4-19
R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and country/region: 2004
(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, electronic scientific services
All countries	27,529	23,288	6,254	791	5,283	551	7,741	843	2,120
Canada	2,702	2,517	503	26	472	16	1,334	38	D
Europe	18,148	15,198	4,451	656	2,117	422	5,750	317	1,477
Belgium	628	465	D	18	D	12	23	0	80
France	1,854	1,762	912	75	136	12	422	D	23
Germany	4,693	4,144	269	190	543	240	2,462	11	D
Sweden	1,525	1,483	83	11	51	D	D	1	D
Switzerland	868	361	104	31	76	4	15	10	236
United Kingdom	5,462	4,434	1,711	177	762	34	1,339	46	849
Asia and Pacific	4,934	4,426	1,164	81	2,108	95	435	D	D
Australia	471	426	92	D	D	1	222	*	D
China	622	538	18	7	468	D	5	D	21
Hong Kong	220	196	4	*	D	2	0	D	D
Japan	1,742	1,552	1,004	45	244	D	114	127	D
Singapore	711	698	8	*	677	D	D	8	4
Taiwan	363	349	11	6	14	0	D	D	1
Latin America/OWH	882	581	124	26	66	16	206	D	D
Brazil	340	328	67	21	61	D	144	2	5
Mexico	D	199	36	5	1	D	53	0	D
Middle East	826	539	6	1	520	1	0	D	D
Israel	824	539	6	1	520	1	0	D	D
Africa	36	27	6	1	0	0	16	2	*
South Africa	30	24	5	*	0	0	16	2	*

D = suppressed to avoid disclosure of confidential information; * = ≤$500,000
NAICS = North American Industry Classification System; OWH = other Western Hemisphere

NOTES: Preliminary 2004 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 U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm, accessed 24 April 2007. See appendix tables 4-45 and 4-46.

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Major channels to acquire or codevelop knowledge and technologies include alliances or partnerships, external R&D services, and technology licensing. Each may interact differently with internal R&D and each present different risks and benefits in terms of innovation strategies and management (Cassiman and Veugelers 2002; Fey and Birkinshaw 2005). In turn, each channel has different implications for public policies aiming at promoting innovation. Indeed, public policies in advanced economies concerned with enhancing growth have evolved to address the many dimensions of industrial innovation. Several policies in the United States have facilitated R&D collaboration among industry, universities, and federal laboratories since the 1980s (see sidebar, “Major Federal Legislation Related to Cooperative R&D and Technology Transfer”).

This section discusses three different types of indicators of knowledge flows and technology linkages: transactions involving R&D, business alliances, and technology transfer from federal sources. Indicators of transactions include domestic contract R&D by R&D-performing companies, exports by U.S. establishments classified in the R&D services industry, and international transactions of R&D services by all companies located in the United States. Not surprisingly, there are differences in scope and methodology across the different sources, as detailed throughout this section. However, each source explores complementary dimensions in the complex web of domestic and international transactions involving R&D and R&D-related services.

Contract R&D Expenses Within the United States

R&D-performing companies in the United States reported $11.7 billion (including $8.9 billion reported by manufacturers) in R&D contracted out to other domestic companies and

A Window Into Open or Collaborative Innovation

Industrial innovation is increasingly global and performed collaboratively, requiring partners, resources, and ideas outside the company and national boundaries (Chesbrough, Vanhaverbeke, and West 2006; OECD 2006c). Knowledge may be generated internally, codeveloped, or acquired from a variety of private and public sources, then further developed for a specific market. Often, to successfully enter the marketplace ahead of competitors, an invention or new organizational method requires a new business model (Chesbrough 2007), as well as complementary assets such as manufacturing, marketing, or distribution capabilities. The latter may also be developed internally, acquired, or outsourced (Howells 2006; Teece 1986). The following excerpts from publications provide a flavor of some of the current industry thinking and activities in this area.

Harvard Business Review
Connect and Develop: Inside Proctor & Gamble's New Model for Innovation

> As we studied outside sources of innovation, we estimated that for every P&G [Procter & Gamble] researcher there were 200 scientists or engineers elsewhere in the world who were just as good—a total of perhaps 1.5 million people whose talents we could potentially use. But tapping into the creative thinking of inventors and others on the outside would require massive operational changes. We needed to move the company's attitude from resistance to innovations "not invented here" to enthusiasm for those 'proudly found elsewhere.' And we needed to change how we defined, and perceived, our R&D organization—from 7,500 people inside to 7,500 plus 1.5 million outside, with a permeable boundary between them. (Huston and Sakkab 2006)

Business Week
Crowdsourcing: Milk the Masses for Inspiration

> Business model innovation is happening at a lightning clip. First there was outsourcing, then open-sourcing, and now crowdsourcing. . . . Crowdsourcing often produces a wealth of ideas, and companies need effective filters to pick the gems. Consider IBM's innovation jam, a two-part brainstorming session launched in July [2006] designed to tap the collective minds of employees, family members, and customers to target potential areas for innovation. CEO Sam Palmisano will put $100 million into promising ideas. (Hempel 2006).

Chemical & Engineering News
Start-Up Firm NineSigma Uses Internet To Match Industrial Clients With Inventive Partners

> In his 28 years at Procter & Gamble, Paul Stiros says he never doubted the wisdom behind connecting R&D to customer needs. As president and chief executive officer of privately held NineSigma, Stiros heads a firm committed to helping corporations acquire technical innovations that will quickly bring tomorrow's star products to market. . . . Competing firms such as InnoCentive and YourEncore also help corporations get research help outside the usual channels. InnoCentive posts specific problems for corporate customers on the Internet and pays a bounty for solutions. YourEncore connects technology and product development needs of member companies with retirees who have scientific backgrounds. (American Chemical Society 2006)

Boeing
YourEncore and Your Retirement

> Boeing partnered in August 2003 with YourEncore Inc. to provide Boeing retirees with scientific and engineering skills [and] challenging and rewarding project opportunities in various industries, including aerospace, chemical, communications, pharmaceutical and consumer products. Retirees can contribute their expertise to major companies on high-level projects while networking among peers and gaining experience in new industries. . . . "YourEncore is an ideal opportunity for Boeing retirees to stay intellectually engaged on a part-time basis to the degree the retiree wishes and get fairly compensated," said Dick Paul, Boeing Phantom Works* vice president, strategic development and analysis. "Boeing retirees can join YourEncore and consult either back at Boeing or with other member companies in varied industries." (Sopranos 2004)

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*Phantom Works is the advanced R&D unit at Boeing.

Major Federal Legislation Related to Cooperative R&D and Technology Transfer

Stevenson-Wydler Technology Innovation Act (1980). Required federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector.

Bayh-Dole University and Small Business Patent Act (1980). Permitted government grantees and contractors to retain title to federally funded inventions and encouraged universities to license inventions to industry. The act is designed to foster interactions between academia and the business community.

Small Business Innovation Development Act (1982). Established the Small Business Innovation Research (SBIR) program within the major federal R&D agencies to increase government funding of research that has commercialization potential within small high-technology companies.

National Cooperative Research Act (1984). Encouraged U.S. firms to collaborate on generic, precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures. The act was amended in 1993 by the National Cooperative Research and Production Act, which let companies collaborate on production and research activities.

Federal Technology Transfer Act (1986). Amended the Stevenson-Wydler Technology Innovation Act to authorize cooperative R&D agreements (CRADAs) between federal laboratories and other entities, including other federal agencies, state or local governments, universities and other nonprofit organizations, and industrial companies.

Omnibus Trade and Competitiveness Act (1988). Established the Competitiveness Policy Council to develop recommendations for national strategies and specific policies to enhance industrial competitiveness. The act created the Advanced Technology Program and the Manufacturing Technology Centers within NIST to help U.S. companies become more competitive.

National Competitiveness Technology Transfer Act (1989). Amended the Stevenson-Wydler Act to allow government-owned, contractor-operated laboratories to enter into CRADAs.

National Cooperative Research and Production Act (1993). Relaxed restrictions on cooperative production activities, enabling research joint venture participants to work together in the application of technologies they jointly acquire.

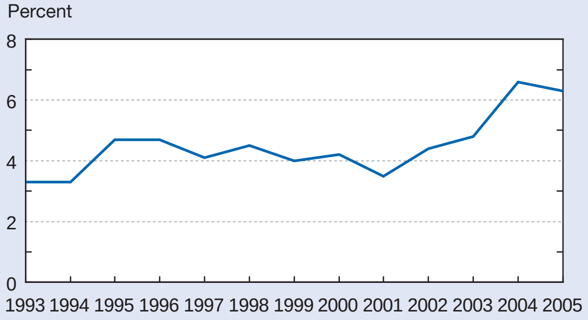
Technology Transfer Commercialization Act (2000). Amended the Stevenson-Wydler Act and the Bayh-Dole Act to improve the ability of government agencies to monitor and license federally owned inventions.

other organizations in 2005, compared with $12.3 billion in 2004, according to NSF data (appendix table 4-50).[33] The ratio of contracted-out R&D to company-funded, company-performed R&D declined from 6.6% in 2004 to 5.7% for all industries in 2005 but remained above 6% for manufacturing (figure 4-31). However, since 1993, these contracted-out expenditures have grown faster than company-funded, company-performed expenditures.

The relative magnitude of payments for R&D conducted by others varies across industries. In 2005, pharmaceutical companies reported $4.6 billion in contracted-out R&D (appendix table 4-51), or 13.2 % of their company-funded, company-performed R&D, followed by scientific R&D services (11.4%); navigational, measuring, electromedical, and control instruments (7.9%); and motor vehicles, trailers, and parts (7.2%). The ratio was only 2.8% for companies classified in computer and electronic products.

For most of the industries highlighted above, close to 80% of contracted-out R&D payments were received by other companies. For scientific R&D services, however, only 53% of these expenditures were received by other companies.[34]

Figure 4-31
R&D contracted out in United States by manufacturing companies as ratio of company-funded and -performed R&D: 1993–2005



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series).

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International Trade in R&D Services

The international flow of knowledge through trade in services represents the convergence of two recent trends: an increase in R&D performance in the service sector and an increase in transactions with external parties (Arora, Fosfuri, and Gambardella 2001; OECD 2006c). U.S. R&D-related trade in services is a relatively new indicator of international industrial knowledge and technology flows. Other such indicators include FDI, trade in high-technology goods, patent royalties, and license fees (see the section entitled “R&D by Multinational Corporations” and also chapter 6). Trade in R&D and technical services are also key to understanding the growing role of services in the U.S. economy and the extent and impact of services “offshoring ” (GAO 2004; Graham 2007; NAPA 2006).[35]

Exports by R&D Services Establishments

The Service Annual Survey (SAS) conducted by the Census Bureau provides national estimates of total revenues, export revenue, and expenses of establishments (single physical locations at which business is conducted and/or services are provided) classified in NAICS service industries.[36] Scientific R&D services (NAICS 5417) cover establishments devoted primarily to R&D, either as stand-alone enterprises or within larger companies.[37] Newly available data on export revenues for this industry are based on revenues for basic and applied research, production services for development, testing services, and licensing of intellectual property. In 2005, U.S. establishments classified in NAICS 54171 (physical, engineering, and life sciences) exported $3.0 billion in R&D services, or 3.9% of their total revenue ($76.4 billion) (table 4-20). Notably, this proportion was about twice as large as the export revenue share for all professional, scientific, and technical services in 2004 and 2005.

Exports and Imports of R&D Services

The preceding discussion of R&D services exports was based on establishments classified in a specific industry sector. The present section examines patterns in services trade, regardless of industry classification, and focuses on research, development, and testing (RDT) services.[38] Since 2001, these data have been available for two major categories of customers or suppliers: trade among unaffiliated companies and trade among affiliates of MNCs. In 2005, total exports (affiliated and unaffiliated) of RDT services reached a record $10.1 billion, compared with record imports of $6.7 billion, resulting in a trade surplus of $3.4 billion (figure 4-32). This trade surplus is little changed from the $3.8 billion surplus in 2004 but smaller than trade surpluses (approximately $5 billion) in both 2002 and 2003. Affiliated exports and imports have been larger than unaffiliated exports and imports (table 4-21). Furthermore, affiliated trade has recorded trade surpluses between $4 billion and $5 billion since 2001. However, unaffiliated trade moved from relatively small surpluses (less than $500 million) in the 1990s to small deficits in the early 2000s, reaching a deficit of slightly more than a billion dollars in 2005 (appendix table 4-52) (NSF/SRS 2006c).

The prominence of affiliated trade in business services, particularly R&D-related services, may reflect advantages of internally managing, exploiting, and protecting complex or strategic transactions involving proprietary technical information (Caves 1996; McEvily, Eisenhardt, and Prescott 2004). For the United States, the large size of affiliated relative to unaffiliated trade in RDT services is consistent with strong U.S. FDI activity, which increases the number of potential affiliated trading partners. It is also consistent with expanded MNC R&D (see the section entitled “R&D by Multinational Corporations”), which increases opportunities for intracompany knowledge flows.

Table 4-20

Estimated total revenue and export revenue for U.S. establishments classified in selected service industries: 2004 and 2005

(Millions of current dollars)

		Revenue		Export revenue		Export revenue as percent of total revenue	
Service industry	NAICS code	2004	2005	2004	2005	2004	2005
Professional, scientific, and technical services (except notaries)	54	966,008	1,058,196	18,415	21,670	1.9	2.0
Scientific R&D services	5417	74,789	81,539	2,680	3,074	3.6	3.8
R&D in physical, engineering, and life sciences	54171	69,989	76,381	2,585	2,978	3.7	3.9
R&D in social sciences and humanities	54172	4,800	5,158	95	96	2.0	1.9

NAICS = North American Industry Classification System

NOTES: Data for taxable and nontaxable employer establishments. Export revenue includes services for unaffiliated and affiliated firms located outside United States. Export revenue excludes services provided to U.S. subsidiaries of foreign mutlinational corporations.

SOURCE: Census Bureau, 2005 Service Annual Survey, Current Business Reports (2007).

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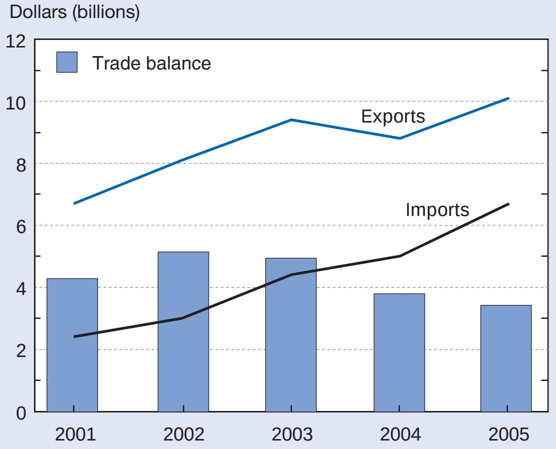
Business Technology Alliances

Industrial technology alliances bring together legally distinct companies for the purpose of collaboration in R&D and other technology activities.[39] Business alliances represent an intermediate organizational mode between full integration (as in mergers and acquisitions or FDI) and arms-length transactions (as in contracts for R&D services with external parties). Drivers for R&D collaboration include cost and risk reductions afforded by pooling resources, strategic or long-term considerations regarding the acquisition of innovation capabilities or entry into new product markets, and the policy environment, notably antitrust regulation and intellectual property protection. In the United States, restrictions on multifirm cooperative research were loosened by the National Cooperative Research Act in 1984 (Public Law 98–462), given concerns about the technological leadership and international competitiveness of American firms in the early 1980s.[40]

Figure 4-32
U.S. trade in research, development, and testing services: 2001–05



SOURCE: Bureau of Economic Analysis, U.S. International Services: Cross-Border Trade 1986–2005, and Sales Through Affiliates, 1986–2004, http://www.bea.gov/international/intlserv.htm, accessed 4 December 2006. See appendix table 4-52.

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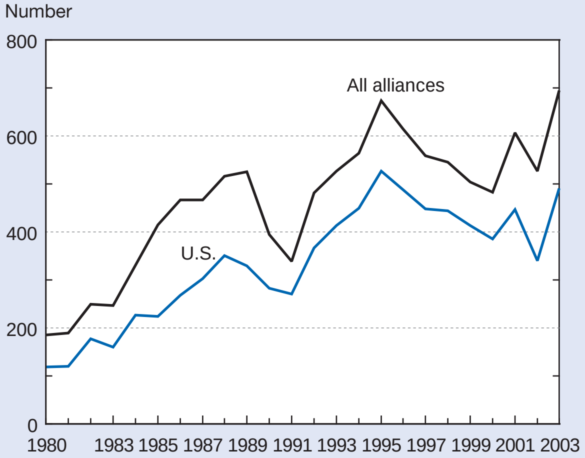
The Cooperative Agreements and Technology Indicators database-Maastricht Economic Research Institute on Innovation and Technology (CATI-MERIT), funded in part by NSF, includes domestic and international technology agreements. It is based on public announcements, tabulated according to the country of ownership of the parent companies involved.[41] According to this database, in 2003 (latest data available) there were 695 new industrial technology alliances worldwide (figure 4-33). These alliances involve mostly companies from the United States, Europe, and Japan, focusing to a large extent on biotechnology and information technology products, services, or techniques. Other technology areas include advanced materials, aerospace and defense, automotive, and (nonbiotechnology) chemicals. For additional details, see Hagedoorn (2002) and NSB (2006).

Figure 4-33
Worldwide industrial technology alliances and those with at least one U.S.-owned company: 1980–2003



NOTE: Annual counts of new alliances.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations.

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Table 4-21
U.S. trade in research, development, and testing services: 2001–05
(Millions of dollars)

	Exports			Imports			Trade balance		
Year	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated	Total	Affiliated	Unaffiliated
2001	6,746	5,700	1,046	2,425	1,700	725	4,321	4,000	321
2002	8,142	7,000	1,142	3,028	2,000	1,028	5,114	5,000	114
2003	9,376	8,200	1,176	4,410	3,100	1,310	4,966	5,100	–134
2004	8,760	7,500	1,260	4,993	3,100	1,893	3,767	4,400	–633
2005	10,095	8,800	1,295	6,717	4,400	2,317	3,378	4,400	–1,022

SOURCE: Bureau of Economic Analysis, U.S. International Services: Cross-Border Trade 1986–2005, and Sales Through Affiliates, 1986–2004, http://www.bea.gov/international/intlserv.htm, accessed 10 December 2006. See appendix table 4-52.

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Federal Technology Transfer and S&T Programs

In the late 1980s, concerns about U.S. industrial strength and global competitiveness led to a series of legislative changes that facilitated public-private partnerships involving industry, universities, and government laboratories (NRC 2003). These partnerships can facilitate technology transfer from the research laboratory to the market in support of both public agencies' missions and technology-based economic growth. Federal technology transfer statutes apply to federally owned or originated technology (see sidebar, "Major Federal Legislation Related to Cooperative R&D and Technology Transfer"). Federal technology indicators include government-owned patents, licensing, and cooperative research and development agreements (CRADAs). This section covers federal technology transfer metrics and federal S&T programs.

Technology Transfer Metrics

R&D performed at federal laboratories, whether run by federal agencies themselves or by contractors,[42] represents a key source for knowledge and technologies supporting both federal agency missions such as defense, health, and energy, as well as economic growth, and general social welfare (Crow and Bozeman 1998; RAND 2003). Technology transfer refers to the exchange or sharing of knowledge, skills, or technologies from sources to users within or across organizations. Federal technology transfer activities and metrics reflect the variety of agency missions, R&D organization and funding structure (e.g., intramural versus extramural laboratories), the character of R&D activities, and the types of potential downstream technologies or users.

For example, scientific or technical publications are a major channel for disseminating R&D results by agencies with large intramural basic research such as NIH (at HHS). Agencies also offer direct technical assistance to private users in settings such as agricultural extension services (USDA), manufacturing extension services (NIST), and federal laboratories (e.g., DOE and NIST). DOE laboratories and FFRDCs offer technical assistance to industrial and academic researchers in the form of user facilities agreements and "work-for-others" agreements. User facilities are advanced scientific facilities, equipment, and software available at DOE laboratories. Work-for-others is work performed for nonfederal sponsors (DOE 2006). In FY 2005, DOE reported about 2,400 work-for-others-agreements and about 2,800 user facility agreements (DOE 2006). In addition, all major U.S. R&D funding agencies, including DOD, HHS, NASA, DOE, and NSF, participate in technology transfer programs involving small businesses and technology entrepreneurs, as described below.

A major technology transfer channel involves cooperative R&D. In particular, CRADAs are agreements between federal laboratories and industrial firms and other organizations for joint R&D activities with the potential to promote industrial innovation consistent with the agency's mission. Private partners may retain ownership rights or acquire exclusive licensing rights for the developed technologies. Federal agencies are engaged in about 3,000 CRADAs annually (NSB 2006), including about 1,500 reported by DOD and 661 by DOE in FY 2003 (latest year available with comparable CRADA data across agencies).

A different set of federal technology transfer metrics involves intellectual property measures such as invention disclosures, patents, and licenses (for academic and corporate patents, see chapters 5 and 6, respectively). Invention disclosures may or may not result in a patent application. Patent and invention licenses (which include licenses of patented inventions) are indicators further along the chain of the technology transfer process in which laboratory results may find applications in agency missions or the marketplace. Table 4-22 shows the 2005 distribution for these metrics for selected agencies.[43]

Table 4-22
Federal technology transfer indicators and intellectual property measures, by selected U.S. agency: FY 2005

Disclosures/patenting/licenses	DOE	DOD	NASA	NIH/FDA	USDA
Invention disclosures and patenting					
Inventions disclosed	1,776	1,220	687	388	125
Patent applications filed	812	798	154	186	88
Patents issued	467	430	157	66	27
Invention licenses					
Active invention licenses	1,535	406	345	NA	320
New invention licenses	198	60	90	313	33

NA = not available

DOD = Department of Defense; DOE = Department of Energy; NASA = National Aeronautics and Space Administration; NIH/FDA = National Institutes of Health/Food and Drug Administration; USDA = U.S. Department of Agriculture

NOTE: NASA data for FY 2004.

SOURCES: USDA, FY 2006 Annual Reporting on Agency Technology Transfer (2006); DOD, Report to Congress on the activities of the DOD Office of Technology Transition (2006); DOE, Annual Report on Technology Transfer and Related Technology Partnering Activities at the National Laboratories and Other Facilities – Fiscal Year 2005 (2006); NASA, Annual Report on Technology Transfer, Programs, Plans, FY 2004 Activities and Achievements (2006); NIH, Office of Technology Transfer Activities, Statistical Tables (2006), http://www.ott.nih.gov/about_nih/statistics.html, accessed 28 February 2007. See appendix table 4-53.

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DOE and DOD had the largest shares of inventions disclosed and patents, whereas NIH/FDA had the largest share of new invention licenses, according to available data. Differences in R&D funding structure (intramural versus extramural funding) and the R&D character of work across agencies may drive the agency distribution of these indicators (table 4-8).[44]

S&T Programs

S&T programs support the development of early-stage technologies and are key components in the dynamics of technology-based entrepreneurship and innovation (Audretsch, Aldridge, and Oetll 2005; Branscomb and Auerswald 2002). This section briefly describes trends in the Small Business Innovation Research (SBIR) program, the Small Business Technology Transfer Program (STTR), and the Advanced Technology Program (ATP) through the latest data available. The section ends with a brief description of the Technology Innovation Program, which replaces ATP.

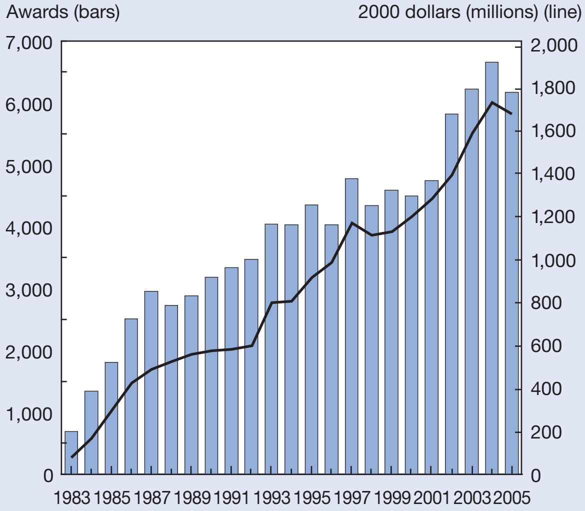
The SBIR program, created in 1982, leverages existing federal R&D funding toward small companies (those with 500 or fewer employees).[45] SBIR's sister program, the STTR program, was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs.[46]

Statutory goals of the SBIR program include the promotion of technological innovation through commercialization of federally funded projects and increasing the participation of small firms and companies owned by minorities or disadvantaged individuals in the procurement of federal R&D. The 1992 SBIR reauthorization bill[47] stipulated a stronger emphasis on the technology commercialization objectives of the program (NRC 2007).

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 SBIR projects. This set-aside has been 2.5% since FY 1997. As of FY 2005, a total of 11 federal agencies participated in the program, including most recently DHS.[48] SBIR has awarded $118.8 billion to more than 89,000 projects through FY 2005. Funded technology areas include computers and electronics, information services, materials, energy, and life sciences applications. In FY 2005, the program awarded $1.9 billion in R&D funding to 6,171 projects (figure 4-34). The upward trend in awards and funding reflects both the increased set-aside percentage over the history of the program, as well as trends in federal funds for extramural R&D. DOD and HHS combined have provided between 60% and 80% of total annual SBIR funds since the program's inception (appendix table 4-54).

STTR involves cooperative R&D performed jointly by small businesses and nonprofit research organizations.[49] As of FY 2005, five federal agencies with extramural R&D budgets exceeding $1 billion participate in the STTR program: DOD, NSF, DOE, NASA, and HHS. Starting in FY 2004, the required set-aside rose from 0.15% to 0.3%, compared with the 2.5% set-aside for SBIR. From FY 1994 to FY 2005, STTR awarded $1.04 billion to 5,000 projects, including $220 million to 832 projects in FY 2005 (appendix table 4-55).

Figure 4-34
SBIR awards and funding: 1983–2005



SBIR = Small Business Innovation Research Program

SOURCE: Small Business Administration, Small Business Innovation Research Program Annual Report (various years). See appendix table 4-54.

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ATP was established by the Omnibus Trade and Competitiveness Act of 1988 to promote the development and commercialization of generic or broad-based technologies.[50] Through FY 2004, ATP awarded funds for 768 projects with a combined funding of $4.37 billion, about equally split between the program and its participants. The projects have involved more than 1,500 participants, which include established companies and start-ups as well as universities and other nonprofit institutions (appendix table 4-56). In FY 2004, 59 R&D projects were initiated, totaling $270 million in combined program and industry funds. The program received $79 million in FY 2006 and an estimated $40 million in FY 2007. The America COMPETES Act (Public Law 110–69 signed in August 2007) replaced ATP in favor of a successor program, the Technology Innovation Program (TIP) also housed at the DOC's National Institute of Standards and Technology.[51] The goal of the program is to assist 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."[52]

Conclusion

U.S. R&D expenditures reached an estimated $340 billion in 2006, having risen steadily since 2002, the year expenditures declined for the first time since 1953. In inflation-adjusted terms, this increase represents a rather steady 2.5% average annual change over the past 4 years.

The business sector accounts for the largest share of U.S. R&D performance. The performance share of this sector peaked in 2000 at 75%, declined following the economic slowdown of 2001 and 2002, but has since leveled to an estimated 71% of U.S. R&D in 2006. The major industrial R&D performers include four manufacturing industries (computer and electronic products; chemicals, including pharmaceuticals and biotechnology; aerospace and defense; and automotive) and two services industries (computer-related services and R&D services). In terms of funding, the industry share peaked at 70% also in 2000, but is estimated to have since dipped somewhat to 64% in 2004 before climbing back to 66% of the 2006 R&D total. On the other hand, the federal share of R&D funding dropped to a low of 25% in 2000. Reflecting primarily increased spending in the areas of defense, health, and counterterrorism, the federal share of R&D funding has inched up in recent years and is estimated at 28% of the R&D funding total in 2006.

The international character of the U.S. R&D enterprise may be examined from different perspectives, including comparisons with other countries, business alliances, MNCs, and, according to recently available data, cross-country linkages in the form of exports and imports of R&D services.

In 2002 (latest available cross-country data), global R&D expenditures totaled at least $813 billion, largely funded by and performed in developed countries. The United States and Japan accounted for 45% of total performance, and OECD countries as a group for more than three-quarters. Some non-OECD countries are growing in international prominence in R&D. South Korea maintained its sizable R&D effort and, according to OECD calculations, China has rapidly moved into the top group of R&D-performing nations while India and Brazil are expanding their R&D activities. However, a solid basis is lacking for direct comparisons of R&D effort across developed and developing countries, leading to uncertainty in the cross-country relationship of absolute spending magnitudes.

Between 1999 and 2004, R&D expenditures by affiliates of foreign companies located in the United States increased faster than overall U.S. industrial R&D (2.1% versus 0.2% annual average rate, inflation-adjusted, respectively). Over the same period, overseas R&D by foreign affiliates of U.S. MNCs increased even faster (6.3% annual average rate, inflation-adjusted), particularly in Asian emerging markets such as China, Singapore, and India. Indeed, the share of R&D by foreign affiliates of U.S. MNCs located in Asian countries except Japan surpassed the shares for affiliates located in Japan for the first time in 1999. In 2004, the former had a share of 11.6%, compared with 6.3% for Japan.

The flow of knowledge through trade in services reflects the growing role of services in global innovation and economic activity. U.S. international trade in research, development, and testing services has posted surpluses since 2001. In 2005, exports of these services reached $10.1 billion, compared with imports of $6.7 billion. Furthermore, U.S. trade surpluses in these services have been driven more by exports from affiliates of foreign MNCs located in the United States rather than by exports from parent companies of U.S. MNCs. This finding is consistent with the growing share these affiliates have in U.S. industrial R&D.

In light of the fast pace of international science, technology, and innovation and related policy analysis needs, federal statistical agencies continue to fine-tune their surveys while engaging in interagency and international collaboration. For example, the ability of respondents in industry to answer questions on innovation beyond R&D inputs is being investigated as part of the redesign of the Survey of Industrial R&D. Another strategy for developing new indicators is mining and integrating related data. Planned or ongoing interagency projects include linking data from R&D and international investment surveys and the development of an R&D Satellite Account. The latter not only measures R&D as an investment within GDP, but also serves as a methodology to measure the impact of R&D on productivity and economic growth. Lastly, federal agencies continue to collaborate with international organizations to facilitate comparable data reflecting the ever-changing innovation landscape.

Notes

1. In this chapter, adjustment for inflation is based on the GDP implicit price deflator. Because GDP deflators are calculated on an economywide rather than R&D-specific basis, their use should be interpreted as a measure of real resources forgone in engaging in R&D rather than in other activities (such as consumption or physical investment), and not a measure of cost changes in doing research. See appendix table 4-1.

2. FFRDCs are 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 nonprofit institution, a university, or a consortium. In some of the statistics provided in this chapter, FFRDCs are included as part of the sector that administers them. In particular, statistics on the industrial sector often include industry-administered FFRDCs because some of the statistics from the NSF Survey of Industrial Research and Development before 2001 cannot be separated from the FFRDC component.

3. See Godin (2006) for a history of the linear model of innovation.

4. The latest data available on the state distribution of R&D performance are for 2004. In 2004, $283.4 billion of the $300.1 billion total U.S. R&D could be attributed to expenditures within individual states, with the remainder falling under an undistributed “other/unknown” category. Approximately equal shares of the R&D that could not be associated with a particular state were R&D performed by the nonprofit sector and by industry. State totals differ from U.S. totals reported elsewhere for four reasons: some R&D expenditures

cannot be allocated to any of the 50 states or the District of Columbia; nonfederal sources of nonprofit R&D expenditures, totaling an estimated $7.1 billion in 2004, could not be allocated by state; state-level university R&D data have not been adjusted for double-counting of R&D passed through from one academic institution to another; and state R&D data are not converted from fiscal years to calendar years.

5. Rankings do not take into account the margin of error of estimates from sample surveys.

6. 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 within the District of Columbia.

7. For most manufacturing industries, the Small Business Association has established a size standard of 500 employees. The NSF Survey of Industrial Research and Development does not sample companies with fewer than five employees because of concerns about respondent burden.

8. A similar measure of R&D intensity is the ratio of R&D to *value-added* (sales minus the cost of materials). 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 materials produced in other sectors. For a more detailed discussion of value-added, see United Nations System of National Accounts 1993 (SNA 1993). For a discussion of the connection between R&D intensity and technological progress, see Nelson (1988).

9. Industry-level estimates are complicated by the fact that each company's R&D is reported in only one industry (see sidebar, "Industry Classification").

10. According to NAICS, the utilities industry is limited to establishments engaged in the provision of electric power, natural gas, steam, water, and the removal of sewage. Establishments that provide telephone and other communication services are included in other NAICS industries.

11. 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 often are suppressed. This prevents the precise tabulation of total R&D performance and the calculation of R&D to net sales ratios for many industries. Appendix table 4-22 presents company-funded R&D to net sales ratios for a wide array of industries.

12. For a recent study on the role of services industries in R&D and innovation, see Gallaher, Link, and Petrusa (2006).

13. Suppression of federal R&D funding prohibits the precise tabulation of total R&D performance for some industries (see note 11). Lower-bound analyst estimates are given in cases where potential disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

14. 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 (which are trials conducted after the drug is licensed and available for doctors to prescribe), whereas the NSF survey definition does not. Also, the NSF survey sales data may contain income from sources not related to the production of drugs and medicines.

15. The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited 2005 statistic, the R&D expenditures of companies in software, other information, and computer systems design and related services 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.

16. Suppression of federal R&D funding prohibits the precise tabulation of total R&D performance for some industries (see notes 11 and 13). Lower-bound analyst estimates are given in cases where potential disclosure of company-reported data or classification issues prevents the publication of total estimates from survey data.

17. NAICS-based R&D estimates are available only back 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 $16.9 billion in 2005.

18. 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).

19. Both tax incentives and direct federal funding represent federal expenses. In terms of the budget, tax incentives generate tax expenditures and government revenue losses because of tax exclusions or deductions. For estimates of tax expenditures arising from the R&E tax credit, see OMB (2007).

20. The federal credit was not in place for activities conducted from July 1995 to June 1996.

21. For tax purposes, R&D expenses are restricted to the somewhat narrower concept of R&E expenditures (Internal Revenue Code Section 174; see also NSF/SRS [2006b]). Such expenditures are limited to experimental or laboratory costs aimed at the development or improvement of a product in connection with the taxpayer's business. Furthermore, the R&E tax-credit applies to a subset of R&E expenses based on additional statutory requirements (Internal Revenue Code Section 41).

22. The credit was not taxable from 1981 to 1988; 50% taxable in 1989; and fully taxable since 1990.

23. Not all R&E claims are allowed. For example, there are limitations on the reduction of total tax liabilities. Data exclude IRS tax forms 1120S (S corporations), 1120-REIT (real estate investment trusts), and 1120-RIC (regulated investment companies).

24. For more information about the 2003 research credit, see tables in IRS (2007). These tables have additional details based on IRS tax form 4765. The return counts obtained from SOI and used in the text represent returns claiming "current year credit for increasing research" (i.e., the number of returns with a non-zero amount in line 41 of IRS tax form 4765).

25. Differences in the structure of tax credits are important in determining effective rates (compared with statutory rates).

26. For other S&T indicators on Asian countries relative to the United States and the EU, see NSF/SRS (2007a).

27. For discussions of R&D diversity measurement, see Archibugi and Pianta (1992). Also see Archibugi and Pianta (1996).

28. Since the mid-1980s, EC funding of R&D has become increasingly concentrated in its multinational Framework Programmes for Research and Technological Development (RTD), which were intended to strengthen the scientific and technological bases of community industry and to encourage it to become internationally competitive. EC funds distributed to member countries' firms and universities have grown considerably. The EC budget for RTD activities has grown steadily from 3.7 billion European Currency Units (ECU) in the first Framework Programme (1984–87) to 17.5 billion ECU for the Sixth Framework Programme (2003–06). The institutional recipients of these funds tend to report the source as "foreign" or "funds from abroad." Eurostat (2001).

29. For these data, the United States includes the 50 states; Washington, DC; Puerto Rico; and all U.S. territories and possessions.

30. For 1999 and 2004 data on U.S. MNCs R&D employment, see BEA (2007b); for 1994 and 1999 comparisons, see NSF (2004a).

31. 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. For selected NSF data on overseas R&D funded by companies with R&D activities in the 50 U.S. states and Washington, DC, see appendix tables 4-48 and 4-49.

32. For example, see Arora, Fosfuri, and Gambardella (2001); Bozeman (2000); and Chesbrough**,** Vanhaverbeke, and West (2006).

33. 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.

34. Approximately 3% of expenditures involved universities and colleges, and 44% involved "other R&D performers."

35. Offshoring refers to the sourcing of production inputs through companies located overseas. Offshoring may be done internally through controlled subsidiaries or affiliates, which involves FDI and related transactions (e.g., affiliated trade), or through external providers. The latter is part of outsourcing activities that in general involve either domestic or overseas external suppliers.

36. Revenue data include operating surplus and other generally acceptable charges for services rendered. For SAS methodology and sample forms, see Census Bureau (2007).

37. Note that except for small companies with a single physical location, company-based and establishment-based industry data are not comparable, even when they refer to the same metric. Furthermore, NSF data for companies classified in NAICS 5417 refer to R&D expenditures, whereas SAS data covered in this section refer to total exports by establishments classified in NAICS 5417. SAS data for establishments classified in professional, scientific, and technical services (NAICS 54) are available since 1998. SAS data for R&D services (NAICS 5417) is available for R&D in the physical, engineering, and life sciences (54171) and social sciences and humanities (54172). Data used in this section are limited to the former. For case studies in services industries, including the scientific R&D services industry, see Gallaher and Petrusa (2006).

38. The category of RDT services is part of business, professional, and technical services (or business services, for short). The latter include royalties and license fees, discussed in chapter 6.

39. Technology alliances may or may not be part of larger agreements involving manufacturing, licensing, or other forms of business collaboration. For recent studies on the role of technology licensing (e.g., technology development, commercialization strategy), see Fosfuri (2006) and Hagedoorn, Lorenz-Orlean, and Kranenburg (2007).

40. As amended by the National Cooperative Research and Production Act of 1993 (Public Law 103–42). See U.S.C. Title 15, Chapter 69. More recently, federal patent and trademark law was amended in order to facilitate patenting inventions resulting from collaborative efforts across different companies or organizations. The amendment was instituted by the Cooperative Research and Technology Enhancement (CREATE) Act of 2004 (Public Law 108–453) and applies to patents resulting from joint research as long as the claimed invention is within the scope of a written contract, grant, or cooperative agreement and made by or on behalf of the parties to the agreement.

41. CATI-MERIT is a literature-based database that draws on sources such as newspapers, journal articles, books, and specialized journals that report on business events. It includes business alliances with an R&D or technology component, such as joint research or development agreements, R&D contracts, and equity joint ventures. Agreements involving small firms and certain technology fields are likely to be underrepresented. Another limitation is that the database draws primarily from English-language materials. No data on alliance duration or termination date are available.

42. Federal laboratories are facilities owned, leased, or otherwise used by a federal agency, according to 15 U.S.C. 3710a(d)(2). They include, for example, intramural laboratories (e.g., the laboratories owned by NIH's National Cancer Institute) and government-owned, contractor-operated laboratories such as some of DOE's FFRDCs. See also the section entitled "Federal R&D."

43. For additional metrics and agencies up to FY 2003, see chapter 4 in NSB (2006), based on data from DOC, Office of the Secretary, Summary Report on Federal Laboratory Technology Transfer: FY 2003 Activity Metrics and Outcomes, 2004 Report to the President and the Congress Under the Technology Transfer and Commercialization Act (2004). An updated report was not available at the time of writing.

44. For studies on patents, citations, and other technology transfer metrics at NASA and DOE, see chapters 9 and 10, respectively, in Jaffe and Trajtenberg (2001). For technology transfer activities and case studies involving USDA R&D, see Heisey et al. (2006).

45. SBIR was created by the Small Business Innovation Development Act of 1982 (Public Law 97–219, U.S.C. Title 15, Section 631). It was last reauthorized in 2000 through September 2008. The 2000 reauthorization bill (Public Law 106–554) also requested that the National Research Council conduct a multiyear SBIR study at five federal agencies with SBIR budgets exceeding $50 million (DOD, HHS, NASA, DOE, and NSF). The study is in progress. See NRC (2007) and National Academies (2007).

46. STTR was created by the Small Business Technology Transfer Act of 1992 (Title II of the Small Business Research and Development Enhancement Act, Public Law 102–564). It was last reauthorized by the Small Business Technology Transfer Program Reauthorization Act of 2001 (Public Law 107–50) through FY 2009.

47. Title I of the Small Business Research and Development Enhancement Act, Public Law 102–564.

48. To obtain this federal funding, 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 can receive a Phase II grant of up to $750,000 over a period of up to 2 years for further development. In Phase III, the innovation must be brought to market with private-sector investment and support; no SBIR funds may be used for Phase III activities.

49. STTR is also structured in three phases.

50. Public Law 100–418; 15 U.S.C. Section 278n.

51. According to the America COMPETES Act, TIP will "continue to provide support originally awarded under [ATP], in accordance with the terms of the original award and consistent with the goals of the Technology Innovation Program." See Library of Congress (2007). For more information on the new bill, see sidebar, "Recent Developments in Innovation-Related Metrics."

52. See Library of Congress (2007).

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-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

EU-25: In 2004, the EU expanded to 25 members with the addition of 10 more countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. (Bulgaria and Romania joined the EU in January 2007, for a total of 27 member countries, EU-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, which are Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

G-8 countries: G-7 countries plus Russia.

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): Market value of goods and services produced within a country.

Intellectual property: Intangible property that is the result of creativity; the most common forms of intellectual property 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 corporation (MNC): A parent company and its foreign affiliates.

National income and product accounts: Economic accounts that display the value and composition of national output and the distribution of incomes generated in its production.

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 employees: Scientists and engineers who perform R&D functions.

R&D intensity: Measure of R&D expenditures relative to size, production, or other characteristic of a country or R&D-performing sector. Examples include company-funded R&D to net sales ratio, R&D to GDP ratio, and R&D per employee.

R&D plant expenditures: Acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

Technology alliance: Type of industrial technology linkage aimed at codevelopment of new products or capabilities through R&D collaboration.

Technology transfer: Exchange or sharing of knowledge, skills, processes, or technologies across different organizations.

U.S. affiliate: Company located in the United States but owned by a foreign parent.

Value-added: Sales minus the cost of materials.

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