Overview

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Introduction

This overview of the National Science Board's *Science and Engineering Indicators 2008* describes some major developments in international and U.S. science and technology (S&T). It synthesizes selected major findings in a meaningful way and is not intended to be comprehensive. The reader will find important findings in the report that are not covered in the overview, for example, public support for science is strong even though public knowledge is limited, S&T activities in different states vary substantially in size and scope, and participation of underrepresented groups in U.S. S&T is growing, but slowly. More extensive data are presented in the body of each chapter, and major findings on particular topics appear in the Highlights sections that precede chapters 1–7.

The reader should note that the indicators included in *Science and Engineering Indicators 2008* derive from a variety of national, international, and private sources and may not be strictly comparable in a statistical sense, especially for international data. In addition, some metrics and data are somewhat weak, and models relating them to each other and to economic and social outcomes are often not well developed. Thus, even though many data series conform generally to international standards, the focus is on broad trends that should be interpreted with care; where data are weak, this is noted in the specific chapter. (For more on the limitations of existing data and analytic models, see "Afterword: Data Gaps and Needs.")

The overview highlights a trend in many parts of the world toward the development of more knowledge-intensive economies, in which research, its commercial exploitation, and other intellectual work play a growing role. Implicit in the discussion are the key roles played by industry and government in these changes.

A healthy economy provides the foundation for investments in scientific research and technological innovation. Therefore, the overview begins by describing broad trends in U.S. competitiveness in the rapidly changing global macroeconomic system. It then traces the growth and structural shifts in international high-technology markets and comments briefly on related developments in medium- and low-technology market segments. There follows an examination of the changing conduct and location of international R&D, which are both fundamental to, and recasting, international high-technology markets.

The overview then turns to the personnel needed to build and maintain knowledge-intensive economic activity. After reviewing evidence of the widespread upgrading of higher education levels in international workforces, the discussion turns to a review of the U.S. S&T labor force, including trends in the production of new workers with S&T skills. It presents data on the U.S. reliance on foreign-born and foreign-educated S&T workers and discusses the growing international mobility of highly trained persons. The overview concludes with a review of the performance of U.S. K–12 students on national and international tests.

Throughout, the overview examines relevant S&T patterns and trends in the United States that bear on, and are affected by, these external changes. Where possible, the overview presents comparative data for the United States, the European Union after its first major enlargement (EU-25), and Japan, China, and eight other selected Asian economies (the Asia-10).

Macroeconomic Indicators

Since the early 1990s, the globalization of S&T has proceeded at a quick pace. More open borders coincided with the development of the Internet as a tool for unfettered worldwide information dissemination and communication. Rising demand for business and leisure travel fostered the growth of dense and relatively inexpensive airline links. Systems of global and more limited trade rules gained in scope and stimulated a vast expansion in the production of, and international trade in, goods and services. Growing creation of wealth, though uneven, touched most countries and regions. Corporations responded by including international markets in their strategic planning and soon moved toward a global-market model for their business activities, suppliers, and customers.

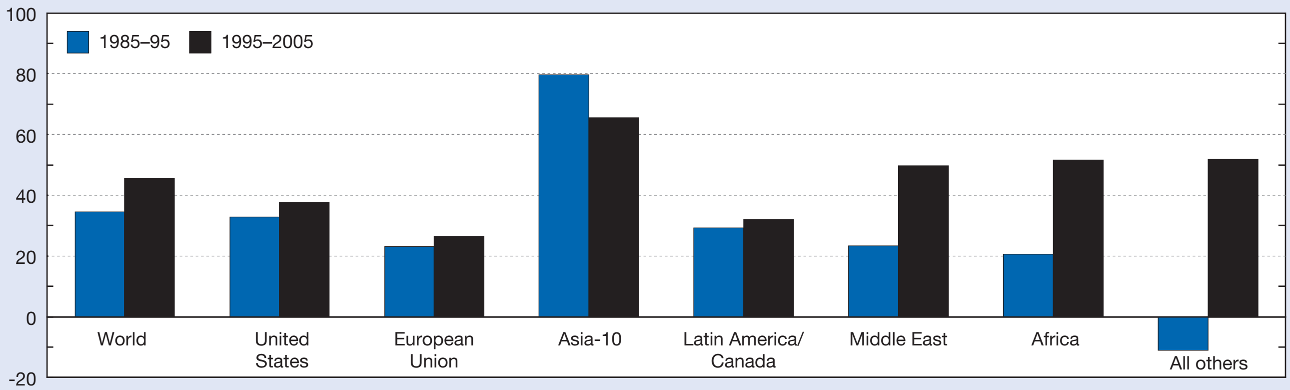
By the late 1990s, many governments had taken note of these developments. They increasingly looked to the development of knowledge-intensive economies for their countries' economic competitiveness and growth. Private companies seeking new markets set up operations in or near these locations, bringing with them technological know-how and management expertise. Governments anticipated and stimulated these moves with targeted and often generous incentives, decreased regulatory barriers, development of infrastructure, and expanded access to higher education. The overarching aim of these policies was the development of a knowledge-intensive economy that promised sustainable growth and economic well-being for decades to come.

In this changed and changing world, the United States continues to occupy a prominent position as the world's largest economy. On a number of broad macroeconomic measures, it has performed well over the past two decades. Its gross domestic product (GDP) growth has been robust, both overall and on a per capita basis, and its productivity growth has been strong.

U.S. GDP growth is robust but cannot match large, sustained increases in China and other Asian economies.

World Bank and other data show that the world's total economic output nearly doubled over the past two decades.[1] Although most world regions participated in this rapid expansion of total economic output, increases did not occur evenly. A group of East and Southeast Asian economies (the Asia-10) gained more rapidly than did most of the rest of the world, initiating a slow shift of the epicenter of world economic growth toward the region (figure O-1). Its GDP nearly tripled as China, India, and South Korea posted strong

Figure O-1
Real GDP growth, by region/country: 1985–95 and 1995–2005



GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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advances, even as Japan's economy struggled with slow growth. The rapid rise in Asian economic output over two decades, combined with slower growth elsewhere, pushed the region's share of world GDP from less than one-quarter in 1985 to 36% in 2005 (figure O-2).

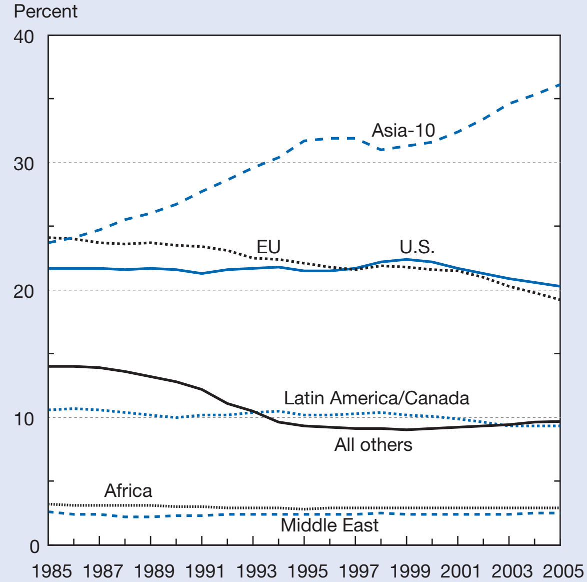
U.S. real GDP growth was slower than Asia's but faster than that of most other mature economies. It resulted in a near-doubling of real output over the two decades, leading to a small decline in the U.S. share of world GDP, from about 22% to just above 20% in 2005 (figure O-2). The EU-25 faced slower growth and a larger share decline from 24% to 19%. Japan's economy continued to grow in real terms but at a declining rate, leading to a fall of the country's world GDP share starting in the early 1990s, from about 8% of the total to 6% by 2005. The "all others" category in figure O-2 largely reflects the breakdown in growth of Eastern European and Asiatic countries of the former Union of Soviet Socialist Republics (USSR).

Even as others gain in per capita GDP, the absolute U.S. advantage widens because of its advantageous starting position.

GDP growth in part reflects increases in population, and GDP per person provides a convenient means of adjusting for this factor, albeit a measure that does not take in-country distribution into account.[2] A comparison of GDP and population growth rates shows a highly variable relationship for different regions and countries: very strong GDP growth for Asia, even after accounting for rising populations; average growth for the United States and the EU-25; and below-average growth for some other regions with fairly large population growth (figure O-3).

Over the past two decades (1985–2005), real annual growth of U.S. per capita GDP averaged 2.0%, almost identical to the world average and the growth rate of the EU-25. Many smaller EU countries, Ireland, the United Kingdom, and a smattering of countries in Latin America, the Middle

Figure O-2
World GDP shares, by region/country: 1985–2005



EU = European Union; GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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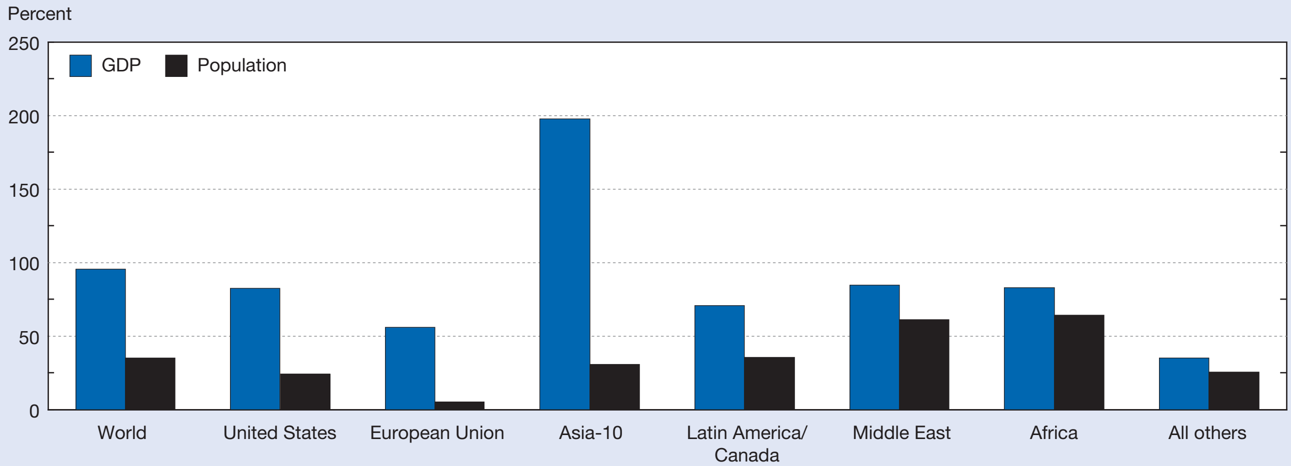
Figure O-3
Real GDP growth and population increase, by region/country: 1985–2005



GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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East, and Africa had higher growth rates. So did virtually all East and Southeast Asian economies, regardless of size. The highest growth rate of real per capita GDP[3] was achieved by China, averaging 6.6% over the period, followed by South Korea, Vietnam, Thailand, and others; India's GDP per capita rose by 4.2%. Of 11 economies with at least twice the U.S. average per capita growth, nine were in Asia (table O-1).

In terms of absolute per capita purchasing power, the United States has for decades led other regions by wide margins, the closest being the EU-25.[4] All regions but Africa and the former USSR-dominated category have shown two-decade increases, and the Asia-10 grouping has doubled its per capita GDP in real terms (figure O-4).

Table O-1
Real per capita GDP growth rates, by selected region/country/economy: 1985–2005
(Percent)

Economy	1985–95	1995–2005	1985–2005
World	1.4	2.3	1.9
United States	1.7	2.2	2.0
China	6.4	6.8	6.6
South Korea	7.8	3.7	5.7
Ireland	4.5	6.6	5.5
Vietnam	4.1	5.9	5.0
Thailand	8.0	1.8	4.9
Myanmar	0.4	9.4	4.8
Taiwan	5.1	3.7	4.4
Chile	5.5	3.0	4.3
Singapore	5.7	2.8	4.2
India	3.6	4.7	4.2
Malaysia	5.6	2.6	4.1

GDP = gross domestic product

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database, January 2007, http://www.ggdc.net.

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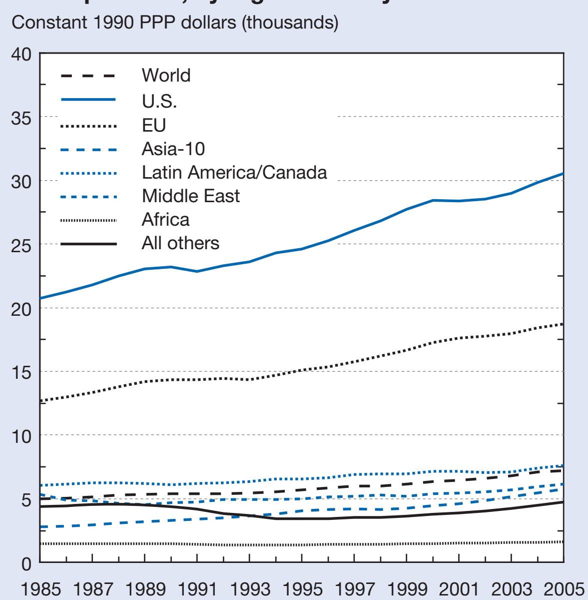
Figure O-4
Per capita GDP, by region/country: 1985–2005



EU = European Union; GDP = gross domestic product; PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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Despite faster rates of growth elsewhere, the United States widened its per capita GDP lead in absolute inflation-adjusted terms because of its large initial advantage. The absolute gap in 2005 was smallest for the EU-25 (about $12,000) and largest for Africa (about $29,000). The Asia-10 gap increased from about $18,000 to $26,000, despite the region's rapid GDP growth. Since 1985, this gap has increased for each region (figure O-5).

For some regions, the per capita GDP gap also increased as a fraction of their own growing per capita GDP. The only region to consistently reduce the relative per capita GDP gap with the United States was the Asia-10 (figure O-6). The Asia-10 group managed to reduce the size of the gap from 8 times its per capita GDP to under 5 times, reflecting impressive underlying GDP growth numbers coupled with moderate (1.4%) population growth (figure O-3).

Large relative productivity gains elsewhere fail to close absolute per-worker output gaps with the United States.

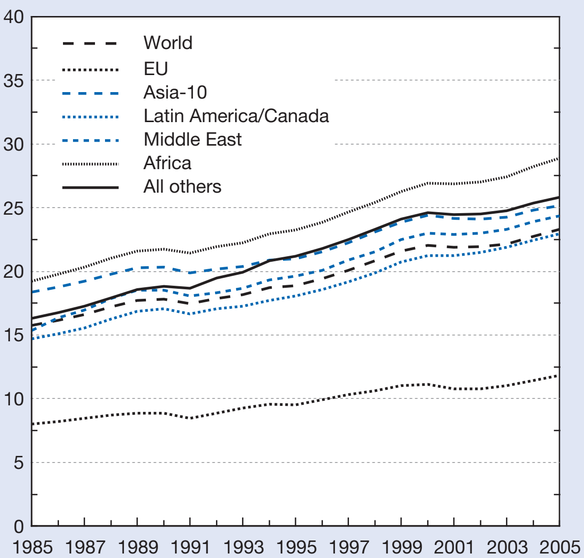
Rising productivity spurs economic growth and higher per capita resources. The preferred measure, volume of economic output per hour worked, is available for only a few countries. It shows that after enduring anemic productivity growth into the mid-1990s, the United States recovered to an annual, inflation-adjusted rate of about 2.5% from 1995 to 2004, significantly above the rates of major European economies and Japan.

A related measure, GDP per person employed, is more widely available and thus allows broad, but approximate, international comparisons. That measure shows generally higher real productivity gains for the regional aggregates in the 1995–2005 decade than in the preceding one, except for the EU-25 (figure O-7). Neither the United States, nor major European countries or Japan achieved the kind of productivity growth rates of some Asian economies. These averaged above 3% during the first decade and approached 4% during the second. China and India had real second-decade productivity growth rates of 6.6% and 4.4%, respectively, albeit from low bases.

In inflation-adjusted dollars, U.S. output per worker increased more steeply over the 20-year period than that of any other economy. Again, this reflects the much higher U.S. output per worker at the beginning of the period: a 2% increase on a high base is much larger, in absolute terms, than the same percentage rise on a small base. As a result, even countries with fast-expanding economies faced a growing gap with the United States (figure O-8). Even the EU-25, with a 20-year average productivity growth rate that matched that of the United States, saw its productivity gap widening after 1995.

Figure O-5
Per capita GDP gap with United States, by region: 1985–2005

Constant 1990 PPP dollars (thousands)



EU = European Union; GDP = gross domestic product;
PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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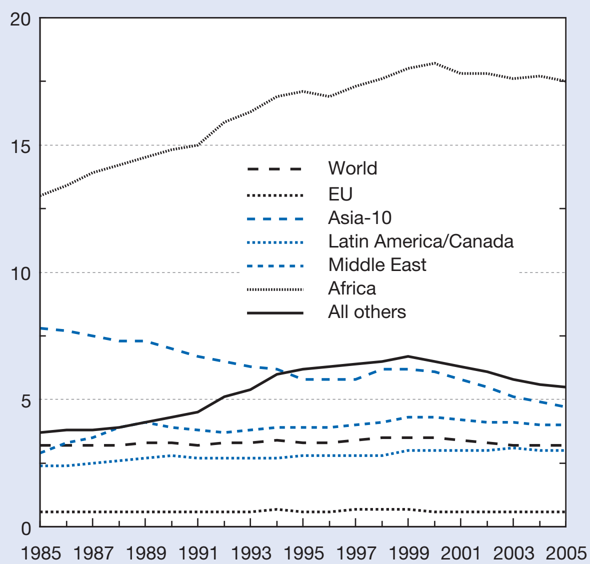
Figure O-6
Per capita GDP gap with United States relative to region's GDP: 1985–2005

Ratio



EU = European Union; GDP = gross domestic product

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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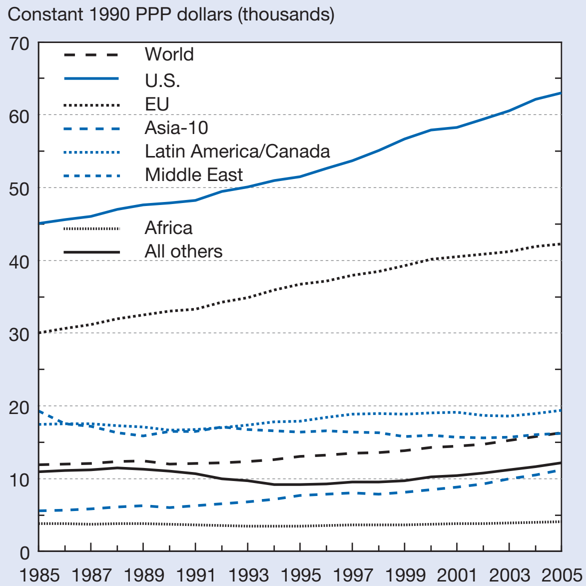
Figure O-7
Productivity output per employed individual: 1985–2005



EU = European Union; PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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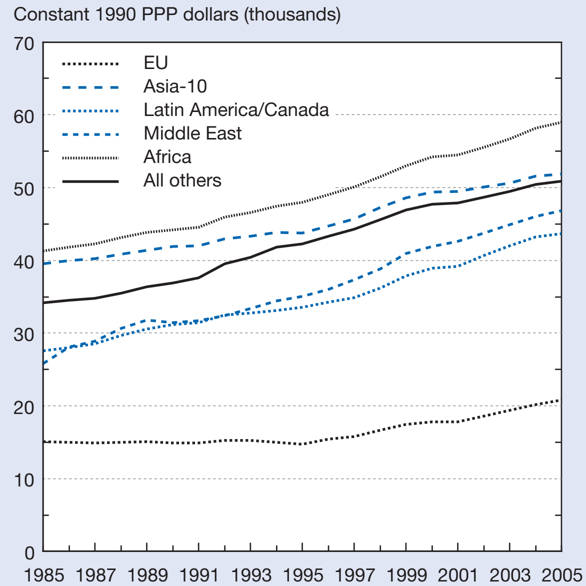
Figure O-8
Inflation-adjusted productivity gap with United States, by region: 1985–2005



EU = European Union; PPP = purchasing power parity

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net.

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The United States remains robustly competitive on these macroeconomic measures.

In terms of these three indicators, the U.S. economy has managed to maintain a strong competitive position. Its absolute GDP growth was sufficiently robust to broadly maintain the U.S. world share in the face of expanding world GDP and a shift of rapid GDP growth toward Asian economies. Similarly, it has maintained its advantages in both purchasing power and productivity. While per capita GDP of economies in Asia and elsewhere was rising at very rapid rates, smaller rates of increase in U.S. per capita GDP kept widening the absolute dollar gap, reflecting and continuing the large initial U.S. advantage. U.S. productivity growth was sufficiently robust to keep the country well ahead, in absolute productivity measures, even as others raise their productivity growth rates from relatively low levels.

Knowledge-Intensive Economies

The notion of a knowledge-intensive economy is of relatively recent vintage but has taken a powerful hold on governments in many parts of the world. It is easy to see why. Industries that rely heavily on the application and exploitation of knowledge are driving growth in both manufacturing and services. They tend to create well-paying jobs, to contribute high-value output, and to stimulate economic activity generally. The global nature of these developments compels governments to take part in them or be left behind, to the detriment of a country's economic standing and well-being.

Industry anticipates and reacts to these same fundamentals. Growing markets, including rapidly expanding ones in Asia, beckon, especially for knowledge- and technology-intensive goods and services. They offer growing buying power, cheap labor, and often strategically structured government incentives intended to attract investment. Spurred by both market and government activities, these economies, and particularly their knowledge-intensive sectors, have grown very rapidly in a number of regions.

Indicators of the shift toward knowledge-intensive economic activity abound. Around the world, service sectors are expanding, driven by rapid growth of their most knowledge-intensive segments. Goods from high-technology manufacturing segments represent a growing share of manufacturing output. Countries are investing heavily in expansion and quality improvement of their higher education systems, easing access to them, and often directing sizable portions of this investment to training in science, engineering, and related S&T fields. The concept of innovation figures prominently in discussions of economic policy.

Taken together, these activities have spawned trends that are reshaping the world's S&T economy, now dominated not only by the United States and the EU, but also by selected Southeast and South Asian economies. The broad changes, generally starting in the mid-1990s and continuing unabated, have the United States holding its own in terms of (generally high) world shares, the EU-25 losing some ground, and the Asia-10 group increasing its world share. In Asia, Japan is losing world share on many indicators, while China is rapidly gaining ground, especially since the mid-1990s.

Knowledge-intensive industries are reshaping the world economy.

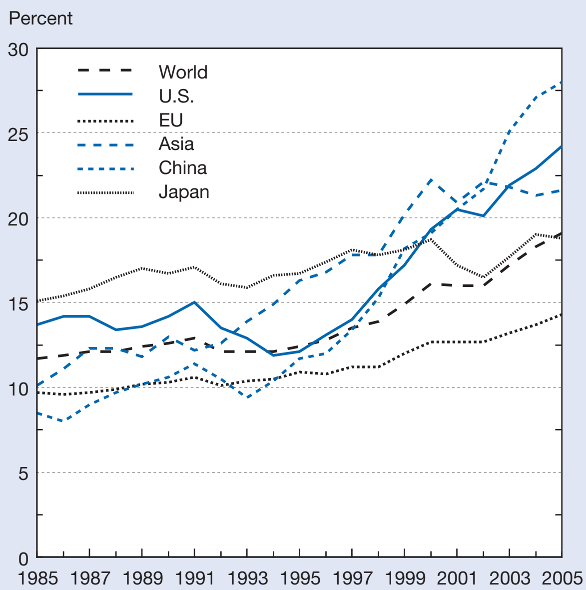
Knowledge-intensive industries, both in services and manufacturing, form a growing share of economic output worldwide and in many individual countries. While the estimated volume of worldwide services doubled between 1985 and 2005, knowledge-intensive services grew faster. After the mid-1990s, their growth accelerated to approximately 3.5% annually in real terms, compared with about 2.5% for other types of services. A similar shift occurred in high-technology manufacturing, where output rose from about 12% of total manufacturing output to about 19% over two decades (figure O-9).

These developments affected various countries and regions differently, leading to considerable shifts in world shares, particularly in high-technology manufacturing. The Asia-10's share increased from 29% to 41% over two decades. However, within the group, Japan's share declined from 25% in 1985 to 16% in 2005, while China's share rose, with sharp acceleration starting in the mid-1990s, from under 2% to 16% over the same period (figure O-10). The EU's share of high-technology manufacturing declined from about 25% through the mid-1990s to 18% in 2005. In contrast, U.S. high-technology manufacturing expanded sharply over the past decade to 24% of all U.S. manufacturing activity by 2005, up from 12% as late as 1995; this has kept the U.S. world share above 30% since the late 1990s.

Trade patterns in knowledge-intensive services and high-technology manufacturing have changed.

Trade volume in high-technology manufactures has risen about 10-fold over the two decades, with exports reaching approximately $2.3 trillion in 2005 (figure O-11). The arrival and rapid expansion of new, mostly Asian, manufacturing locations has shifted world export patterns, shrinking the shares of established manufacturing centers. The EU's world share fell from 39% to 28%, that of the United States from 23% to 12%, and Japan's from 21% to 9%. China's share increased dramatically after the late 1990s, reaching 20%, while the share of other Asian economies rose quite steadily from 7% to 25% in 2005 (figure O-12).

Figure O-9
High-technology manufacturing share of total manufacturing, by region/country: 1985–2005



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

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

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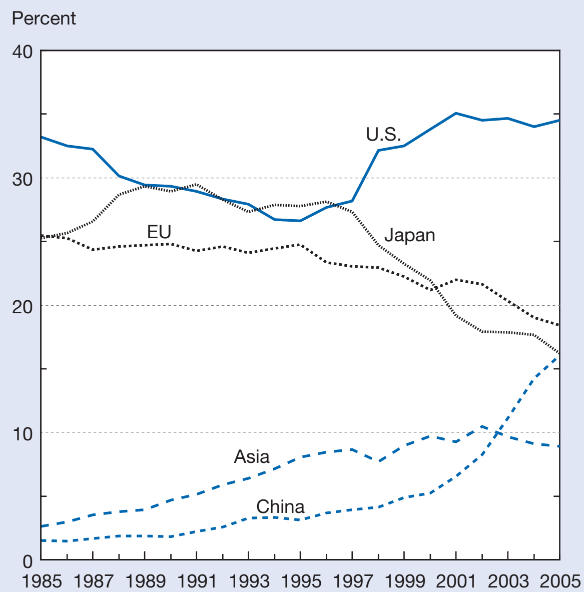
Figure O-10
World share of high-technology manufacturing, by region/country: 1985–2005



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

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

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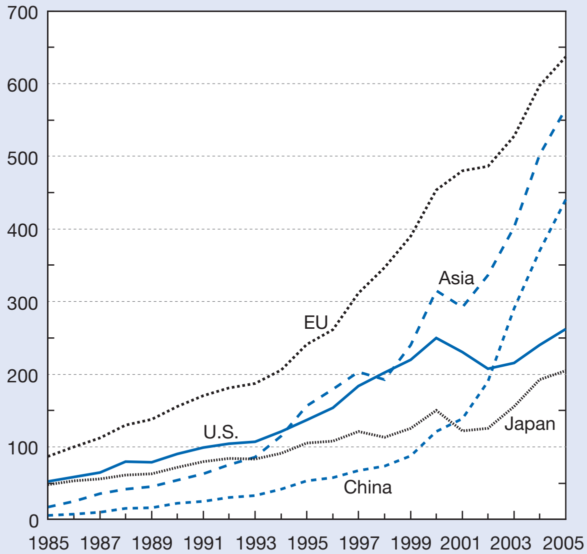
Figure O-11
Export volume of high-technology manufactures, by region/country: 1985–2005

Constant 2000 dollars (billions)



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

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

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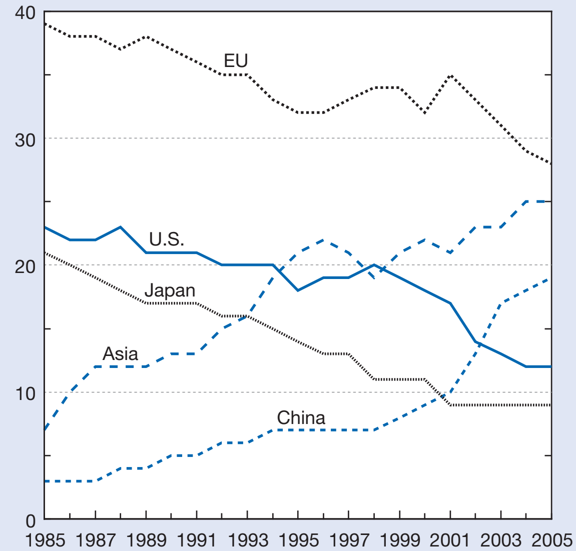
Figure O-12
World share of high-technology manufacturing exports, by region/country: 1985–2005

Percent



EU = European Union

NOTES: Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

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

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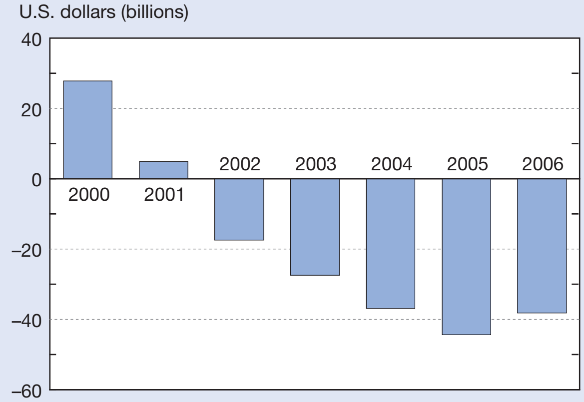
The comparative strength of the U.S. economy over the past several years was reflected in U.S. trade in high-technology goods, especially in information and communications technologies (ICT). The strong U.S. economy boosted imports of high-technology goods, which rose to $291 billion in 2006 from $196 billion in 2000. However, U.S. exports of these types of goods failed to keep pace, and imports have exceeded exports since 2002, producing the first U.S. trade deficit in this segment of the U.S. economy (figure O-13).

The growing technological sophistication of Asian trade partners is evident in the growing imports of high-technology goods from Asia that are not balanced by U.S. exports to these economies. The overall high-technology goods deficit is driven by trade with Asia, while trade with Europe, North American Free Trade Agreement (NAFTA) partners, and Latin America is broadly in balance (figure O-14).

However, the United States continues to maintain a healthy position in royalties and fees for intellectual property. This includes both cross-border intrafirm transactions and transactions between unaffiliated firms; the latter accounted for approximately 25% of all such transactions over the past two decades (figure O-15).

Figure O-13
U.S. trade balance in high-technology goods: 2000–06

U.S. dollars (billions)



SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

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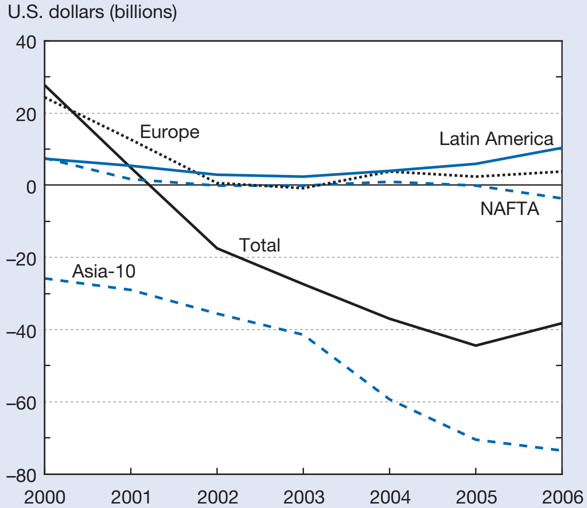
Figure O-14
U.S. advanced technology product trade balance, by region: 2000–06



NAFTA = North American Free Trade Agreement

NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong. Europe includes EU-25 plus Norway; Latin America includes Argentina, Brazil, Chile, Costa Rica, Peru, and Venezuela.

SOURCE: Census Bureau, Foreign Trade Division, special tabulations.

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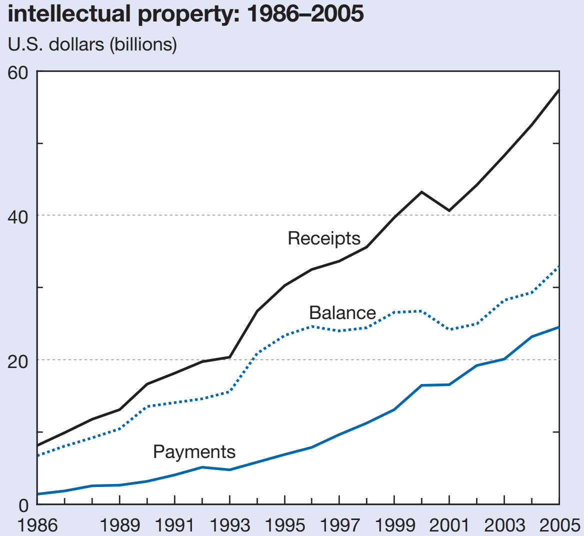
Figure O-15
U.S. receipts and payments of royalties and fees for intellectual property: 1986–2005



SOURCE: Bureau of Economic Analysis, U.S. International Services: Cross-Border Trade 1986–2005, and Sales Through Affiliates, 1986–2004, table 4, http://www.bea.gov/international/intlserv.htm, accessed 28 June 2007.

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Nascent S&T capabilities are reflected in gains in patenting and scientific publishing.

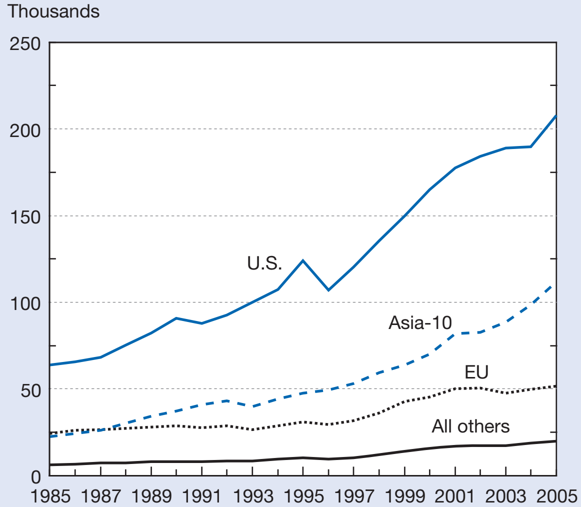
As countries strive to develop knowledge-intensive segments of their economies, they promulgate policies to strengthen domestic S&T capabilities so as to become less reliant on foreign expertise. Some results of these efforts are difficult to measure, such as the quality of rising numbers of higher education degrees awarded, but others are eventually reflected in readily quantified data. Intellectual property rights in major markets in the form of patents are generally accepted as indicating a degree of technological innovativeness and sophistication. Publication of rising numbers of scientific and technical articles in international, peer-reviewed journals is evidence of growing scientific capacity, as are increasing international collaborations. A number of governments are actively encouraging these activities and monitoring these and related indicators.

Patent applications to the U.S. Patent and Trademark Office (USPTO) seek intellectual property protection in the world's largest national economy. Applications from foreign sources reveal growing technological capabilities around the world, as well as rising incentives to protect the exploitation of potentially economically valuable inventions. Such applications have more than tripled since 1985, with U.S. applications consistently accounting for 53% or more through 2005. Over the period, applications from EU countries little more than doubled, while those from Asia increased fivefold (figure O-16).

These divergent growth rates created large shifts in the country and regional shares of U.S. patent applications. The EU, long the major non-U.S. source, lost ground in the late 1980s to a nascent Asia, as the EU's share declined from 21% to 13% of total applications registered by the USPTO; Asia's share in the meantime rose from 19% to 29%. Within Asia, Japan's share fluctuated around 18% to, briefly, 22% while that of smaller Asian economies such as South Korea, Taiwan, and Singapore rose from 1% to 9% (figure O-17). Chinese applications, however, do not yet register in any significant way, suggesting room for further development of the country's domestic technology base.

Progress in building the S&E base underlying indigenous technical advances is registered in articles published in the international peer-reviewed literature. On this measure, the U.S. and Japanese outputs grew marginally over the 1995–2005 decade, while Asia's output doubled (figure O-18). China moved to fifth place in total article output, and a number of other Asian economies, including South Korea, Singapore, and Taiwan, registered steep publications increases, suggesting improving basic scientific infrastructure. But a broad citation measure (citations received adjusted for the volume of articles available for citation) indicates a more measured pace of increasing article quality for many Asian locations.

Figure O-16
USPTO patent applications, by region/country: 1985–2005



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Country of origin based on residence of first-named inventor. Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: USPTO, Number of Utility Patent Applications Filed in the United States, by Country of Origin, Calendar Years 1965 to Present (1), and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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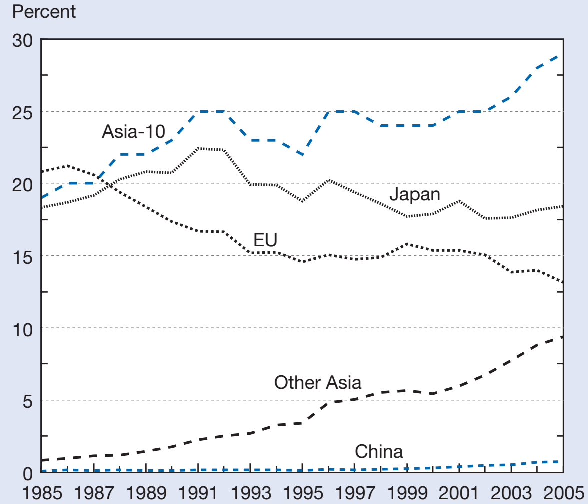
R&D in Knowledge-Intensive Economies

Knowledge-intensive economies draw on a broad range of knowledge, goods, skills, and activities, including the funding and performance of R&D. The level of R&D relative to other expenditures provides an indication of the priority given to advancing S&T relative to other public and private goals.

A growing emphasis on R&D is a measure of the development of a knowledge-intensive economy. In government accounts, R&D must compete for funding with other programs supported by discretionary spending, from education to national defense. The budget share devoted to R&D thus indicates governmental and societal investment in R&D relative to other activities. Similarly, the amount for-profit companies spend on R&D relative to other investments indicates how important they consider technological improvements to be as a basis for developing markets and exploiting demand for better processes, goods, and services.

R&D enables but does not guarantee invention, and invention does not automatically lead to innovation, the introduction of new goods, services, or business processes in the marketplace. Differences in national systems of innovation may make one country more effective than another in trans-

Figure O-17
Proportion of total USPTO patent applications from Asia and EU: 1985–2005



EU = European Union; USPTO = U.S. Patent and Trademark Office

NOTES: Country of origin based on residence of first-named inventor. Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: USPTO, Number of Utility Patent Applications Filed in the United States, by Country of Origin, Calendar Years 1965 to Present (1), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm, accessed 21 September 2007; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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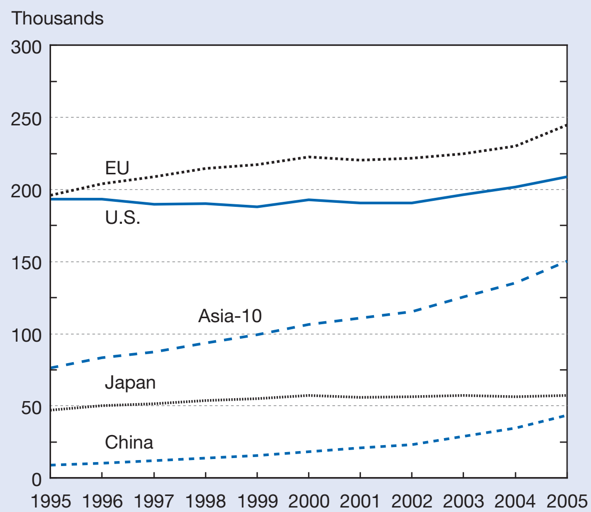
Figure O-18
Scientific and technical articles in peer-reviewed journals, by region/country: 1995–2005



NOTES: Asia-10 includes China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

SOURCES: Thomson Scientific, Science Citation Index and Social Sciences Citation Index; ipIQ Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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lating R&D investments into economic growth or other social benefits. In the end, it is the results of R&D expenditures that matter, not their amount.

Internationally, R&D is concentrated but becoming less so. Over the past two decades, R&D has principally been performed and funded in North America, Europe, and Asia by the 30 developed member nations of the Organisation for Economic Co-operation and Development (OECD) (figure O-19).[5] The United States and Japan provided close to 60% of the estimated $772 billion OECD total in 2005, little changed from 61% of the $480 billion OECD total in 1995.

But this picture is changing (table O-2). For nearly a decade, R&D expenditures are estimated to have risen rapidly in selected Asian and Latin American economies and elsewhere. The average annual R&D growth rate of nine non-OECD economies (Argentina, China, Israel, Romania, Russian Federation, Singapore, Slovenia, South Africa, and Taiwan; there are no data for India) tracked by the OECD was about 15.5% from 1995 to 2005, compared with an OECD average of 5.8%. Over the decade, the OECD share of the combined total dropped from an estimated 92% to 82%. Likewise, the combined share of the United States and Japan, the two largest R&D-performing countries, declined from 56% of the total in 1995 to 48% in 2005.

China's expansion of R&D was by far the most rapid and sustained of all (figure O-20). According to OECD figures, it had the fourth largest expenditures on R&D in 2000 ($45 billion), which increased in 2005 to an estimated $115 billion, further moving it up in rank. Given the lack of R&D-

Table O-2
R&D expenditures for selected regions/countries: 1995, 2000, and 2005

Region/country	1995	2000	2005
	Current PPP dollars (billions)		
All selected regions/countries	480.1	687.2	939.5
OECD	440.3	606.8	771.5
U.S./Japan	266.5	366.6	455.2
U.S.	184.1	267.8	324.5
Japan	82.4	98.8	130.7
Selected non-OECD	39.8	80.5	168.0
	Percent		
All selected regions/countries	100	100	100
OECD share all	92	88	82
U.S/Japan share OECD	61	60	59
U.S./Japan share all	56	53	48

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

SOURCE: OECD, Main Science and Technology Indicators, 2006 and 2007.

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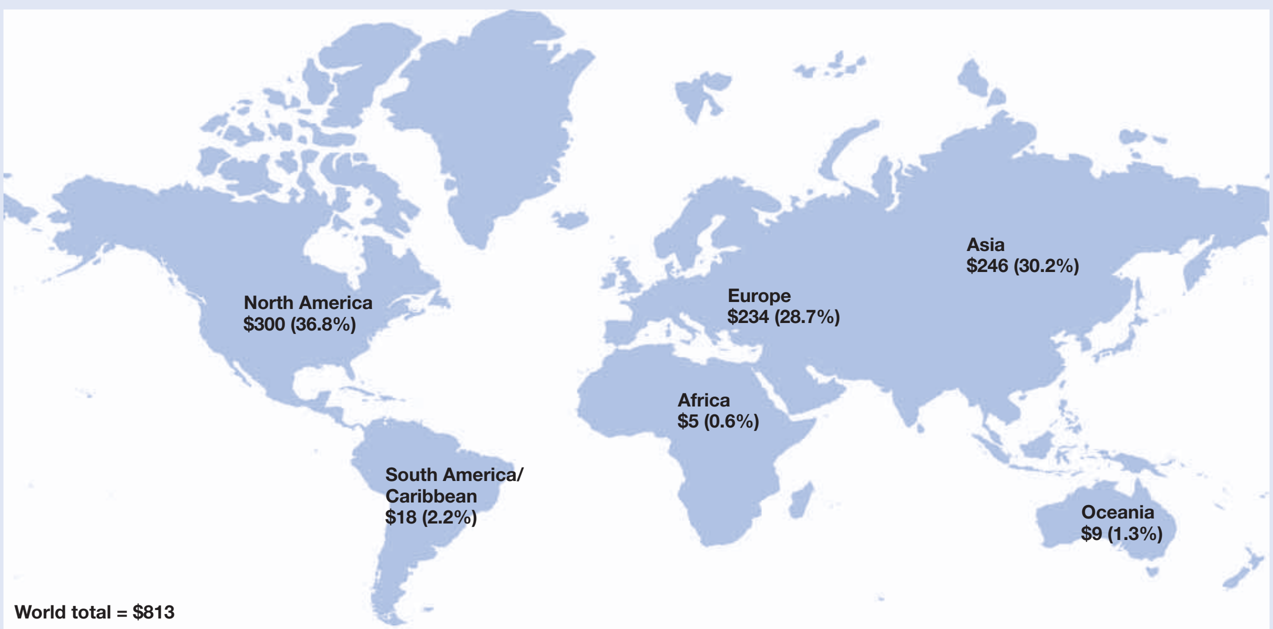
Figure O-19
Estimated R&D expenditures and share of world total, by region: 2002



NOTES: 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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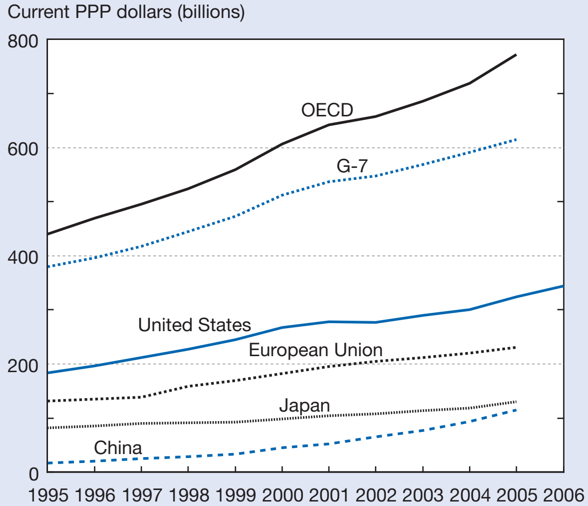
Figure O-20
Gross domestic expenditures on R&D, by selected region/country: 1995–2006



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

NOTE: European Union (EU)-25 from 1998–2000, EU-27 thereafter.

SOURCE: OECD, Main Science and Technology Indicators 2004–07.

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specific exchange rates, it is difficult to draw conclusions about China's absolute R&D volume, but its nearly decade-long, steep ramp-up of R&D expenditures and R&D intensity is unprecedented in the recent past. Other less-developed countries that appear set to become sizable R&D performers include Brazil ($14 billion in 2004) and India ($21 billion in 2000).

Industry R&D in manufacturing and services is expanding and increasingly crossing borders.

In most OECD countries, the manufacturing and services sectors account for more than 60% of total R&D funding and performance. However, sector concentration and sources of funding vary substantially among these countries.

Industrial R&D in the United States is highly diversified. No single U.S. industry accounted for more than 16% of total business R&D (table O-3 and figure O-21). 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.

Most other countries display higher sector concentrations than the United States. 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. 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. 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.

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.

One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of

Table O-3
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
United States (2006)	71.1	13.7	11.0	4.2
Germany (2005)	69.9	16.5	13.6	NA
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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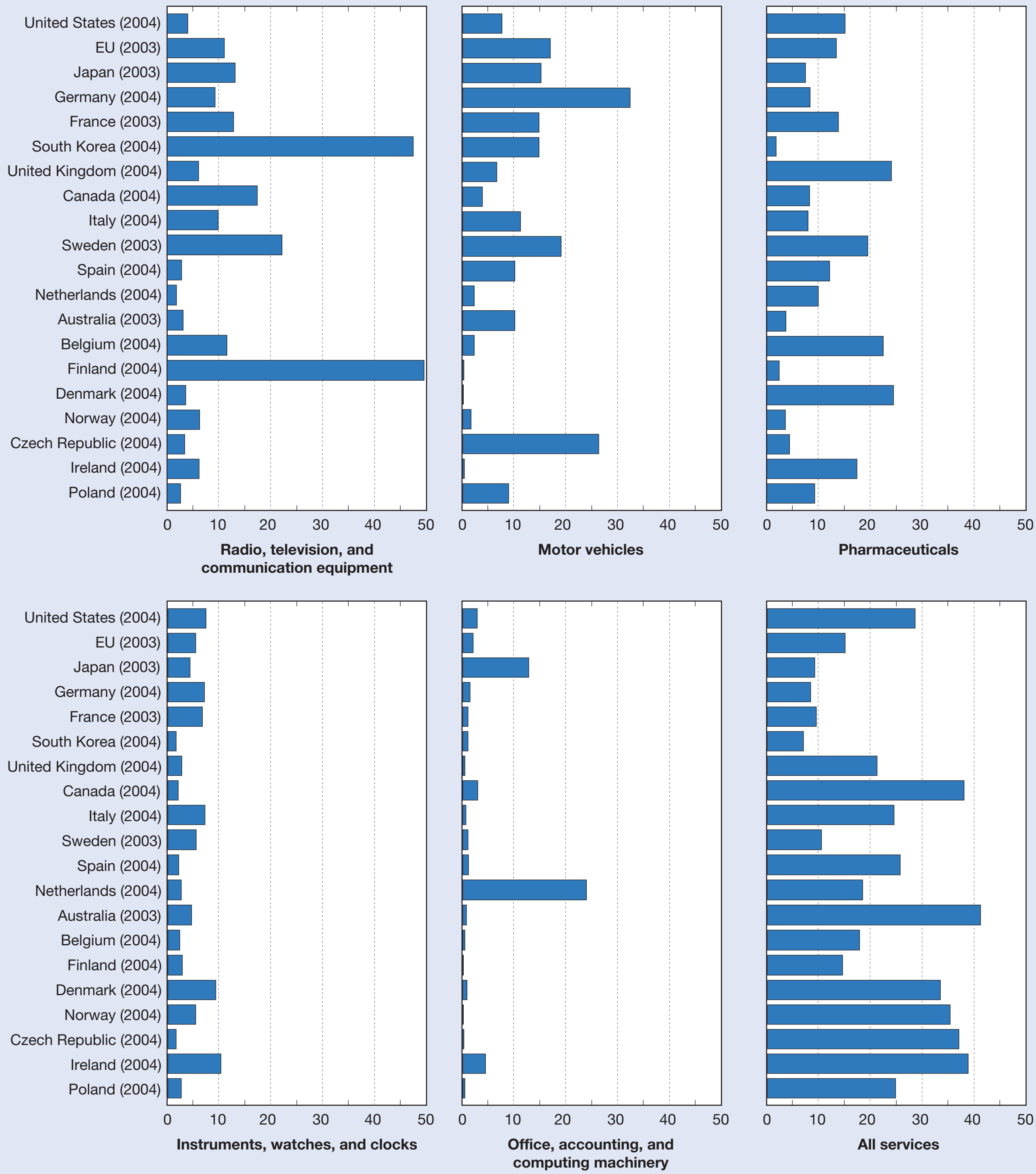
Figure O-21
Share of industrial R&D, by industry sector and selected region/country: 2003 or 2004
(Percent)



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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R&D in the service sector. ICT services account for a substantial share of the service R&D totals.

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 O-22). In 1981, government provided 21% of the funds used by industry in conducting R&D within OECD countries. By 2001, government's funding share of industrial R&D had fallen below 7% and continued to fluctuate between 6.8% and 7% through 2005. Among major industrial countries, government financing of industrial R&D performance shares ranged from as little as 1.2% in Japan to 54% in Russia in 2005. 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 Department of Defense contracts.

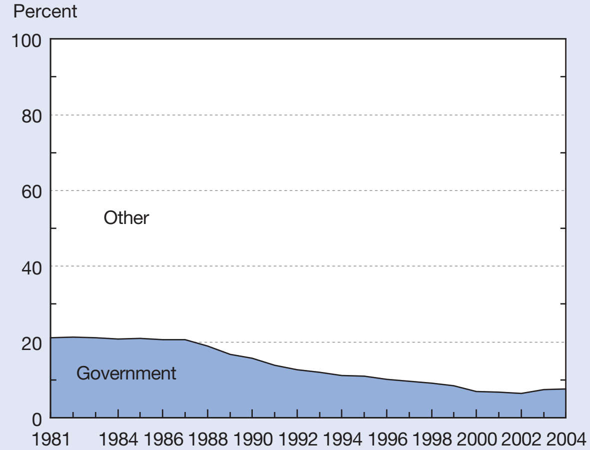
An indicator of the globalization of industrial R&D, the relative prominence of foreign sources of funding for business R&D, increased in many countries in the 1990s (figure O-23). The role of foreign funding varies by country, accounting for less than 1% of industrial R&D in Japan to as much as 23% in the United Kingdom in 2004. Directly comparable data on foreign funding sources of U.S. R&D performance are unavailable, but data on U.S. investments by foreign multinational corporations (MNCs) suggest this is rising as well. (See section on multinationals' R&D conducted abroad later in this overview.) This funding predominantly comes from foreign corporations; however, some of it also comes from foreign governments and other foreign organizations. For European countries, growth in foreign sources of industry R&D funds may reflect the expansion of coordinated EU efforts to foster cooperative shared-cost research through its European Framework Programmes for Research and Technological Development.

R&D/GDP ratio is an elusive policy goal but a useful indicator of R&D intensity.

A country's ratio of R&D to GDP depends on many things, among them the extent and structure of industrialization, orientation toward R&D in various sectors of the economy, availability of trained personnel, the nature of R&D infrastructure, and government policy. This makes meeting any specific R&D/GDP ratio an elusive policy goal. However, R&D/GDP ratios do provide a quick view of the R&D intensity of an economy relative to support of other public and private goals. Thus, emphasis on R&D can be seen as a measure of a knowledge-intensive economy.

Existing wealth generally bestows an advantage in moving toward a knowledge-intensive economy. R&D intensity indicators, such as R&D/GDP ratios, show that the developed, wealthy economies are well ahead of lesser developed economies. In many cases, this ratio heavily reflects the level of industry-funded R&D. Although industrial R&D does not generally respond directly to government policies, it thrives where favorable framework conditions exist, and these are subject to government influence.

Figure O-22
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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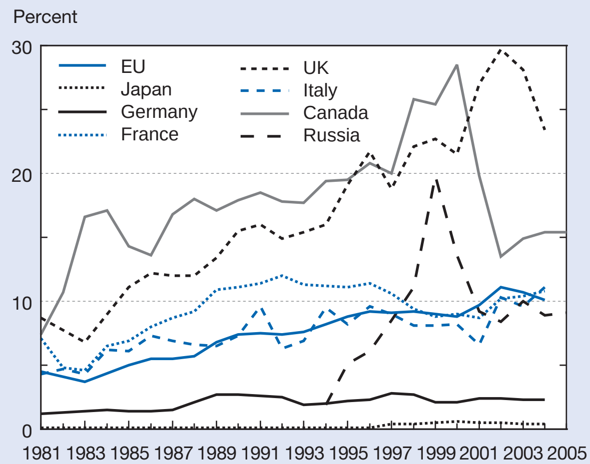
Figure O-23
Industrial R&D financed by foreign sources: 1981–2005



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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Overall, the United States ranked seventh among OECD countries in terms of reported R&D/GDP ratios (2.6% in 2005). 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%) (table O-4).

Most non-European, non-OECD, or developing countries invest a smaller share of their economic output in R&D than do OECD members. Despite its rapidly rising investment in

Table O-4
R&D share of GDP, by region/country/economy: Most recent year
(Percent)

Country/economy	Share
All OECD (2004)	2.25
EU-25 (2005)	1.77
Israel (2005)	4.71
Sweden (2005)	3.86
Finland (2006)	3.51
Japan (2004)	3.18
South Korea (2005)	2.99
United States (2006)	2.57
Germany (2005)	2.51
Taiwan (2004)	2.42
France (2005)	2.13
United Kingdom (2004)	1.73
China (2005)	1.34
Ireland (2005)	1.25
Argentina (2005)	0.46
Mexico (2003)	0.43

EU = European Union; GDP = gross domestic product;
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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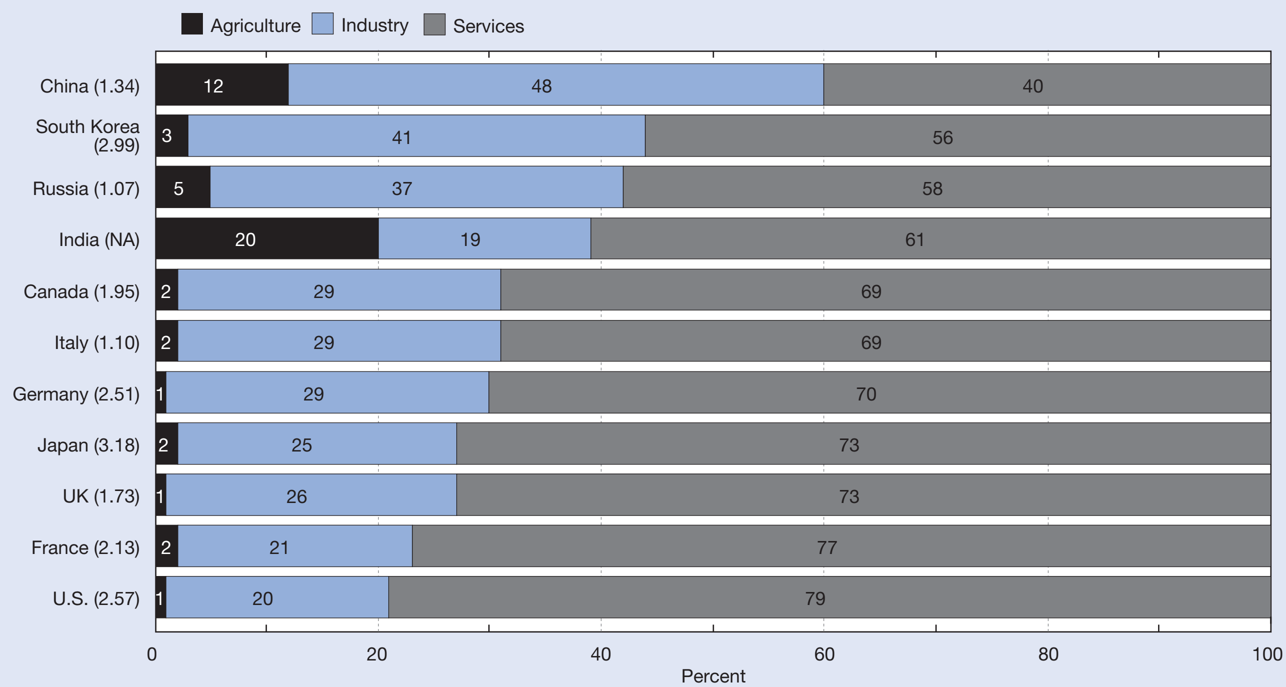
R&D, China reported an R&D/GDP ratio of just 1.3% for 2005—but relative to a GDP marked by sustained, record growth. All Latin American countries for which such data exist have R&D/GDP ratios at or below 1%. The pattern of this indicator broadly reflects the wealth and level of economic development of these countries.

High-income countries that emphasize the production of high-technology goods and services (i.e., have or are moving toward knowledge-intensive economies) are also those that tend to invest heavily in R&D activities. The private sector in low-income countries often has few high-technology industries, resulting in low overall R&D spending and therefore low R&D/GDP ratios (figure O-24).

Countries have different investment levels for national defense and associated R&D. The ratio of nondefense R&D to GDP reflects the portion of R&D that is more directly tied to scientific progress, economic competitiveness, and standard-of-living improvements. On this indicator, the United States falls below Germany and just above Canada (figure O-25). This is because the United States devotes more of its R&D than any other country to defense (16% in 2006), primarily for development rather than research. For historical reasons, Germany and Japan spent less than 1% of their R&D on defense. Approximately 10% of the United Kingdom's total R&D was defense related in 2004.

Figure O-24
Composition of GDP and R&D/GDP ratio for selected countries, by sector: 2006 or most recent year



NA = not available
GDP = gross domestic product; UK = United Kingdom

SOURCE: Central Intelligence Agency, *The World Factbook 2007,* http://www.cia.gov/cia/publications/factbook/index.html, accessed 2 March 2007. See table 4-12.

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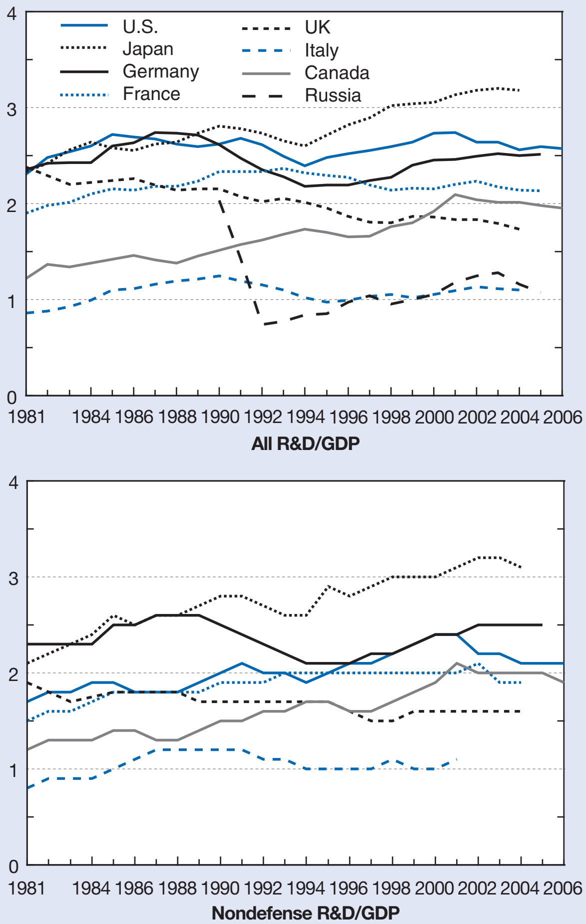
Figure O-25
R&D share of gross domestic product, by selected countries: 1981–2006



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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Figure O-26
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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Basic research plays a special role in developing new technologies.

Basic research generally has low short-term returns but builds intellectual capital and lays the groundwork for future advances in S&T.[6] High basic research/GDP ratios generally reflect the presence of robust academic research centers in the country or a concentration of high-technology industries with patterns of strong investment in basic research.

Investment in basic research relative to GDP indicates differences in national priorities, traditions, and incentive structures with respect to S&T. Among OECD countries with available data, Switzerland has the highest basic research/GDP ratio at 0.8% (figure O-26), significantly above the U.S. and Japanese ratios of 0.5% and 0.4%.

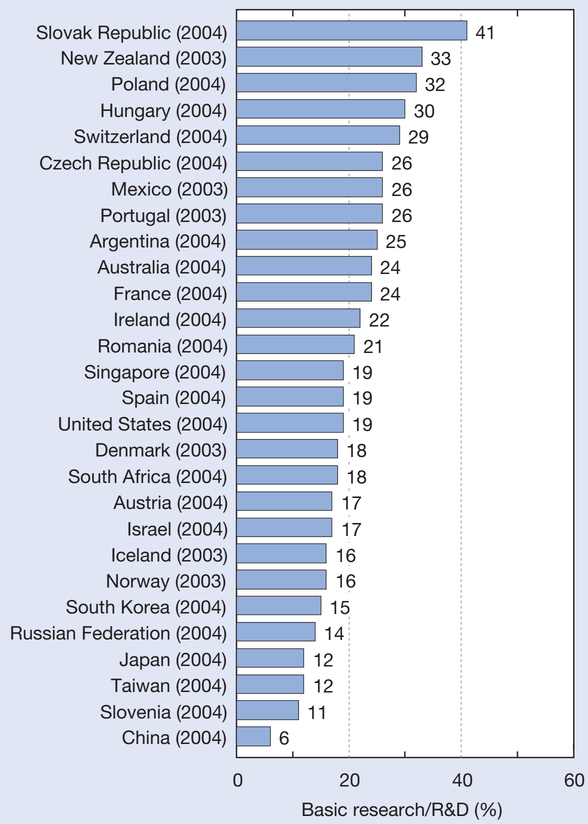
Switzerland devoted almost 30% of its R&D to basic research in 2004 (figure O-27). This small, high-income country boasts the highest number of Nobel prize winners, patents, and science citations per capita worldwide and an industrial R&D share comparable with the United States and Japan. The higher Swiss basic research share reflects the concentration of chemical and pharmaceutical R&D in Swiss industrial R&D and the "niche strategy" of focusing on specialty products adopted by many Swiss high-technology industries.

China, despite its growing R&D investment, has one of the lowest basic research/GDP ratios (0.07%), below Romania (0.08%) and Mexico (0.11%). With its emphasis on applied R&D aimed at short-term economic development, China follows the pattern of Taiwan, South Korea, and Japan whose basic research is 15% or less of total R&D (figure O-27). Singapore's basic research share, 12% in 2000, has risen to 19%, on a par with that of the United States.

Multinationals' R&D outside their home countries is growing in the United States and elsewhere.

Industrial R&D activities ceased long ago to be national in scope. Their increasingly international scope in the search

Figure O-27
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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for useful innovations is reflected in growing direct R&D investments by foreign-based MNCs in the United States and by U.S.-based firms abroad. Much of this work is supported by firms' foreign direct investment (FDI) to majority-owned affiliates abroad, reflected in the data shown in figure O-28.

Since 1990, R&D expenditures by U.S. affiliates of foreign companies have increased faster than total U.S. industrial R&D, and for the past decade they have exceeded R&D performed overseas by majority-owned affiliates of U.S. parent companies (table O-5). U.S. affiliates of European companies accounted for three-fourths ($22.6 of $29.9 billion) of U.S. affiliates' R&D.

Overseas R&D by U.S. MNCs has started shifting away from Europe, Canada, and Japan, which received 90% of all such funds in 1994 but only 80% in 2001. Increasingly, such R&D FDI is located in emerging Asian markets. This has led to considerable shifts in the region (figure O-29), where Japan's share remains the largest but has fallen from 64% in 1994 to 35% in 2004. In contrast, the Asian R&D shares of U.S. foreign affiliates located in China (including Hong Kong) and Singapore reached 17% and 14%, respectively, in 2004. U.S. affiliates' R&D expenditures in India doubled from $81 million in 2003 to $163 million in 2004, pushing India's Asia share just above 3%.

In 2004, three manufacturing industries accounted for 70% of U.S. foreign-affiliate R&D: transportation equipment (28%), chemicals including pharmaceuticals (23%), and computer and electronic products (19%) (table O-6). Among nonmanufacturing industries, professional, technical, and scientific services (which includes R&D and computer services) expended an additional 8%. The same three manufacturing industries accounted for 58% of the R&D performed by foreign affiliates in the United States: chemicals (34%), transportation equipment (13%), and computer and electronic products (11%).

R&D in the United States is robust and dominated by industry.

R&D growth in the United States was robust after the recession-related slowdown of 2001–02. After declining 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 to $340 billion in 2006.

The industrial sector, including manufacturing and services, accounts for the largest share of both U.S. R&D performance and funding (figure O-30). Its share of U.S. R&D performance increased from 66% in the early 1970s to a high of 75% in 2000. Following the 2001–02 recession, many firms curtailed R&D growth, and industry's share fell to 69% of the U.S. total before rising again to 71% in 2006. Industry funding shares behaved similarly, rising from about 40% in the early 1970s to a 2000 peak at 70%, dipping to 64% in 2004 and reaching 66% in 2006.

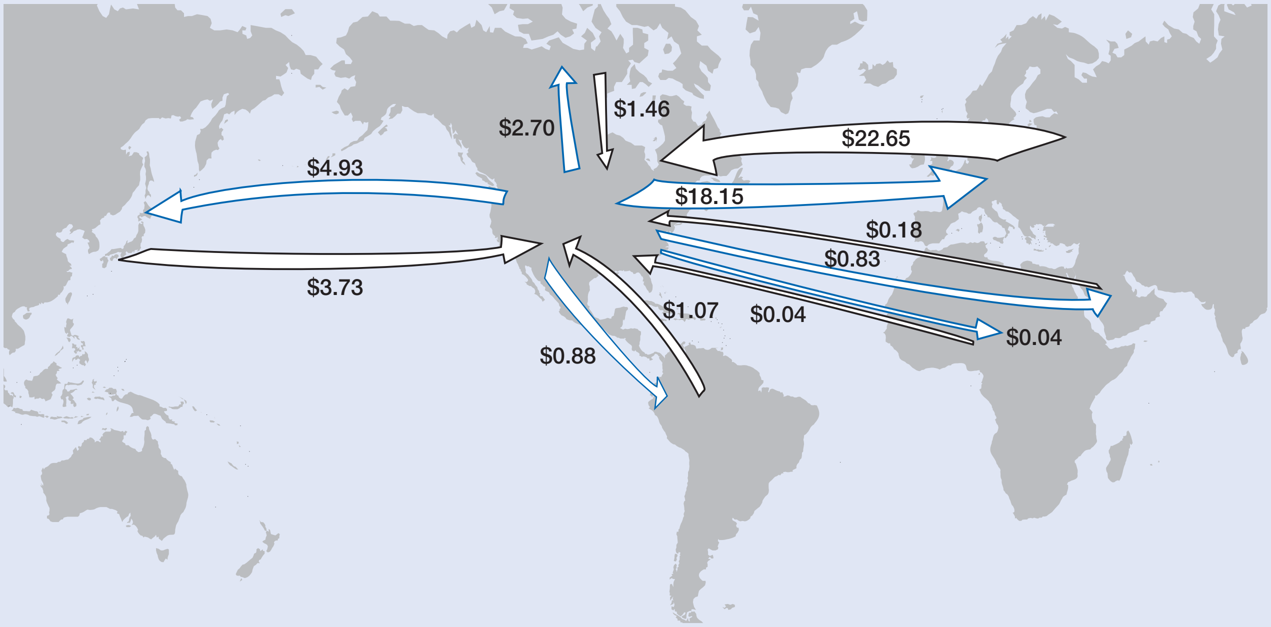
Four manufacturing and two services industries account for more than three-fourths of all industrial R&D: computer and electronics products, chemicals, aerospace and defense manufacturing, automotive manufacturing, computer-related services, and R&D services. Their aggregate R&D intensity (R&D/net sales) was 7.7% in 2005; the comparable figure for all other industries was 1.3% (table O-7). In the manufacturing segment, nine automotive companies reported R&D expenditures of more than $100 million in 2004, representing more than 80% of this industry's R&D.

The federal government had for nearly three decades supplied half or more of the nation's total R&D funds, but in 1979 its share fell below 50%. It continued to drop to a low of 25% in 2000 but is projected to reach 28% in 2006 (figure O-31). This recent recovery mainly reflects increased health-related research spending and, more recently, rising development spending related to defense and counterterrorism. The federal government's performance share, about 20% of U.S. R&D in the early 1970s, has been declining and was 11% in 2006.

Defense-related R&D has accounted for at least half of the federal R&D funding portfolio for the past three decades. It increased from 50% of the federal R&D budget in 1980 to almost 70% in the mid 1980s, declined to 53% in 2001, and

Figure O-28
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 most recent 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 O-5
R&D expenditures by majority-owned affiliates in United States and R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies: Selected years, 1990–2004
(Millions of dollars)

Year	U.S. affiliates of foreign MNCs	Foreign affiliates of U.S. MNCs	Balance
1990...........	8,511	10,187	-1,676
1992...........	10,745	11,084	-339
1994...........	12,671	11,877	794
1996...........	15,641	14,039	1,602
1998...........	22,375	14,664	7,711
2000...........	26,180	20,547	5,633
2002...........	27,507	22,793	4,714
2004...........	29,900	27,529	2,371

MNCs = multinational corporations

SOURCES: U.S. affiliates of foreign MNCs data from appendix table 4-43; foreign affiliates of U.S. MNCs data for 2002 and 2004 from appendix table 4-45; for 1994 to 2000 from National Science Board, *Science and Engineering Indicators 2006*, appendix table 4-51; and for 1990 and 1992 from *Science and Engineering Indicators 1998*, appendix table 4-51.

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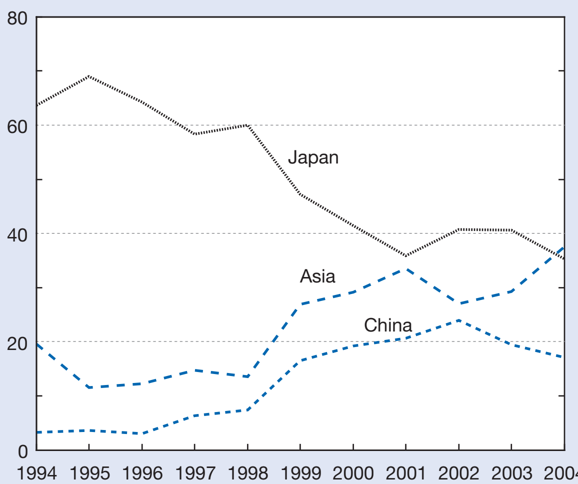
Figure O-29
R&D performed in Asia by majority-owned affiliates of U.S. parent companies, by region and selected country: 1994–2004

Percent



NOTES: Preliminary estimates for 2004. Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. Data for some intervening years are extrapolated.

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

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Table O-6
R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies and foreign companies in United States, by selected NAICS industry of affiliate: 2004
(Millions of current U.S. dollars)

Industry/sector	Foreign affiliates	U.S. affiliates
All industries	29,900	27,529
Manufacturing	20,891	23,288
Chemicals	10,045	6,254
Machinery	1,547	791
Computer and electronic products	3,279	5,283
Electrical equipment	238	551
Transportation equipment	3,728	7,741
Nonmanufacturing	9,009	4,241
Information	898	843
Professional, technical, scientific services	1,442	2,120

NAICS = North American Industrial Classification System

SOURCE: 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 4-44 and 4-46.

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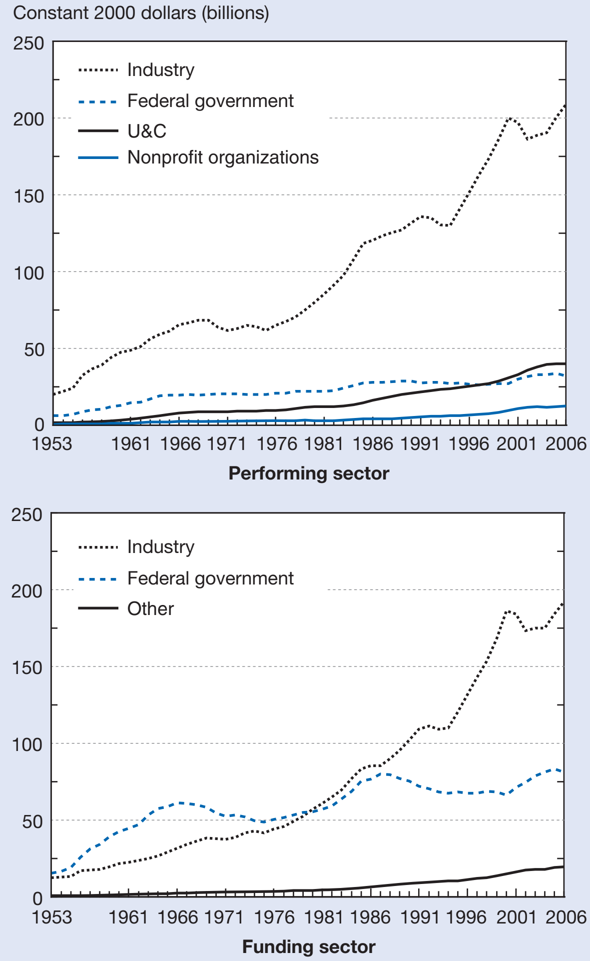
Figure O-30
National R&D, by performing and funding sectors, 1953–2006



U&C = universities and colleges; Other = U&C, nonprofit, and state and local government

NOTE: Federal performers of R&D includes federal agencies and federally funded research and development centers.

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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increased steadily to a projected 60% in 2008. Nondefense R&D is dominated by health support (52% of the proposed FY 2008 nondefense R&D budget) (figure O-32). Health R&D has accounted for the single largest share of federal nondefense R&D since at least 1980, when its share was 25%.

U.S. R&D performance is dominated by the development function (figure O-33), which has fluctuated between 58% and 65% since 1970. Development of new and improved goods, services, and processes is dominated by industry, 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 in defense-related activities.

Basic research provides the essential underpinning for a vibrant and flexible S&T system. In the United States, well over half (58%) of all basic research is conducted at universities and colleges. Two-thirds of the funding is supplied by the federal government, but the academic institutions themselves provided 17% in 2007, the second-largest share. An additional 5% to 6% each is provided by industry and state and local governments. A key product of academic basic research, in addition to new knowledge, is the production of young researchers through the strong ties of graduate training and research.

Table O-7
R&D and domestic net sales, by selected business sector: 2004 and 2005
(Millions of current dollars)

Sector	All R&D		Federal R&D		Company R&D		Domestic net sales		All R&D/sales ratio (%)	
	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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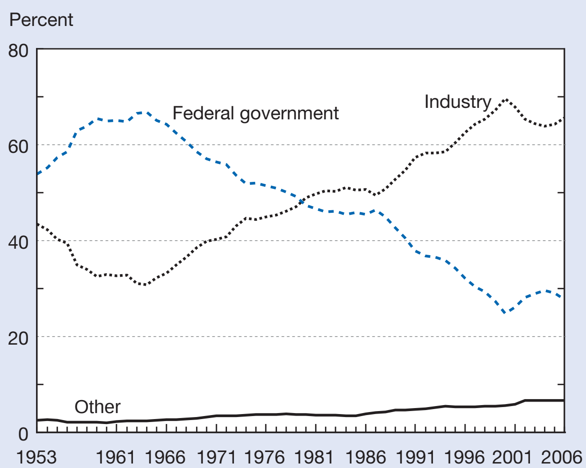
Figure O-31
National R&D expenditures, by funding sector: 1953–2006



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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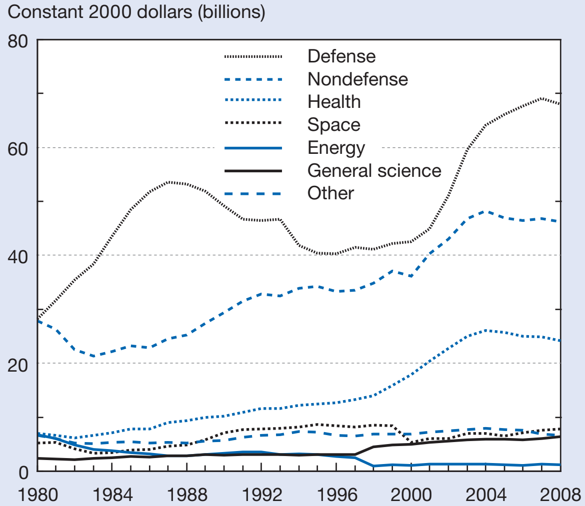
Knowledge and the S&E Workforce

The progressive shift toward more knowledge-intensive economies around the world is dependent upon the availability and continued inflow of individuals with postsecondary training to the workforce. The expansion of higher education systems in many countries that started in the 1970s and continues today has enabled this shift to occur. Such broadening of higher education availability and access in many cases entailed greater relative emphasis than in the United States on education and training in engineering, natural sciences, and mathematics.

Demographic structures, stable or shrinking populations, expanding opportunities in other fields, and declining interest in mathematics and science among the young are viewed by governments of many mature industrial countries as a potential threat to the sustained competitiveness of their economies. The topic has assumed increasing urgency in meetings of ministers of OECD member countries.

Figure O-32
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 were 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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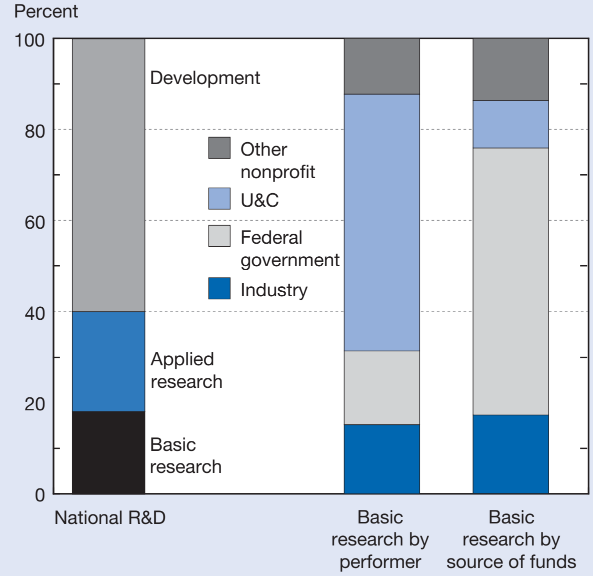
Figure O-33
National R&D expenditures, by character of work, and basic research, by performer and source of funds: 2006



U&C = universities and colleges

NOTES: Figures rounded to nearest whole number. National R&D expenditures projected at $347 billion in 2006. Federal performers include federal agencies and federally funded research and development centers.

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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Growing educational and technical sophistication mark international workforces and reduce traditional U.S. advantage.

Reliable, internationally comparable data on S&E labor force growth are unavailable. However, the number of individuals 15 years and older with a tertiary education, broadly comparable to at least a U.S. technical school or associate's degree, can serve as a proxy measure for the expansion of highly educated populations. A two-decade snapshot shows very rapid growth in overall numbers and considerable shifts in the geographical location of these individuals (figure O-34).

From 1980 to 2000 (the latest available estimate), the number of individuals with a tertiary education rose from 73 million to 194 million, a 165% increase. The U.S. share of these degree holders declined from 31% to 27%.

Japan's shrinking share of the tertiary educated (from 10% to just above 6%) notwithstanding, the combined total of five other Asian nations, China, India, South Korea, the Philippines, and Thailand, rose from 14% in 1980 to 34% in 2000, an increase from 10 million to 66 million. The 56 million people added by these countries alone broadly match the entire 2000 U.S. total.

Worldwide, researcher numbers are rising robustly.

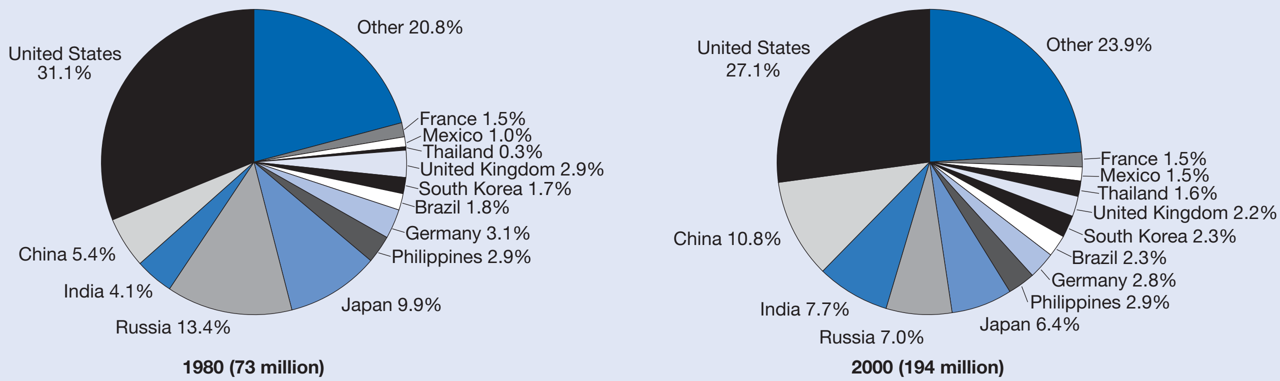
The size of the research workforce is another indicator of the economic importance of efforts to develop new knowledge and innovative products and processes. As is the case with S&E workforce numbers, reliable, internationally comparable data about individuals actively engaged in R&D are unavailable for much of the world. However, OECD captures such figures for its member countries and selected other economies. For all these combined, the data show robust 50% growth from 1995 to 2005 (figure O-35).

This overall growth was uneven, with the number of researchers doubling in selected non-OECD economies including China,[7] slower growth in the United States (35%) and the EU (29%), stagnation in Japan (5%), and faster-than-average growth in the other OECD member countries (60%). The overall trend is toward an increase in personnel dedicated to R&D functions in the world's economies. According to OECD, a strong countervailing trend persists in the Russian Federation, where the number of researchers dropped from 610,000 in 1995 to 465,000 in 2005.

In the United States, S&E occupations have long grown faster than others.

Long-term data on the U.S. workforce show a trend toward increasing numbers of workers in S&T-related occupations (figure O-36). Although different data sources yield somewhat different estimates of the size of the S&E labor force, there is no doubt that overall growth has been large

Figure O-34
Population 15 years old or older with tertiary education, by country/region: 1980 and 2000



SOURCE: Adapted from Barro RJ and Lee J-W, Center for International Development, International Data on Educational Attainment (2000).

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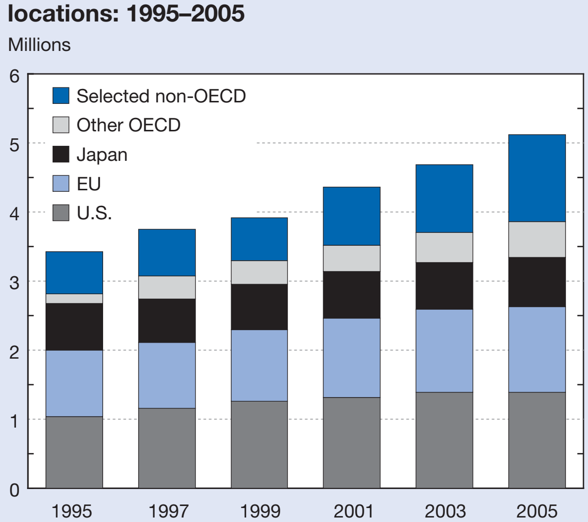
Figure O-35
Researchers in OECD and selected non-OECD locations: 1995–2005



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

NOTES: Selected non-OECD includes China, Romania, Singapore, Slovenia, and Taiwan. 1996 data for Taiwan substituted for 1995. EU data for 1999 and beyond reflect enlarged EU-25 membership.

SOURCE: OECD, Main Science and Technology Indicators (2007) and various earlier volumes.

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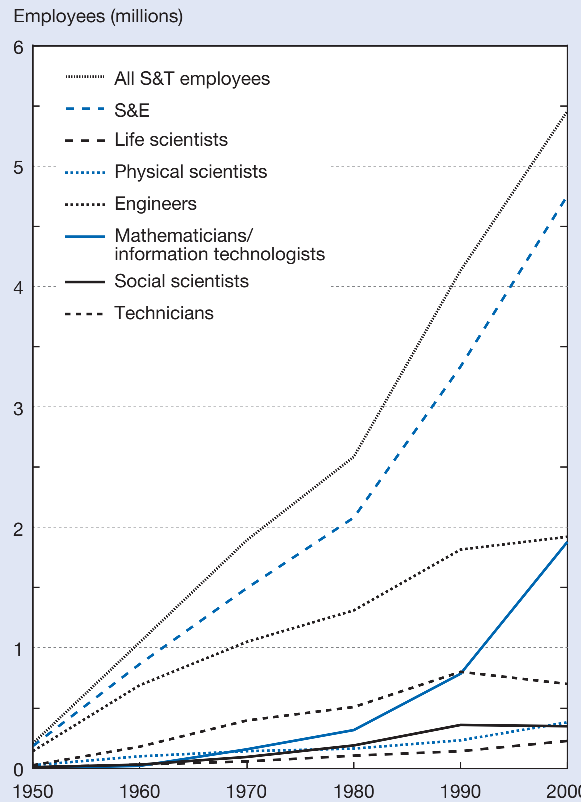
Figure O-36
Science and technology employment: 1950–2000



S&T = science and technology

NOTE: Data include bachelor's degrees or higher in science occupations, some college and above in engineering occupations, and any education level for technicians and computer programmers.

SOURCE: Adapted from Lowell BL, Regets MC, A Half-Century Snapshot of the STEM Workforce, 1950 to 2000, Commission on Professionals in Science and Technology (2006).

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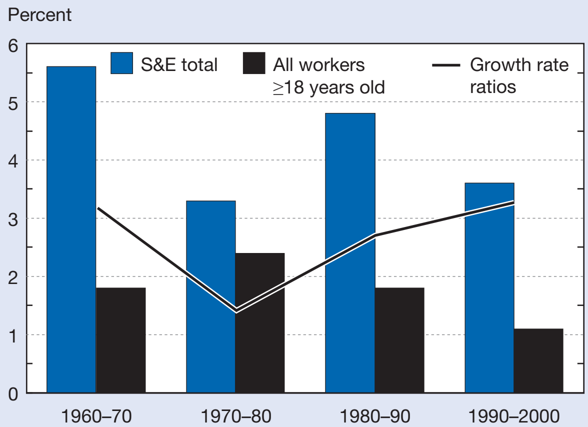
and steady for more than a half century. During this period, growth patterns within individual occupations have varied. In the 1990s, for example, widespread computerization was accompanied by a sharp rise in the numbers of people working as mathematicians and information technologists, while the number of workers classified as engineers or technicians changed relatively little.

For decades, the workforce growth rates in S&E occupations have exceeded those in the general labor force (figure

O-37); consequently, the proportion of the workforce in S&E occupations has risen by 60% since the early 1980s. Nonetheless, S&E employees still represent a small fraction of the total U.S. workforce: the Census Bureau's Current Population Survey estimates that jobs in S&E occupations increased from 2.6% in 1983 to 4.2% in 2006 (figure O-38).

Individuals in S&E occupations are distributed throughout the economy (figure O-39). Economic sectors with large proportions of workers in S&E occupations tend to have higher average salaries for both S&E workers and those in other occupations (table O-8). The association between sectors with relatively large amounts of S&T-related work and sectors that enable many workers to enjoy middle-class incomes has fueled government efforts to encourage development of industries in which S&E work is important.

Figure O-37
Average annual growth rates of S&E occupations versus all workers: 1960–2000



SOURCE: National Science Foundation, Division of Science of Science Resources Statistics, Decennial Census data, special tabulations.

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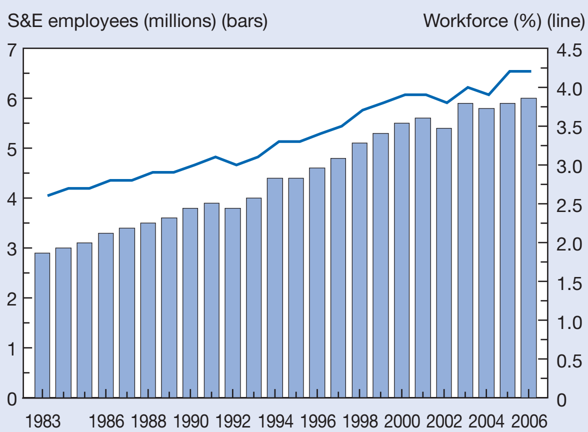
Successive cohorts entering the U.S. workforce have higher proportions in S&E occupations.

As productive uses of knowledge become more central to economic activity, larger percentages of young workers find jobs in S&E occupations. Census data show how this movement toward a more knowledge-intensive economy is reflected in the changing profile of the workforce (Figure O-40). Since 1950, workers in S&E occupations have been found disproportionately in the younger cohorts of the prime working-age population (ages 25–64). Among workers 25–34 years old, the proportion of S&E workers increased from 1.7% in 1950 to 5.2% in 2000. Similar increases occurred in the other prime working-age groups, with the proportion of workers in S&E occupations approximately tripling in each group between 1950 and 2000 (figure O-40).

Over a lifetime, workers move both into and out of S&E jobs. Those moving into S&E jobs may have acquired the necessary skills through workforce experience or adult education to respond to the growing demand for S&E workers; those moving out of these jobs may acquire managerial roles, change occupations, or fail to maintain or acquire S&E-related skills that are in demand. For each generation of workers, the numbers in S&E occupations increase until some time in midlife and then decrease as workers near or reach retirement. In the generations born before or during World War II, the proportion of workers who were in S&E occupations at different ages did not follow a consistent pattern. For example, for those born between 1936 and 1945,

Figure O-38
U.S. workforce in S&E occupations: 1983–2006



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations from Bureau of Labor Statistics, Current Population Survey Monthly Outgoing Rotation files (1983–2006).

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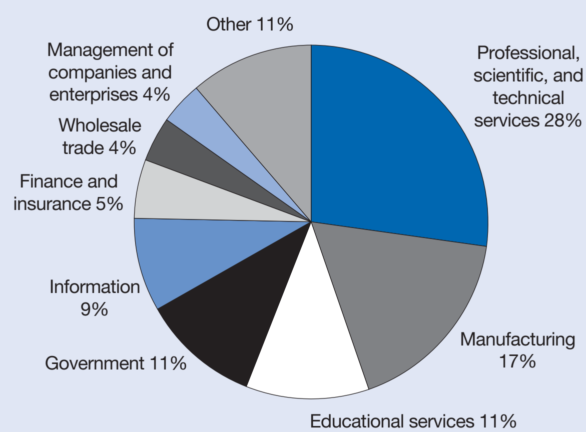
Figure O-39
Largest sectors of employment for individuals in S&E occupations, by NAICS sector: May 2005



NAICS = North American Industry Classification System

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (2005).

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Table O-8
Employment distribution and average earnings of 4-digit NAICS industry classifications, by proportion of employment in S&E occupations: 2005

			Average worker salary ($)	
Workers in S&E occupations (%)	All occupations	All S&E occupations	Non-S&E occupations	S&E occupations
>40	1,987,910	918,400	66,980	74,335
20–40	3,384,810	952,320	51,350	75,195
10–20	9,951,540	1,444,490	51,588	69,819
4–10	13,728,020	880,540	44,260	64,578
<4	99,480,140	988,950	33,489	59,713

NAICS = North American Industry Classification System

NOTE: NAICS is a hierarchical structure that uses 2–4 digits; 4-digit NAICS industries are subsets of 3-digit industries, which are subsets of 2-digit sectors.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (May 2004 and May 2005).

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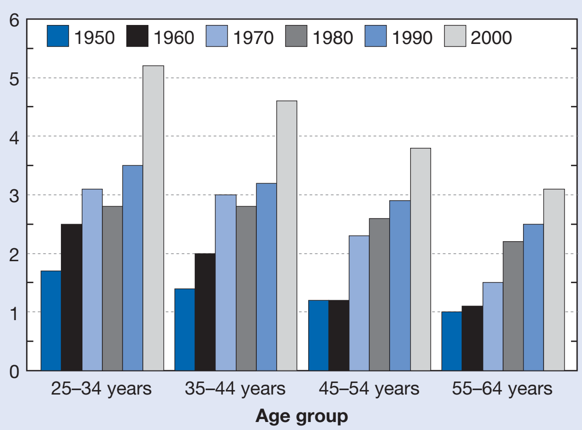
Figure O-40
Workers in S&E occupations, by age group: 1950–2000



SOURCE: Census Bureau, decennial census, various years.

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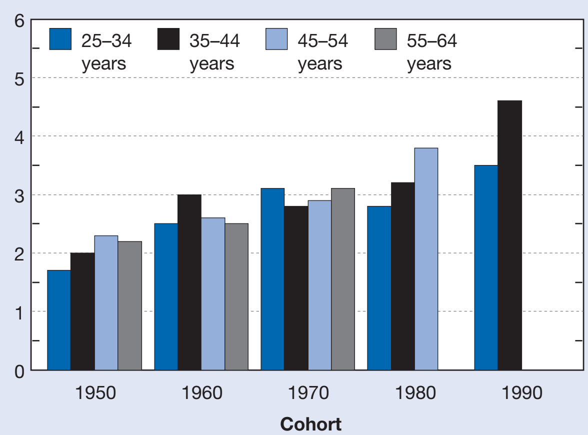
Figure O-41
S&E workers by cohort and age group



NOTES: Cohort is group of workers who were 25–34 years old in same decennial census year. 1950 cohort, for example, was 25–34 years old at 1950 census. Each group of bars presents data for a different cohort, using data from successive decennial censuses to show proportion of cohort in S&E workforce at different ages.

SOURCE: Census Bureau, decennial census, various years.

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the proportion was almost constant for four decades, a pattern shown by no other generation.

With accelerating movement toward a knowledge-intensive economy, however, younger generations appear to experience a net movement into S&E occupations over the course of their working lives. Beginning with the “baby boom” generation of workers born after World War II (1946–55), the proportion in S&E occupations increased substantially with time. Thus, 2.8% of baby boomers were in S&E occupations in 1980, rising to 3.8% in 2000; for workers born in the next decade, the proportion increased from 3.5% in 1990 to 4.6% in 2000 (figure O-41). Immigrant S&E workers partly account for the increasing proportion of S&E workers over time in this cohort, but the number increases among the native-born as well.

A knowledge-intensive economy requires skills of S&E-trained persons in a wide range of sectors and positions.

The relevance of S&E knowledge goes beyond narrowly defined S&E occupations. Although most people with S&E degrees do not work in S&E occupations, a large majority of degree holders say that they need at least a bachelor’s degree-level knowledge of S&E in their jobs (figure O-42).

Most S&E degree holders work in for-profit companies. In 2003, about three of five individuals whose highest degree was in S&E worked in this sector. Education (16%) and government (13%) were the next largest employers of workers with S&E degrees. Among those with S&E doctoral degrees, the higher education sector is the largest employer (44%), but the for-profit sector share is also large (33%) (figure O-43). These data suggest that many for-profit companies find S&T-related skills, including the advanced skills associated with doctoral education, useful for competing in the private economy.

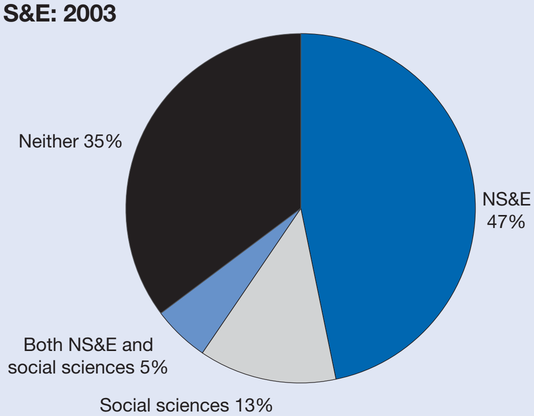
Almost 40% of R&D workers are found in non-S&E occupations.

Workers with S&E degrees for whom R&D is a significant work activity have backgrounds in a variety of S&E fields, suggesting that R&D skills relevant to a knowledge-intensive economy can develop through multiple paths. Substantially more of these R&D workers are trained in engineering than in any other field. A sizeable proportion of S&E-trained workers for whom R&D is a major work activity are not in S&E occupations (39%), and many of them (26%) are not in S&E-related occupations. For workers who devote at least 10% of their work time to R&D, the comparable proportions (55% and 40%) are even higher (figure O-44).

Higher Education

As knowledge becomes more central to economic activity in both developed and developing economies, large segments of the population complete some form of higher education. Government programs designed to advance the development of a knowledge-intensive economy bolster private incentives to obtain knowledge and skills that may lead to better, higher-paying jobs. Lifelong learning, including acquisition of additional formal education, becomes both more possible and more necessary even for people with significant workforce experience.

Figure O-42
Bachelor's degree-level S&E knowledge needed by individuals in workforce with highest degree in S&E: 2003



NS&E = natural sciences and engineering

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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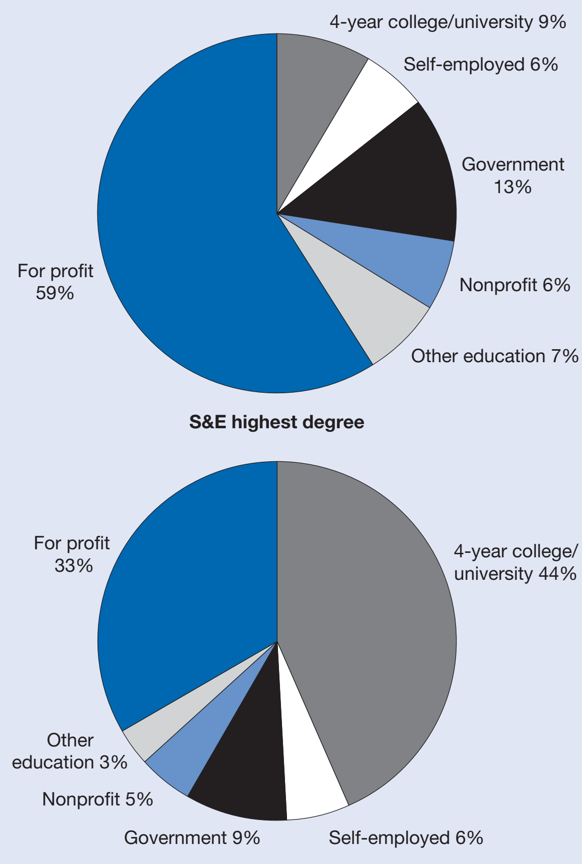
Educational credentials are only an approximate indicator of useful labor force skills. They do not register quality differences, skills acquired through job experiences or informal learning, or skills decay brought on by the progress of knowledge and economic change. In addition, workers may take advantage of publicly supported educational opportunities to gain labor market advantages, but may not use the additional skills at work, while employers may hire readily available workers without using their most advanced skills.

Human capital development responds to incentives of the knowledge-intensive economy.

In international comparison, the United States has a larger proportion of the working-age population with a higher education degree (39%) than most other countries (figure O-45). Only the Russian Federation (55%), Israel (45%), and Canada (45%) have higher percentages for this indicator.

Figure O-43
Employment sector for individuals with highest degree in S&E and S&E doctorate holders: 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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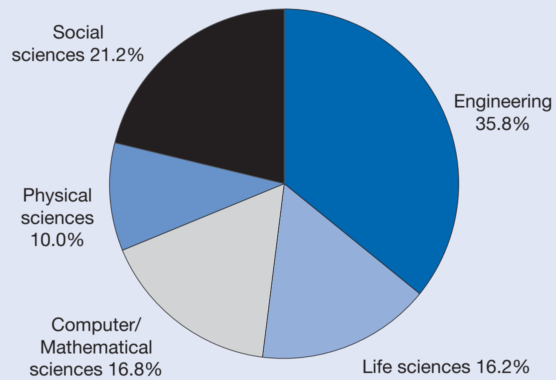
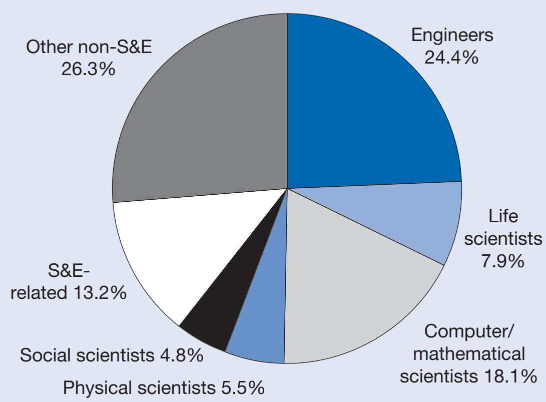
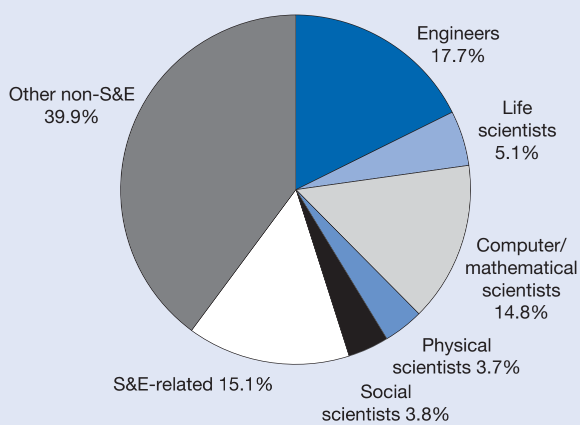
Figure O-44
Distribution of S&E degree holders with R&D as major or significant work activity, by field of highest degree and occupation: 2003



R&D as major work activity, by field of highest degree



R&D as major work activity, by occupation



Workers spending at least 10% of work time on R&D, by occupation

SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2003, http://sestat.nsf.gov.

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Figure O-45
Total tertiary degree attainment by 25–64-year-olds, by country: 2004

OECD = Organisation for Economic Co-operation and Development

NOTES: Tertiary education includes International Standard Classification of Education (ISCED) levels 5A, 5B, and 6 programs. ISCED 5A programs largely theory-based and designed to provide sufficient qualifications for entry into advanced research programs and professions with high skill requirements. ISCED 5B programs focus on practical, technical, or occupational skills for direct entry into labor market. ISCED 6 programs devoted to advanced studies and original research leading to award of an advanced research qualification. In United States, ISCED 5B corresponds to associate's, ISCED 5A corresponds to bachelor's and master's, and ISCED 6 corresponds to doctoral degrees.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006.

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More recent age cohorts obtain higher postsecondary degree rates than earlier ones.

In almost all countries, higher education is more common in the younger cohorts entering the workforce than in older cohorts, mirroring the trend toward knowledge-intensive economies. For OECD member countries, the average difference between the youngest cohort with generally completed formal schooling and the working-age population as a whole is about 6 percentage points; in several nations the difference is more than 10 percentage points. Differences are especially large for South Korea and Japan, the two Asian OECD members, but some European countries (France, Ireland, Spain, and Belgium) also recorded substantial differences.

The United States and Germany are exceptions to the overall OECD pattern: in these two countries there is no substantial difference between the 25–34-year-olds and the working-age population as a whole. These age patterns in educational attainment suggest that, in the future, other developed countries will more closely resemble the United States in the availability of workers with postsecondary credentials (figure O-46).

Substantial advanced training prepares the U.S. workforce for high-skill work.

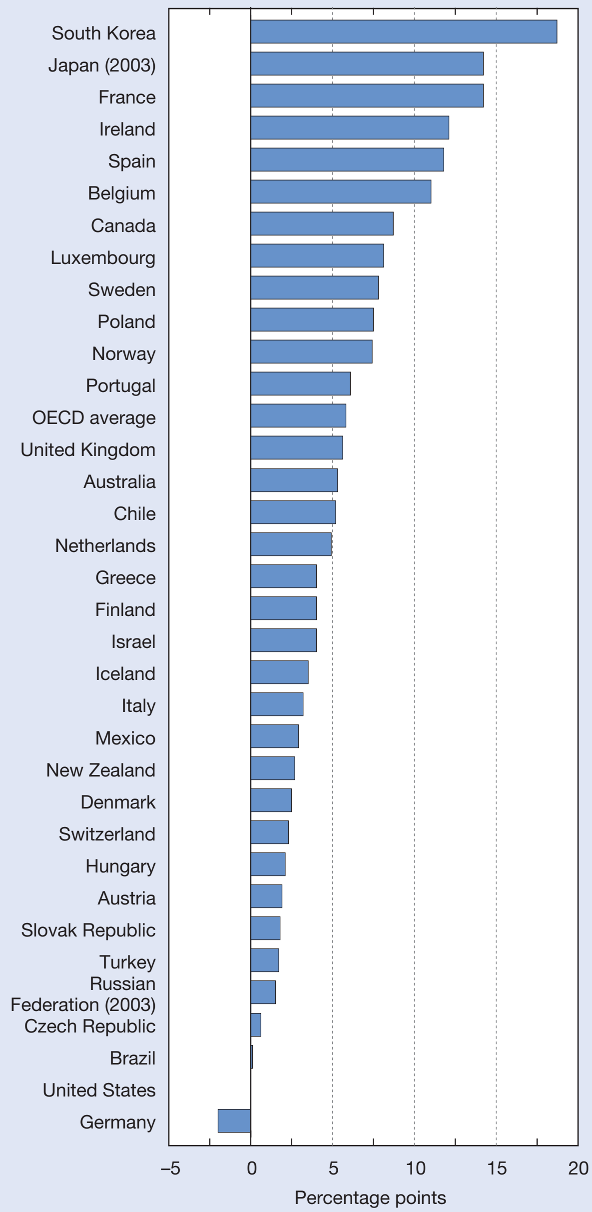
The proportion of 25–64-year-olds with advanced[8] education, as evidenced by a bachelor's degree or beyond, is an indicator of the workforce that is equipped to develop and apply knowledge in innovative ways. In the United States, a substantially higher proportion than in other large, developed economies has completed such a course of study, although a few smaller countries have proportions that match or nearly match the U.S. percentage (figure O-47). Such additional training can prepare students for high-skill work and more advanced training in research.

Throughout the developed world, the proportion of the population in the youngest working cohort with education at or beyond the bachelor's level is higher than for the working-age population as a whole. Again, however, this difference is smaller in the United States and Germany than in any of the other countries for which data are available. As younger cohorts of workers enter the labor forces in the future, the U.S. lead on this indicator can be expected to shrink. Nonetheless, the United States ranks behind only a few small countries—Norway, Israel, the Netherlands, and South Korea—in the proportion of the cohort that is entering the labor force that receives this kind of education (figure O-48).

Advanced training in natural sciences and engineering is becoming widespread, eroding the U.S. advantage.

The number of first university degrees a nation awards in natural sciences and engineering (NS&E) is a workforce indicator that is more specifically focused on a nation's capacity to innovate in S&T. Because of its population size, the United States has seen much larger numerical increases in first university NS&E degrees than other countries. China

Figure O-46
Difference in total tertiary degree attainment between 25–34-year-olds and 25–64-year-olds, by country: 2004



OECD = Organisation for Economic Co-operation and Development

NOTES: Tertiary education includes International Standard Classification of Education (ISCED) levels 5A, 5B, and 6 programs. ISCED 5A programs largely theory-based and designed to provide sufficient qualifications for entry into advanced research programs and professions with high skill requirements. ISCED 5B programs focus on practical, technical, or occupational skills for direct entry into labor market. ISCED 6 programs devoted to advanced studies and original research leading to award of an advanced research qualification. In United States, ISCED 5B corresponds to associate's, ISCED 5A corresponds to bachelor's and master's, and ISCED 6 corresponds to doctoral degrees.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006.

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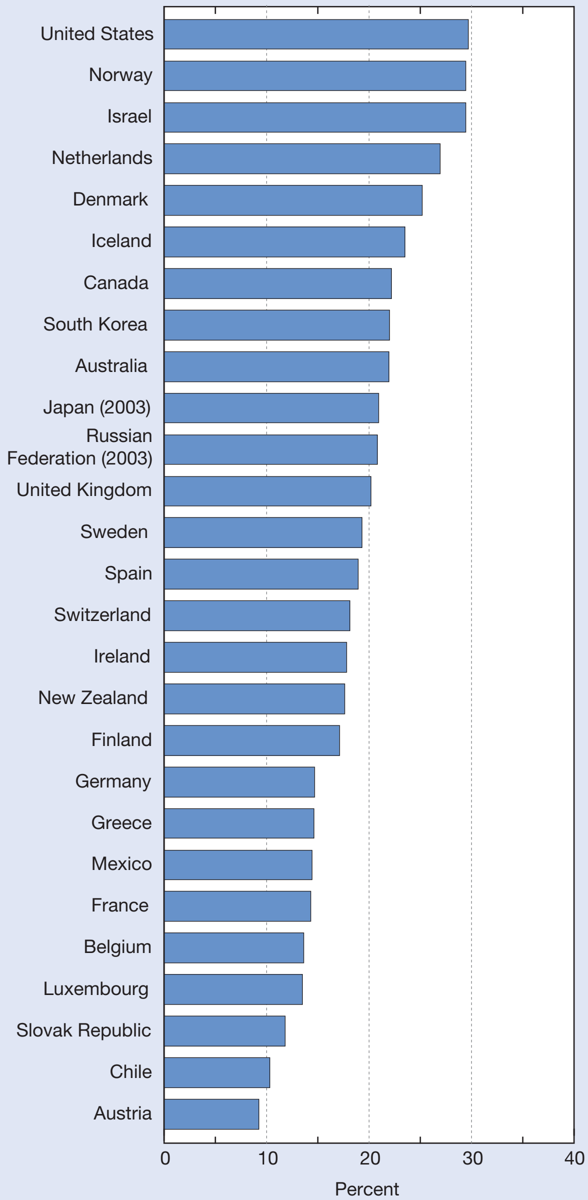
Figure O-47
Attainment of tertiary-type A and advanced research degrees by 25–64-year-olds, by country: 2004



NOTES: Tertiary-type A programs (International Standard Classification of Education [ISCED] 5A) largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although typically last 4 years. In United States, correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification, e.g., doctorate.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2006 (2006).

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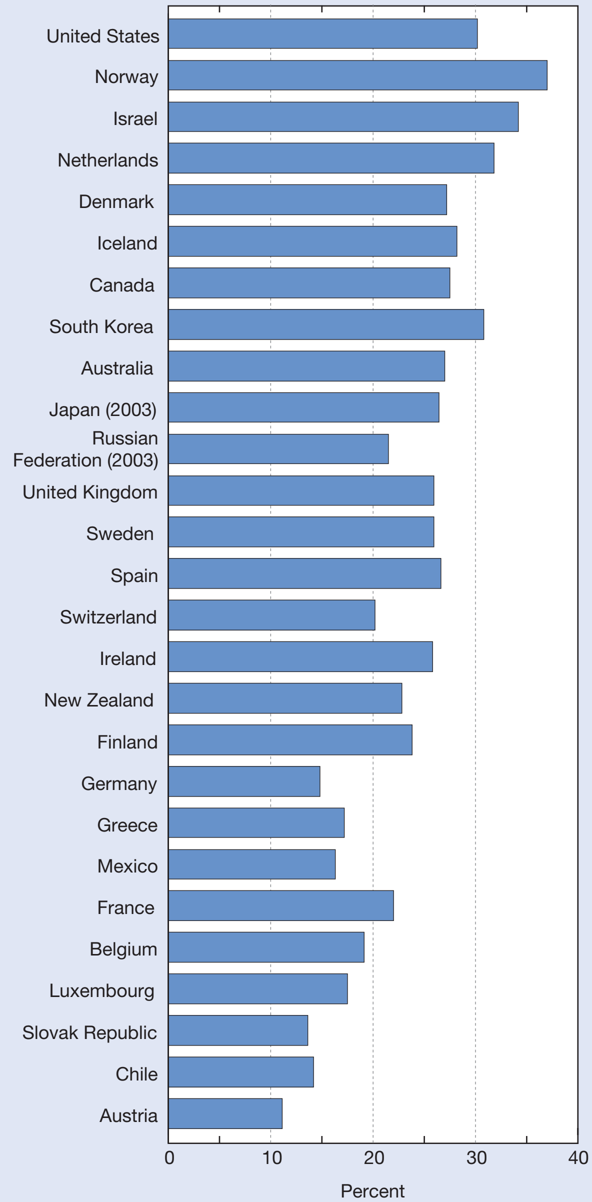
Figure O-48
Attainment of tertiary-type A and advanced research degrees by 25–34-year-olds, by country: 2004



NOTES: Tertiary-type A programs (International Standard Classification of Education [ISCED] 5A) largely theory-based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although typically last 4 years. In United States, correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification, e.g., doctorate.

SOURCE: Organisation for Economic Co-operation and Development (OECD), Education at a Glance: OECD Indicators 2006 (2006).

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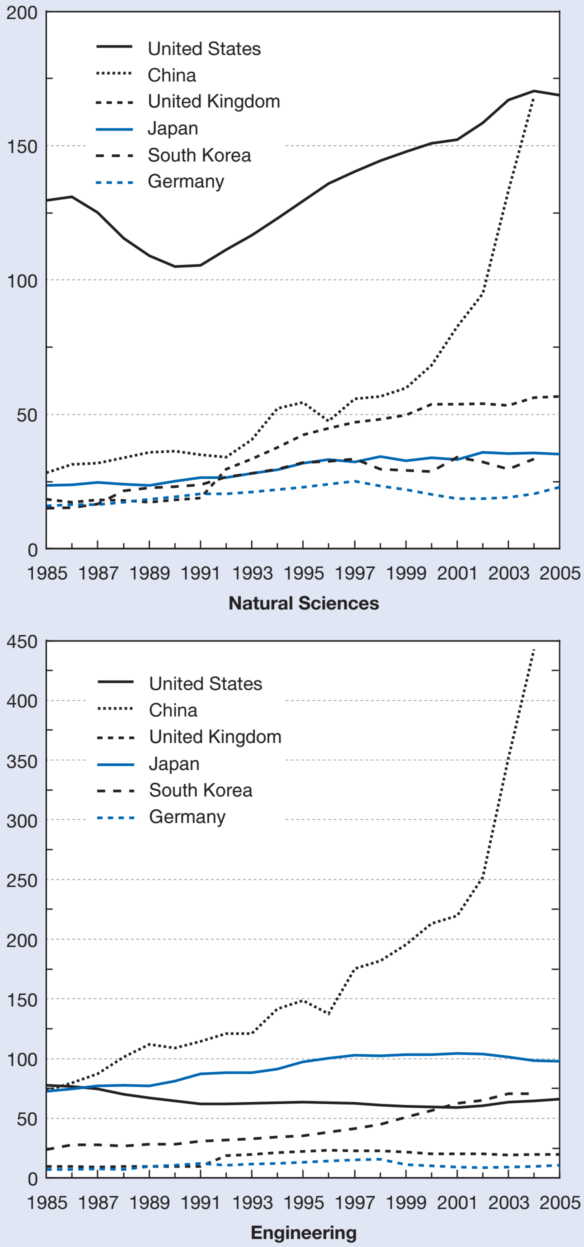
Figure O-49
First university natural sciences and engineering degrees, by selected country: 1985–2005



NOTES: Natural sciences include physical, biological, earth, atmospheric, ocean, agricultural, and computer sciences and mathematics. German degrees include only long university degrees required for further study.

SOURCES: China—National Bureau of Statistics of China, *China Statistical Yearbook*, annual series (Beijing) various years; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, Education Online Database, http://www.oecd.org/education/database; United Kingdom—Higher Education Statistics Agency; Germany—Federal Statistical Office, Prüfungen an Hochschulen; and United States—National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-38.

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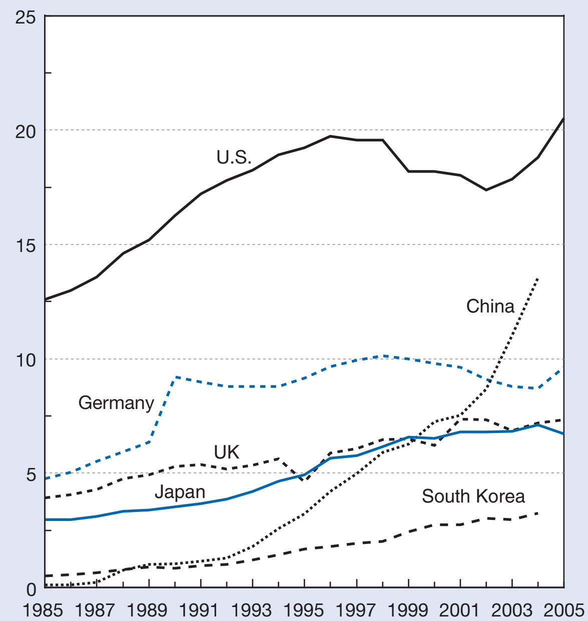
is an exception. It has experienced a huge recent increase in NS&E degree recipients, although there are questions about the quality of some of its graduates. The rising number of Chinese-trained engineers is similarly striking, especially in contrast with declining numbers of U.S. engineering graduates (Figure O-49).

Many countries have also increased the numbers of individuals they train in NS&E at the doctoral level over the past 20 years (Figure O-50). Most of the U.S. growth occurred during the first half of this period, when the number of doctorates awarded by U.S. institutions increased steadily; although the number peaked in 2005, this was the first year in which it exceeded the 1997 total. However, virtually all of the recent U.S. growth reflected rising proportions of degrees to non-U.S. citizens: more than half in engineering and computer science and nearly 45% in the physical sciences. In contrast, China's growth was most marked after 1993 and its growth rates after 2000 were especially high. Over the course of the entire period, China surpassed numerous other

Figure O-50
Natural sciences and engineering doctoral degrees, by selected country: 1985–2005



UK = United Kingdom

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

SOURCES: China—National Research Center for Science and Technology for Development; United States—National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Higher Education Bureau, Monbusho Survey of Education; South Korea—Organisation for Economic Co-operation and Development, Education Online database, http://www.oecd.org/education/database/; United Kingdom—Higher Education Statistics Agency; and Germany—Federal Statistical Office, Prüfungen an Hochschulen. See appendix tables 2-42 and 2-43.

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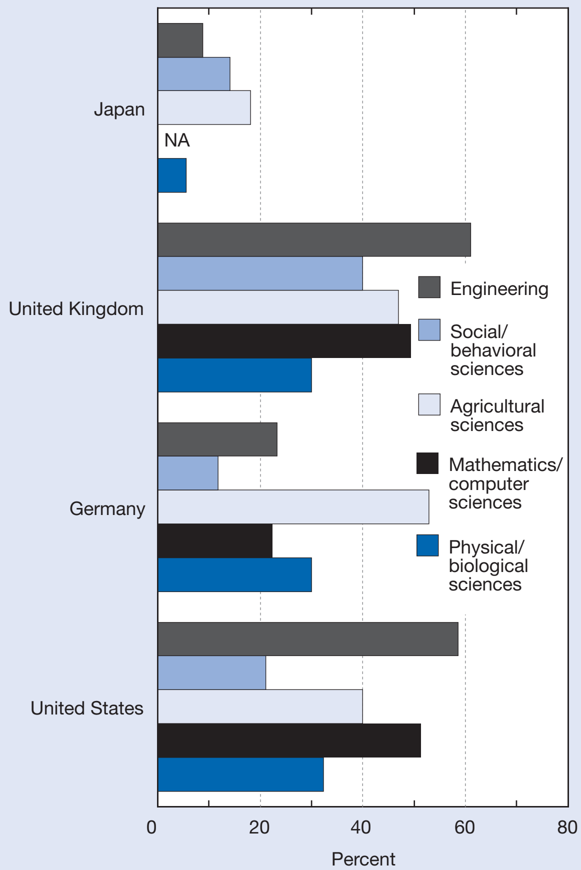
Figure O-51
S&E doctoral degrees earned by foreign students, by selected industrialized country and field: 2005 or most recent year



NA = not available

NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Japanese data for university-based doctorates only; exclude *ronbun hakase* doctorates awarded for research within industry. Japanese data include mathematics in natural sciences and computer sciences in engineering. For each country, data are for doctoral recipients with foreign citizenship, including permanent and temporary residents.

SOURCES: Germany—Federal Statistical Office, Prüfungen an Hochschulen 2005; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, special tabulations; United Kingdom—Higher Education Statistics Agency, special tabulations (2007); United States—National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-49.

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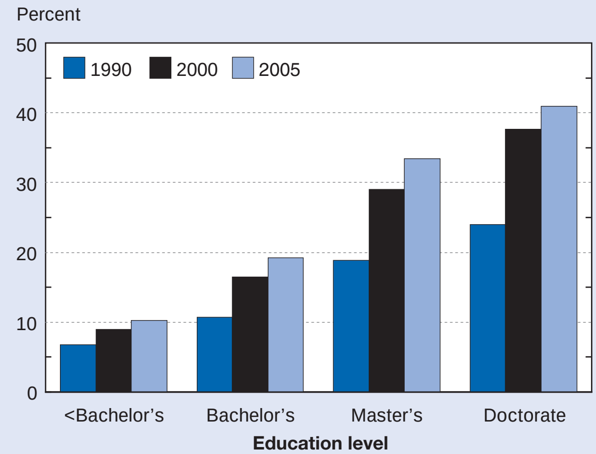
countries in doctorate production, and the U.S.-China difference is narrowing.

High-skilled knowledge workers are increasingly internationally mobile, and many come to the United States for training or work.

Knowledge workers are increasingly mobile across national boundaries, especially at the doctoral level. As is the case in the United States, in highly developed countries

Figure O-52
Foreign-born individuals in U.S. S&E workforce, by degree level: 1990, 2000, and 2005



SOURCES: Census Bureau, decennial census, various years; and American Community Survey (2005).

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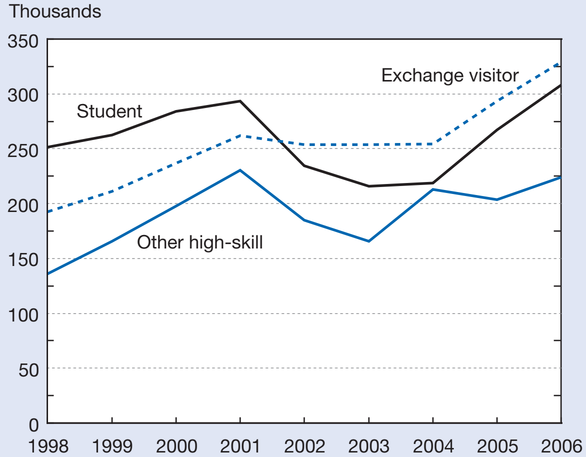
many S&E doctoral degrees are awarded to foreign students, often from the developing world (Figure O-51). Experienced in adapting to life in a different culture and equipped with flexible skills, these workers are well positioned to compete in a global market for knowledge workers.

In the United States, increasing proportions of S&E workers are foreign born and/or foreign educated, a fact that has been interpreted from a variety of perspectives. Some observers stress strengths of the U.S. economy that pull in foreign workers, including the attractiveness of living in the United States and the favorable opportunities for high incomes and career advancement in the S&E workforce. Other observers express concern about the inability of U.S. society to prepare and interest young Americans in the S&E jobs that the economy makes available (see section on U.S. K–12 education).

According to census data, the number of foreign-born workers in the U.S. S&E workforce more than quadrupled between 1980 and 2000, with most of the increase taking place in the 1990s. As a result, the percentage of foreign-born workers in the U.S. S&E workforce increased from nearly 10% in 1980 to 12% in 1990 and 18% in 2000.

Increases occurred among S&E workers at all educational levels but were especially pronounced among the more highly educated (figure O-52). Thus, the proportion of foreign-born doctorate-level workers rose from 24% in 1990 to 38% in 2000, and the corresponding figures for master's-level workers were 19% and 29%. Census data for 2005 shown in figure O-52, although not fully comparable to the earlier data, suggest that the percentage of foreign-born workers is continuing to increase. In addition, a growing proportion of S&E doctoral faculty, who are not included in the census data counts, are also foreign born. Their proportion increased from 21% in 1992 to 28% in 2003.

Figure O-53
Student, exchange, and other high-skill-related U.S. temporary visas issued: 1998–2006



NOTE: Student = F-1; exchange visitor = J-1; other high-skill-related visas = L-1, H-1B, H-3, O-1, O-2, and TN.

SOURCE: Immigrant Visa Control and Reporting Division administrative data, special tabulations.

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High-skill-related visa issuances have increased to, or beyond, their pre-9/11 record.

The 2001 terrorist attacks, subsequent government responses, and reactions abroad combined to depress previously rising visa issuances for foreign students, exchange visitors, and other high-skill-related visa categories (figure O-53). Student visas in particular dropped by 25% in the immediately succeeding years, a decline that prompted concern about the long-term impact on the United States' ability to attract the best foreign talent.

The latest data show an upswing in high-skill-related visas issued, starting in 2004 and carrying into 2006, with record numbers of temporary high-skill-related visas issued. The number of student and exchange-visitor visas issued in 2006 was higher than ever before, and the sum of the other high-skill-related visa categories was near the 2001 high, suggesting a continuing attractiveness of the United States to those with advanced education.

U.S. K–12 Education

Concern about the relationship of science and mathematics achievement to American global competitiveness, workforce preparation, and development of an educated citizenry has drawn intensive public scrutiny to the achievement levels of American students in mathematics and science in recent years.

Mathematics and science performance of U.S. students: both disappointing and encouraging.

The current performance of U.S. elementary and secondary students in mathematics and science is both disappointing and encouraging. A national study that followed the same student cohort found that students from different demographic groups entered kindergarten with varied mathematics knowledge and skills, that all groups made gains during elementary school, and that gains were uneven. Thus most mathematics achievement gaps remained or had grown by the time students reached grade 5 (table O-9 and appendix table 1-2). A second national cohort study that assessed mathematics knowledge in both grades 10 and 12 mirrored the findings of the previous study.

Repeated cross-sectional studies of mathematics and science performance provide information about trends in the performance of different student cohorts. In 2005, students

Table O-9
Average mathematics scores of students from beginning kindergarten to grade 5, by race/ethnicity: 1998, 2000, 2002, and 2004

Race/ethnicity	Fall 1998 kindergarten	Spring 2000 grade 1	Spring 2002 grade 3	Spring 2004 grade 5	Gain from kindergarten to grade 5
All students	22	39	91	112	89
White, non-Hispanic	25	43	97	118	93
Black, non-Hispanic	19	33	79	99	80
Hispanic	19	36	85	108	89
Asian	25	39	94	118	93
Other[a]	20	38	86	107	86

[a]Includes non-Hispanic Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and children of more than one race.

NOTES: Early Childhood Longitudinal Survey (ECLS) mathematics scale ranged from 0 to 153. In 2004 followup for ECLS kindergarten class of fall 1998, 86% of cohort was in grade 5, 14% was in a lower grade, and <1% was in a higher grade. For simplicity, students in ECLS followups referred to by modal and expected grade, i.e., first graders in spring 2000 assessment, third graders in spring 2002 assessment, and fifth graders in spring 2004 assessment.

SOURCES: National Center for Education Statistics, ECLS, fall 1998 and spring 2000, 2002, and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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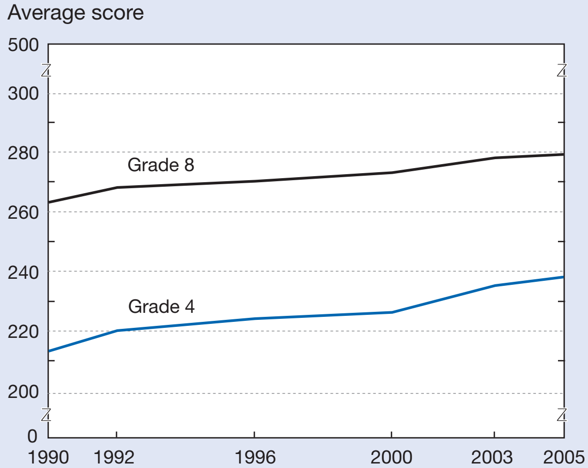
Figure O-54
Average mathematics score of students in grades 4 and 8: Selected years, 1990–2005



NOTE: Scores on 0–500 scale across grades 4 and 8. 2005 grade 12 mathematics assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); and National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments. See appendix table 1-5.

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in grades 4 and 8 posted higher mathematics scores than students in those same grades in 1990 (figure O-54). This trend was evident for both males and females, across racial/ethnic and income groups, and for students in different performance ranges (table O-10). In science, average scores increased for fourth grade students, largely reflecting improvements among lower- and middle-performing students; held steady for eighth graders; but declined for 12th graders between 1996 (the first year the assessments were given) and 2005 (table O-11). The latest (2007) assessment results for mathematics and science show continuing improvement for students in grades 4 and 8.

International assessments offer a mixed picture.

In the 2003 Trends in International Math and Science Study (TIMSS), which sought to measure mastery of curriculum-based knowledge and skills, U.S. students in the lower and middle grades performed above the international average of the mixture of developed and developing countries in which the test was administered (figure O-55). Performance scores for U.S. eighth graders in mathematics and science were improved over those in the 1995 TIMSS, but scores for fourth graders showed no change.

However, U.S. 15-year-olds scored below the international average in both mathematics and science on the 2003 Programme for International Student Assessment (PISA) tests, which were intended to measure students' ability to apply

Table O-10
Changes in mathematics performance of students in grades 4 and 8, by student characteristics and other factors: 1990–2005 and 2003–05

Student characteristic	Grade 4 1990–2005	Grade 4 2003–05	Grade 8 1990–2005	Grade 8 2003–05
Average score				
Total	▲	▲	▲	▲
Sex				
Male	▲	▲	▲	▲
Female	▲	▲	▲	▲
Race/ethnicity				
White, non-Hispanic	▲	▲	▲	▲
Black, non-Hispanic	▲	▲	▲	▲
Hispanic	▲	▲	▲	▲
Asian/Pacific Islander[a]	NA	▲	NA	▲
American Indian/Alaska Native[b]	NA	▲	NA	•
Percentile scores[c]				
10th	▲	▲	▲	▲
25th	▲	▲	▲	▲
50th	▲	▲	▲	▲
75th	▲	▲	▲	▲
90th	▲	▲	▲	▲

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a]Insufficient sample size in 1990 for Asian/Pacific Islanders precluded calculation of reliable estimates.
[b]Insufficient sample size in 1990 for American Indians/Alaska Natives precluded calculation of reliable estimates.
[c]Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-5.

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Table O-11
Changes in science performance of students in grades 4, 8, and 12, by student characteristics and other factors: 1996–2005 and 2000–05

Student characteristic	Grade 4		Grade 8		Grade 12	
	1996–2005	2000–05	1996–2005	2000–05	1996–2005	2000–05
Average score						
Total	▲	▲	•	•	▼	•
Sex						
Male	▲	▲	•	•	▼	•
Female	•	▲	•	•	▼	•
Race/ethnicity						
White, non-Hispanic	▲	▲	•	•	•	•
Black, non-Hispanic	▲	▲	▲	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	NA	•	•	•	•
American Indian/Alaska Native	•	•	▼	▼	•	•
Percentile scores[b]						
10th	▲	▲	•	•	▼	•
25th	▲	▲	•	•	▼	•
50th	▲	▲	•	•	•	•
75th	•	•	•	•	▼	•
90th	•	•	•	•	▼	•

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a]National Center for Education Statistics (NCES) did not publish 2000 science scores for grade 4 Asians/Pacific Islanders because of accuracy and precision concerns.
[b]Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

SOURCES: NCES, The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress,1996, 2000, and 2005 science assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-7.

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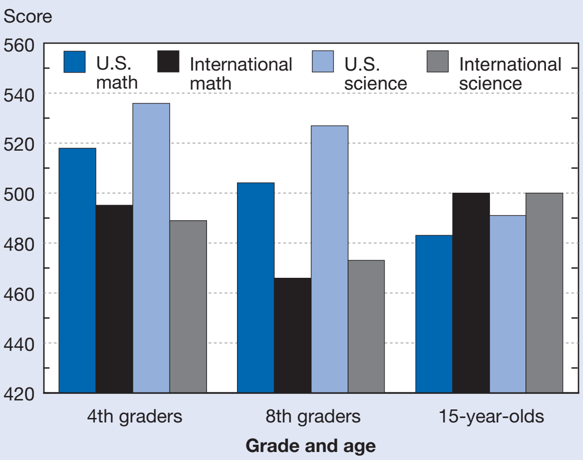
Figure O-55
U.S. and international math and science scores for grades 4 and 8 and 15-year-old students: 2003



NOTES: For 15-year-old students, international average from Organisation for Economic Co-operaton and Development average. For fourth and eighth graders, results from Trends in International Mathematics and Science Study. For 15-year-olds, results from Programme for International Student Assessment.

SOURCE: National Science Board, *Science and Engineering Indicators 2006*, appendix tables 1-9 through 1-14.

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scientific and mathematical concepts and skills to problems they might encounter outside the classroom (figure O-55). The PISA averages are based on scores from 30 industrialized OECD member countries.

Conclusion

The world of S&T is undergoing rapid changes along trends that emerged in the late 1990s. Increased government recognition of the importance of knowledge-intensive segments of their economies often led to the implementation of strategic policies to promote their development, and the expansion of education and advanced training in support of this goal. MNCs, seeking new markets and a broad range of operating efficiencies and responding to opportunities abroad, increasingly took advantage of and drove these developments, resulting in a shift in the epicenter of world S&T activities, led by China's emergence, toward several rapidly growing Asian economies.

These pronounced shifts have occurred over a relatively short time and have had a differential impact on mature, developed countries. In Asia, China's rapid rise economically and across the S&T spectrum has made it the world's second-largest economy, and certain other smaller Asian economies are increasingly prominent on the world stage.

By comparison Japan appears stagnant and, in fact, has lost world market share in a number of S&T areas. The EU's world position has also degraded, including in areas linked to high-technology trade. The United States is broadly holding its own, thanks, in part, to its large, mature, and diversified S&T system. But it, too, faces robust challenges affecting its education, workforce, R&D, and S&T systems that arise from the far-reaching and rapid worldwide changes.

Afterword: Data Gaps and Needs

Science and Engineering Indicators leaves many questions about the state of the S&E enterprise unanswered. Nationally representative or internationally comparable information is lacking about significant factual aspects of the S&T community in the United States and abroad. Following are some examples.

Chapter 1. Elementary and Secondary Education

- Informal learning experiences in K–12 education, including advanced courses taken in local colleges or via distance learning; participation in research, science or technology competitions, or internships; advanced coursetaking in engineering; and involvement in informal S&E learning through museums, science centers, zoos, planetariums, aquariums, and similar community-based institutions
- Teacher preparation and quality, including elementary teacher qualifications in science, technology, engineering, and mathematics (STEM) disciplines and STEM teacher test scores on subject matter knowledge
- STEM teacher career paths, including better data on teacher mobility across different kinds of schools and districts, reentry into teaching, and teachers on temporary visas or other noncitizen teachers
- Teacher involvement in informal learning

Chapter 2. Higher Education in Science and Engineering

- Emergence of multidisciplinary degree programs, new fields, and new institutional forms
- Student involvement in research experiences or in cooperative learning programs
- Undergraduate involvement in R&D work
- Quality indicators for postsecondary STEM teaching

Chapters 1 and 2

- Internationally comparable indicators of curriculum content or rigor
- Indicators of achievement or interest in STEM for gifted students at all education levels

Chapter 3. Science and Engineering Labor Force

- Internationally comparable data on S&T workforce characteristics
- Worldwide data, including industry breakdowns, on international flows of workers with S&T training, in S&T-related occupations, and/or performing R&D
- S&T-related skills used in the workforce and non-S&T skills that S&E workers use in their jobs
- Data on the role of postdoctorates in the nonacademic S&E workforce
- Employer-provided training and other forms of lifelong learning for S&E workers
- S&E workforce location relative to employer location

Chapters 4. Research and Development: National Trends and International Linkages, and 6. Industry, Technology, and the Global Marketplace

- R&D by line of business (For companies with more than one line of business, current industry R&D data attribute R&D to the company as a whole and not necessarily to the part of the company for which the work is done.)
- R&D in relation to firm or line-of-business characteristics, including profitability, productivity, growth, etc.
- R&D performance data on very small companies (fewer than five employees), state and local governments, nonprofit organizations, and individuals performing R&D independent of a corporation, university, or other organization
- Non-S&E R&D outside academic institutions (Other countries collect these data and include them in their national statistics.)
- R&D in international commerce, including R&D performed in the United States that is financed from foreign sources, characteristics (e.g., basic, applied, or development work; location) of R&D expenditures by U.S. affiliates of foreign multinational corporations, characteristics of R&D expenditures by foreign affiliates of U.S. multinational corporations, and trade in knowledge-intensive service industries
- Innovation indicators, including technology licensing; numbers, characteristics, R&D activities, and other operations data for business technology alliances; and technology parks, clusters, and incubators
- Outsourcing and offshoring of S&E jobs

Chapter 5. Academic Research and Development

- R&D funded from institutional or departmental resources and not separately budgeted, including use of funds for infrastructure, equipment, student support, and other purposes, and ultimate source of institutional or departmental funds

- R&D expenditures by U.S. corporations at foreign universities and by foreign corporations at U.S. universities
- Individuals who author S&E articles (Current data attribute articles to institutions or departments and do not include information about the characteristics of individual authors [e.g., employer, employment sector, disciplinary background, national origins, collaborative patterns, career stage, main work activities])
- Indicators of multidisciplinary S&E research
- Accessibility, use, and other characteristics of large, curated academic databases

Chapters 4 and 5

- Indicators of the spread, development, and use of R&D-related cyberinfrastructure
- Worldwide centers of R&D excellence by discipline and industry

These gaps are descriptive and could be addressed with new data. However, in many cases, gaps are as much analysis gaps as they are data gaps. To understand the global flow of S&E workers, for example, will require not only better, more internationally comparable data about credentials, skills, and migration patterns, but will also require developing models and testing hypotheses based on data that already exist (Regets 2007). Similarly, understanding the determinants of technological innovation involves building theories of innovation, testing them against existing data, and identifying and collecting new data that would be necessary to elaborate and test promising theoretical models (Nelson 1993). Accordingly, as part of a recent White House Office of Science and Technology Policy initiative, the National Science Foundation (NSF) has begun a program to support fundamental research aimed at developing a Science of Science and Innovation Policy. The initial emphases of the program are on analytic tools and model building.

Many other questions relevant to science policy involve a similar interplay among theory, analysis, and data. In addition, compelling answers to the “why” and “what if” questions that policymakers often ask can remain uncertain even when data bearing on these questions are available.

The federal government and its statistical agencies continuously engage in efforts to address significant data gaps or enhance the quality of the data generated from ongoing collections. Current examples include:

- Redesign of NSF’s Survey of Industrial Research and Development to collect data on the line of business to which R&D is attributable in diversified firms, foreign R&D activities of companies that do R&D in the United States, technology licensing activities, and demographic and educational characteristics of the U.S. R&D workforce.
- A project of NSF’s Division of Science Resources Statistics (SRS) to count nonacademic postdoctorates and collect data on the work roles and demographic, career, and educational characteristics of postdoctorates.
- Collaboration between the Department of Homeland Security and SRS to examine whether immigration records can be made available for use as a basis for collecting more timely and complete data on foreign-educated scientists and engineers.
- A Department of Commerce advisory committee effort to identify “holes” in the national data collection system that limit the nation’s ability to measure innovation.

Collecting high-quality data can be exceedingly expensive, and governments cannot afford to collect all the data they could use productively. Beyond cost, however, there are numerous other persistent obstacles to remedying data gaps:

- Many concepts in the list of data gaps are difficult to measure. Informal learning experiences, teaching quality, S&E-related workplace training, multidisciplinary research, and innovation are less readily classified and quantified than many of the S&E indicators reported in this volume.
- For difficult-to-measure concepts, a succession of small-scale studies is usually necessary to refine measures and test them in a variety of situations before national or international data collection is possible. This kind of development work takes time.
- For S&T data to be meaningful, organizations and individuals must be willing and able to supply reasonably accurate information. In some cases, the burden on survey respondents of supplying such information makes it impossible to secure the necessary cooperation and collect good data.
- As S&T becomes increasingly globalized, internationally comparable data become increasingly important for mapping personnel and resource flows. Successful efforts under the auspices of the Organisation for Economic Co-operation and Development to coordinate the collection of R&D data across numerous national statistical systems indicate that coordination is feasible, but also that it is difficult and resource intensive.
- Data are most valuable when they extend back in time as well as outward across national boundaries. New data will not be able to address many questions until several data collection cycles have been completed.
- Legal and technical obstacles limit opportunities for merging data from different sources and making merged data widely available for analysis. Obstacles associated with merging datasets from different countries are especially daunting.

Notes

1. Data drawn from Conference Board and Groningen Growth and Development Centre, Total Economy Database (January 2007), http://www.ggdc.net, are measured in constant 1990 purchasing power parities (PPPs) converted into

U.S. dollars. World Bank data are based on different conversion factors but show congruent trends.

2. No internationally comparable data on in-country inequality are available.

3. The growth rate of real per capita GDP is measured in constant 1990 PPPs.

4. The estimated total is extended backwards to 1985.

5. Data in the overview are more current than those available in chapter 4.

6. Distinctions between basic and applied research often involve a greater element of subjective assessment than other R&D indicators, and about 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.

7. Time-series data are available for China, Taiwan, Singapore, Romania, and Slovenia.

8. "Advanced" degrees are defined as International Standard Classification of Education Degrees, tertiary-type A and advanced research programs only.

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.

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

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-25: Includes the EU-15 countries Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. 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.

EU-27: Bulgaria and Romania joined the EU-25 (see definition above) in January 2007, for a total of 27 EU member countries.

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: The group of seven industrialized nations: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

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.

Knowledge-intensive economies: Economies with a large number of industries that incorporate science, engineering, and technology into their products and services.

Multinational corporation (MNC): A parent company and its foreign affiliates.

R&D: According to the Organisation for Economic Co-operation and Development, 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).

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.

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

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