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Overview

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Introduction

This overview of the National Science Board's *Science and Engineering Indicators 2014* highlights some major developments in international and U.S. science and engineering (S&E).

The international component of the overview is focused primarily on relatively recent changes affecting patterns in the ways science and engineering are translated into innovations with commercial and economic value. It pays particular attention to describing how the global map of science and technology (S&T)-related economic activity in the wake of the severe economic downturn in 2008–09 is different from the patterns present in data from before the downturn.

The domestic component of the overview has a significantly different focus in two respects. First, it takes a much more long-term view than the international component, counted mostly in decades rather than in years. Second, it focuses primarily on the institutions that are or have been centrally involved in producing research outputs such as publications and patents. It summarizes continuities and changes in the kinds of people who staff those institutions, the practices that characterize them, and the products they make.

Especially over the long term, the international and domestic S&E trends that *Science and Engineering Indicators* describes can be understood in light of the worldwide trend toward more knowledge-intensive economies. In this type of economy, research, its commercial exploitation, and other intellectual work are of growing importance. Such economies rely on sustained investment in research and development that produces useful innovations. They also rely on higher education that prepares students to use S&E knowledge and related research skills to develop new and better ways to make products and perform services. As a result, data on trends in R&D and human resources infrastructure feature prominently in both parts of the overview and throughout *Science and Engineering Indicators*. Knowledge-intensive economies, however, also rely on other kinds of infrastructure, including reliable and modern transportation and communications and a broadly educated and literate population, to enable them to function effectively.

The overview is not intended to be comprehensive. Numerous important topics that are addressed in individual chapters, and even some that crosscut the volume, are not covered in the overview. Major findings on particular topics can be found in the "Highlights" sections that appear at the beginning of chapters 1–7.

The indicators included derive from a variety of national, international, public, and private sources and are not always strictly comparable in a statistical sense. As noted in the text, in some cases the quality of available data is less than ideal, and the metrics and models relating them to each other and to economic and social outcomes need further development. Thus, the emphasis is on broad trends. Individual data points and findings should be interpreted with care.

Science and Technology in the World Economy

Knowledge- and Technology-Intensive Economic Activity

Knowledge- and technology-intensive (KTI) industries represent a growing portion of global S&T economic activity. KTI industries accounted for 27% of world gross domestic product (GDP) in 2012. They consist of high-technology (HT) manufacturing (e.g., aircraft and spacecraft; pharmaceuticals) and knowledge-intensive (KI) services (e.g., commercial business, financial, and communication services). These industries play a larger role in the United States than in the economy of any other large developed country, accounting for 40% of U.S. GDP.[1] KTI concentrations were in the range of 29%–30% for other large, developed regional and national economies (European Union [EU; see "Glossary" for member countries], Canada, Japan, and South Korea). The trend since 1999 indicates that, except for Japan between 2005 and 2012, the KTI share for all of these economies has been rising (figure O-1).

The KTI share of the world's developed economies grew from 29% to 32% between 1997 and 2012. This was due mostly to increases in commercial and public (education and health) KI services, indicating a continuing movement away from manufacturing and toward services in these economies.

In recent years, regional and national shares of worldwide KTI production have been shifting. Regionally, the shift has produced a growing concentration of commercial KTI economic activity in East and Southeast Asia.[2] That region is approaching a concentration of commercial KTI activity comparable to that of the world's established regional centers, North America and Western Europe.

Likewise, an increasing amount of worldwide KTI production is occurring in the developing world. To a large extent, this is due to China's large modernizing economy. Economic growth in other Asian locations, however, has contributed as well, and KTI economic activity is also growing in countries such as Brazil, Turkey, and South Africa (figure O-2).

The growth of KTI activity in the developing world is most apparent in manufacturing and is largely due to China. Between 2003 and 2012, China's HT manufacturing rose more than fivefold, resulting in its global share climbing from 8% to 24% in 2012. Even amid this shift, the United States remains the largest global provider of HT manufacturing (27% of the global total) (figure O-3).

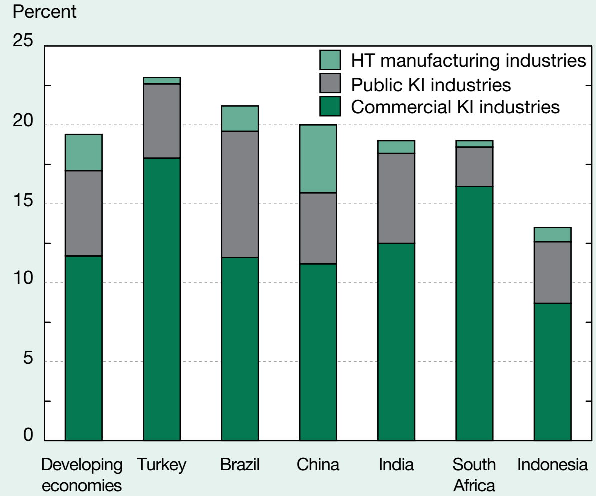
KI services, despite growth in worldwide production attributed to developing countries, remain concentrated in developed countries. The United States is the world's largest provider of commercial KI services (32%), followed by the EU (23%). China's commercial KI services account for 8% of the world total, much more than any other developing country. China is tied with Japan as the third-largest global provider of these services. The share of developed countries in worldwide production of commercial KI services fell from 90% in 2003 to 79% in 2012, due entirely to a collective 15 percentage point decline in the global shares of the United States, the EU, and Japan (figure O-4). Nonetheless, developed countries continue to dominate global trade in these industries.

The value added of commercial KI services in developed economies grew between 2003 and 2008. Due to the international economic downturn, however, these services then contracted before resuming growth in 2010. In the United States, commercial KI services' value added rebounded after 2009 and, in 2012, stood 12% higher than its level prior to the global recession. The EU fared much worse. The EU's production of commercial KI services remained stagnant between 2009 and 2012 and was below its pre-recession peak at the end of this period. As a result, following the international economic downturn, the EU's global share in these KI services industries declined considerably. In contrast, the U.S. global share not only remained steady, but employment in commercial KI services in the United States rose above levels prior to the global downturn. At the same time, commercial KI services in developing countries, and especially in China, grew rapidly.

As the distribution of commercial KTI production gradually shifted from developed to developing countries during the international economic downturn, parallel changes occurred in trade in KTI goods and services. The developed world generally lost market share in global KTI exports during this period. Japan, for example, suffered marked declines in global market share, as did the EU. But some large European economies, notably Germany and the United Kingdom (UK), fared better than other parts of the EU. The United States was more successful in maintaining its position in global KTI competition than most other long-established developed economies.

Figure O-2

Output of KTI industries as a share of GDP for selected developing economies: 2012



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and measuring, testing, and control instruments. Developing economies are classified by the World Bank as higher- and lower-middle income and low income.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix tables 6-3–6-7.

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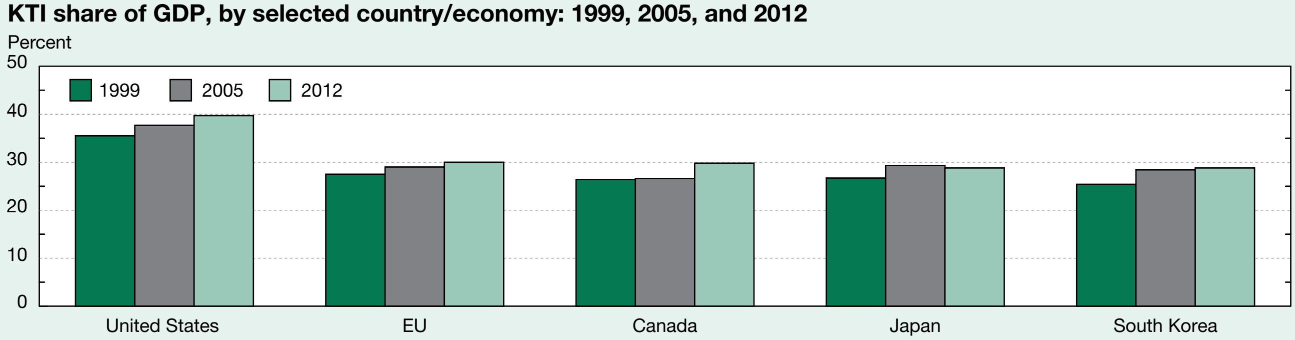
Figure O-1

KTI share of GDP, by selected country/economy: 1999, 2005, and 2012



EU = European Union; GDP = gross domestic product; KTI = knowledge and technology intensive.

NOTES: KTI industries include knowledge-intensive (KI) services and high-technology (HT) manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, special tabulations (2013) of the World Industry Service database. See appendix table 6-18 for a full list of countries in each region.

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R&D Performance

R&D expenditures increase human and knowledge capital, laying the groundwork for innovations, including those that fuel KTI industries. In 2011, the proportion of global R&D performance attributable to the East and Southeast Asia region, including China, was comparable (31.8%) to that in North America (32.2%) and substantially larger than that in Europe (24.0%) (figure O-5).

Among individual countries, the United States is by far the largest investor in R&D. In absolute terms, the top three R&D performing countries—the United States ($429 billion), China ($208 billion), and Japan ($147 billion)—accounted for over half of the estimated $1.44 trillion in global R&D in 2011. The U.S. share was 30% of the global total in 2011. China (15%) and Japan (10%) were the next-largest R&D performers. The total for the EU was 22% (figure O-6).

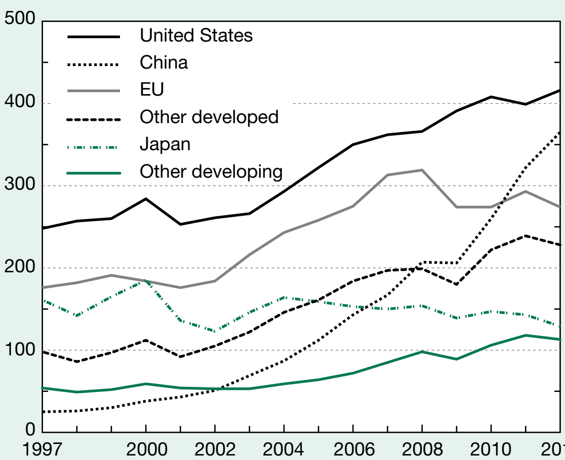
Despite growth in nominal measures of R&D, both the United States and the EU experienced substantial declines in the last decade in their shares of global R&D. Between 2001 and 2011, the U.S. share declined from 37% to 30% of the global total, while the EU share dropped from 26% to 22%. During the same period, the economies of East and Southeast Asia and South Asia—including China, India, Japan, Malaysia, Singapore, South Korea, and Taiwan—saw an increase in their combined share from 25% to 34% of the global total. The pace of growth over the past 10 years in China's overall R&D remains exceptionally high at about 18% annually adjusted for inflation, propelling it to 14.5% of the global total in 2011, up from 2.2% in 2000.

Although the United States performs far more R&D than any other individual country, several other economies have greater *R&D intensity*—that is, a higher ratio of R&D expenditures to GDP. In 2011, R&D intensity in the United States was 2.8%. Most economies with higher R&D intensity—including Israel, Finland, South Korea, Sweden, Denmark, Taiwan, and Switzerland—tend to be much smaller than the United States. More apt comparisons are with Germany, France, the UK, and Japan, which allocated, respectively, 2.9%, 2.2%, 1.8%, and 3.4% of GDP to R&D. However, relatively high R&D investments alone are no guarantee of robust economic growth, as indicated by the experience of Japan during the last decade.

Moreover, in several countries, R&D intensity has been growing rapidly (figure O-7). Along with China, South Korea is a notable example. In 1991, gross expenditure

Figure O-3
Output of HT manufacturing industries for selected regions/countries/economies: 1997–2012

Billions of dollars



EU = European Union; HT = high technology.

NOTES: Output of HT manufacturing industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries classified as high-income countries by the World Bank. Developing countries classified as upper- and lower-middle-income countries and low-income countries by the World Bank.

SOURCE: IHS Global Insight, World Industry Service database (2013). See appendix table 6-7.

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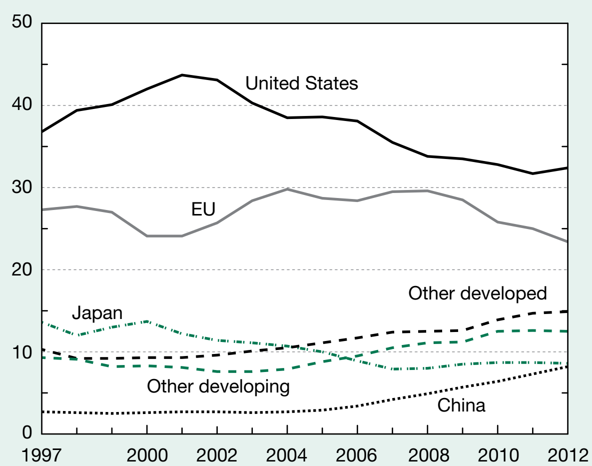
Figure O-4
Global share of commercial KI services value added for selected countries/economies: 1997–2012

Percent



EU = European Union; KI = knowledge intensive.

NOTES: Output of knowledge- and technology-intensive industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed economies are classified by the World Bank as high income. Developing economies are classified by the World Bank as upper- and lower-middle income and low income.

SOURCE: IHS Global Insight, World Industry Service database (2013).

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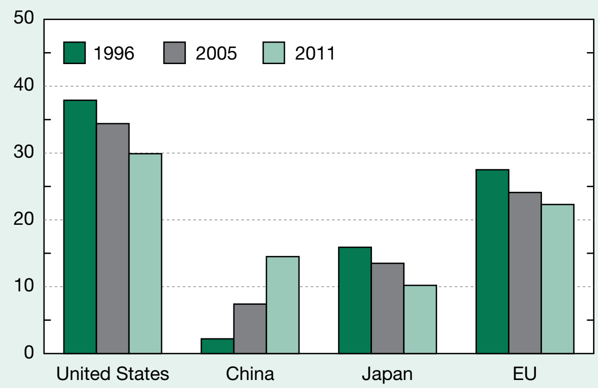
on R&D as a share of GDP was 1.8% for South Korea. By 2011, that measure had increased to over 4.0%. A stated goal by the European Union (one of the five targets for the EU in 2020 [EC 2013]), along with many individual developed countries, is to achieve a 3% R&D-to-GDP ratio to promote innovation.

At the same time that the growth of KI economies around the world intensifies the competition among national economies, it also increases interdependencies. Taking advantage of improved worldwide capacity to perform R&D and other knowledge-oriented economic activities, multinational corporations (MNCs) have increasingly made R&D investments outside their home countries. To be sure, the bulk of R&D by U.S. MNCs is still performed in the United States (84% of their $252 billion in R&D globally in 2010) and in Europe. But rapid growth in R&D by majority-owned foreign affiliates (MOFAs) of U.S. MNCs in China, India, Brazil, and Israel is closing the gap between these emerging countries and traditional centers of U.S. MOFA investments in Europe, Canada, and Japan.

Notably, U.S. MOFA R&D performance in China more than doubled in current dollars from 2005 to 2008, with year-to-year, double-digit increases to a record $1.7 billion in 2008. This is consistent with increases in total R&D performed in China in recent years and with China's

Figure O-6
Global share of expenditures on R&D, by selected country/economy: 1996, 2005, and 2011



EU = European Union.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, estimates (August 2013), based on data from the Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2013/1); and the United Nations Educational, Scientific and Cultural Organization Institute for Statistics, http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx, table 25, accessed 2 August 2013.

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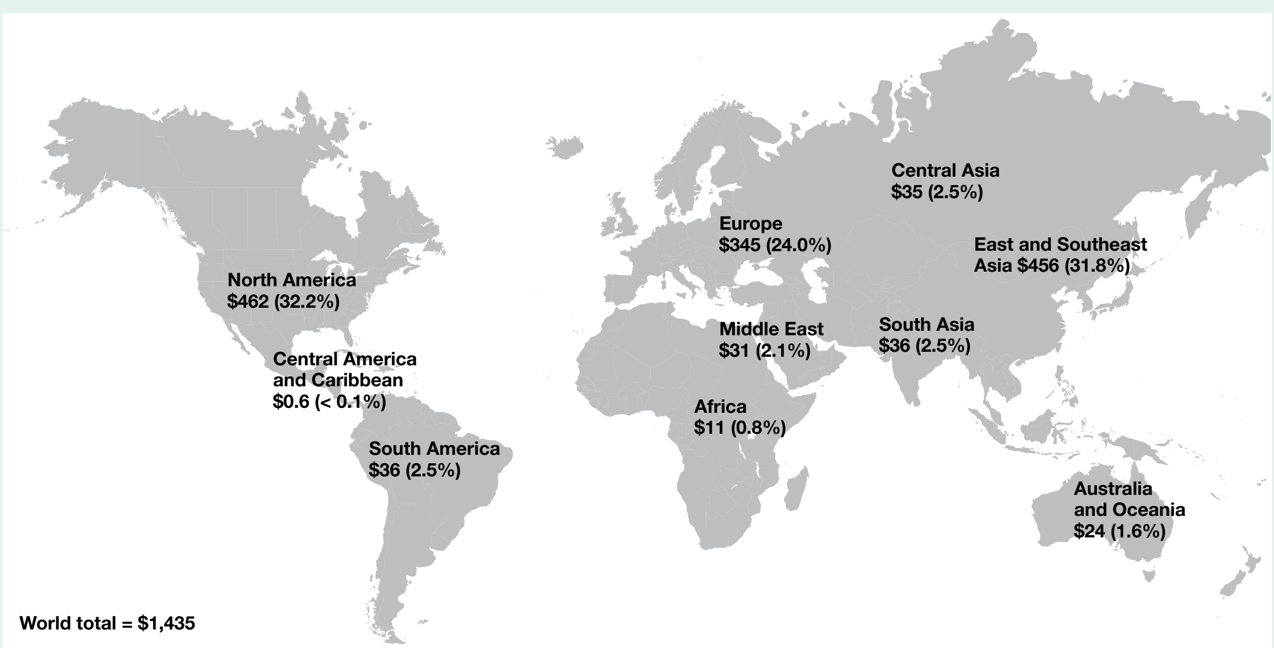
Figure O-5
Global R&D expenditures, by region: 2011

Billions of U.S. PPP dollars



PPP = purchasing power parity.

NOTES: Foreign currencies are converted to U.S. dollars through PPPs. Some country figures are estimated. Countries are grouped according to the regions described by *The World Factbook*, available at www.cia.gov/library/publications/the-world-factbook/index.html.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, estimates (August 2013). Based on data from the Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2013/1); and the United Nations Educational, Scientific and Cultural Organization Institute for Statistics, http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx, table 25, accessed 2 August 2013.

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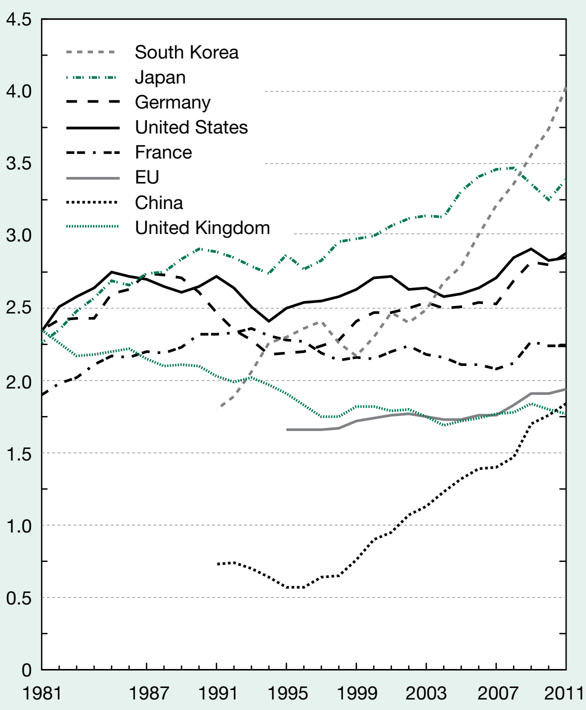
emergence as the second-largest R&D-performing country. Reported R&D activity by U.S. MOFAs tripled in India and more than doubled in Brazil from 2007 to 2010. U.S. MOFA R&D expenditures in Brazil and India are now on par with those in China.

Concurrently, affiliates of foreign MNCs located in the United States (U.S. affiliates) performed $41.3 billion of R&D in 2010, a slight increase after almost no change in 2009 and 2008. R&D by these companies has accounted for 14%–15% of U.S. business R&D performance since 2007. Three-fourths of R&D by U.S. affiliates of foreign MNCs in 2010 was performed by firms owned by parent companies based in five countries: Switzerland (22.0%), the UK (14.5%), Germany (13.8%), France (12.7%), and Japan (12.4%).

In addition to lowering R&D labor costs, MNCs' overseas R&D investments bring development work closer to emerging markets and enable product designers to take advantage of proximity to consumers and better information about whether and how consumers are likely to use new products. These investments, often encouraged by governments in developing countries, also increase local capacity for performing further R&D work (Thursby and Thursby 2006).

Figure O-7
Gross expenditures on R&D as share of GDP, for the United States, EU, and selected other countries: 1981–2011



EU = European Union; GDP = gross domestic product.

NOTES: Data are not available for all countries in all years. The table includes the top seven R&D-performing countries. Figures for the United States reflect international standards for calculating gross expenditures on R&D, which differ slightly from the National Science Foundation's protocol for tallying U.S. total R&D. Data for Japan for 1996 onward may not be consistent with earlier data because of changes in methodology.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2013/1). See appendix table 4-13.

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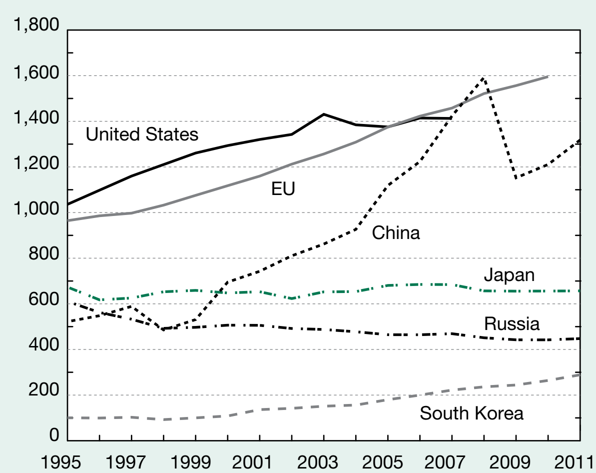
Workers with S&E Skills

The presence of workers with S&E skills is one of the key indicators of national competitiveness. Comprehensive, internationally comparable data on the worldwide S&E workforce do not exist. However, the Organisation for Economic Co-operation and Development (OECD) reports international data on professionals engaged in research. Although national differences in these data may be affected by survey procedures and interpretations of international statistical standards, the data can be used to make broad comparisons of national trends.

The United States continues to enjoy a distinct but decreasing advantage in the supply of human capital for research and other work involving S&E. In absolute numbers, the United States had one of the largest populations of researchers at the latest count, but China—which almost tripled its number since the mid-1990s—has been catching up (figure O-8).[3]

Figure O-8
Estimated number of researchers in selected countries/regions: 1995–2011



EU = European Union.

NOTES: Data are not available for all countries/regions for all years. Researchers are full-time equivalents. Before 2009, counts for China were not consistent with Organisation for Economic Co-operation and Development (OECD) standards.

SOURCE: OECD, *Main Science and Technology Indicators* (2013/1 and earlier years), http://www.oecd.org/sti/msti.htm.

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There is no doubt that the worldwide total of workers engaged in research has been growing strongly and that growth has been more robust in some countries than in others. The most rapid expansion has occurred in South Korea (which doubled its number of researchers between 1995 and 2006 and continued to grow strongly thereafter) and China (which reported tripling its number of researchers between 1995 and 2008 and likewise reported substantial growth in later years).[4] The United States and the EU experienced steady growth at lower rates, with a 36% increase in the United States between 1995 and 2007 (OECD data for the United States are not available after 2007) and a 65% increase in the EU between 1995 and 2010. Exceptions to the worldwide trend between 1995 and 2011 were the numbers of researchers in Japan (which remained flat) and in Russia (which declined).

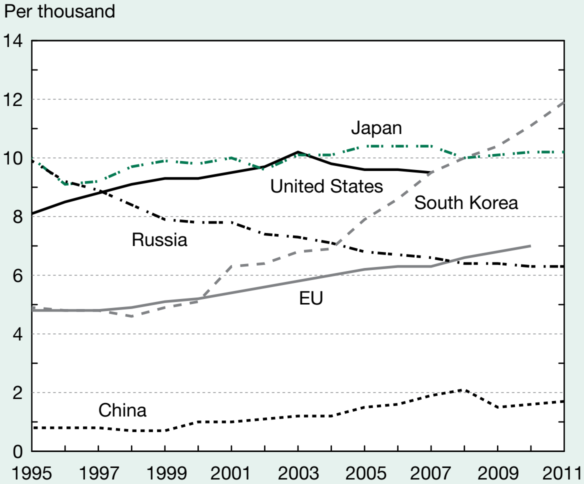
Researchers measured as a share of employment is another indicator of national competitiveness in an international knowledge economy. Several economies in Asia have shown a sustained increase in that statistic since 1995. Foremost among them is South Korea (figure O-9), but growth is also evident in others—for example, in Singapore, Taiwan, and China. Singapore, for instance, has published estimates suggesting that its total number of workers with S&E skills will increase by nearly 50% by 2030 (NPTD 2013).[5]

Data on recipients of higher education degrees also indicate that other countries are catching up to—and, in some respects, surpassing—the United States. Between 2001 and 2010, the number of first university degrees in the United States increased from 1.3 million to 1.7 million. During the same time period, the number of first university degrees in China grew from 0.5 million to 2.6 million. The rates of growth in the EU and in Japan, South Korea, and Taiwan were comparable to that in the United States (figure O-10).

S&E degrees, important for an innovative knowledge economy, are more prevalent in some countries than others. Globally, the number of first university degrees in S&E reached about 5.5 million in 2010. Almost a quarter of those degrees were conferred in China (24%), 17% in the EU, and 10% in the United States. In several Asian countries, these degrees comprise a larger proportion of all first university degrees than they do in the United States. Differences in engineering are especially large: whereas 5% of all bachelor's degrees awarded in the United States were in engineering, 31% of such degrees in China were in this field.

The S&E proportion of all first university degrees in Western countries has typically been stable in recent years. From 2001 to 2010, this share held steady in the United States (from 31.8% to 31.5%) and in Germany (from 37.3% to

Figure O-9
Researchers as a share of total employment in selected countries/regions: 1995–2011



EU = European Union.

NOTES: Data are not available for all countries/regions for all years. Researchers are full-time equivalents per thousand total employment. Before 2009, counts for China were not consistent with Organisation for Economic Co-operation and Development (OECD) standards.

SOURCE: OECD, *Main Science and Technology Indicators* (2013/1 and earlier years), http://www.oecd.org/sti/msti.htm.

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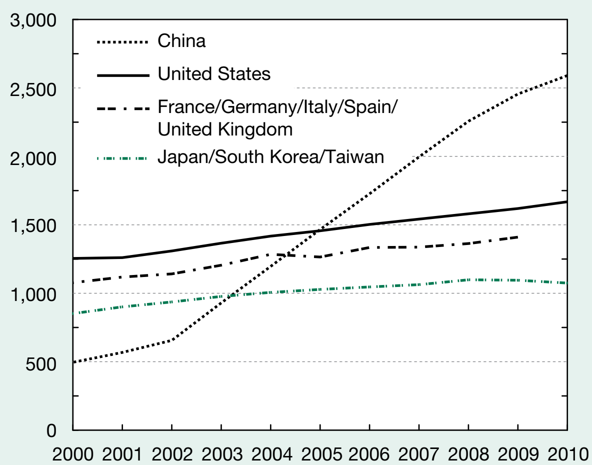
Figure O-10
First university degrees, by location: 2001–10



NOTES: Data for first university degrees use International Standard Classification of Education, level 5A. Data not available for all locations in all years.

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, Monbusho Survey of Education (annual series; various years); Taiwan—Ministry of Education, Educational Statistics of the Republic of China (annual series; various years); United Kingdom—Higher Education Statistics Agency, special tabulations (various years); United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, and National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System, http://webcaspar.nsf.gov; and other countries—Organisation for Economic Co-operation and Development, OECD Stat Extracts, http://stats.oecd.org/Index.aspx.

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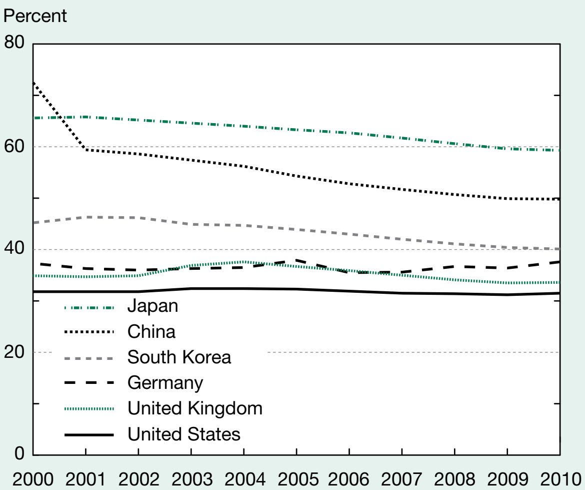
37.6%). In contrast, this proportion decreased considerably in several Asian countries, such as China (from 72.5% to 49.8%), Japan (from 65.6% to 59.3%), and South Korea (from 45.2% to 40.1%) (figure O-11).

The relationship between degrees conferred in a country and future capabilities in its workforce is complicated by the fact that increasing numbers of students are receiving higher education outside their home countries. The United States remains the destination of choice for the largest number of internationally mobile students worldwide. In 2012, foreign graduate students in S&E fields (163,390) outnumbered foreign students pursuing S&E undergraduate degrees (116,640) in the United States. Other popular destinations for internationally mobile students are the UK, Australia, France, and Germany (figure O-12). Yet, due to efforts by other countries to attract more foreign students as well as increased enforcement of visa requirements for students wanting to pursue a degree in the United States (among other factors), the U.S.-enrolled share of the world's internationally mobile students fell from 25% in 2000 to 19% in 2010. While a declining share of international students in the natural sciences and engineering opted for the United States, this drop in numbers was offset by an increase in international students coming to the United States to study social and behavioral sciences.

Whereas the U.S. share of internationally mobile students fell, the actual number of foreign undergraduate students entering the United States increased, rising by 18% between fall 2011 and fall 2012. Within the S&E fields, the largest increases occurred in engineering and the social sciences. The majority of foreign students studied in non-S&E fields. Foreign undergraduates in the United States predominantly originate from China, South Korea, and Saudi Arabia.

The number of foreign graduate students in the United States increased by 3% between fall 2011 and fall 2012. A much larger share of those students (nearly 6 out of 10) was enrolled in S&E fields as compared to undergraduate students (3 out of 10). This cohort of foreign graduate students chose somewhat different fields of study from earlier years: more studied mathematics, social sciences, and psychology, and fewer studied computer science, biological sciences, and engineering.

Figure O-11
S&E first university degrees as a share of all first university degrees, by country: 2000–10



NOTE: Data for first university degrees use International Standard Classification of Education, level 5A.

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, Monbusho Survey of Education (annual series; various years); Taiwan—Ministry of Education, Educational Statistics of the Republic of China (annual series; various years); United Kingdom—Higher Education Statistics Agency, special tabulations (various years); United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, and National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System, http://webcaspar.nsf.gov; and other countries—Organisation for Economic Co-operation and Development, OECD Stat Extracts, http://stats.oecd.org/Index.aspx.

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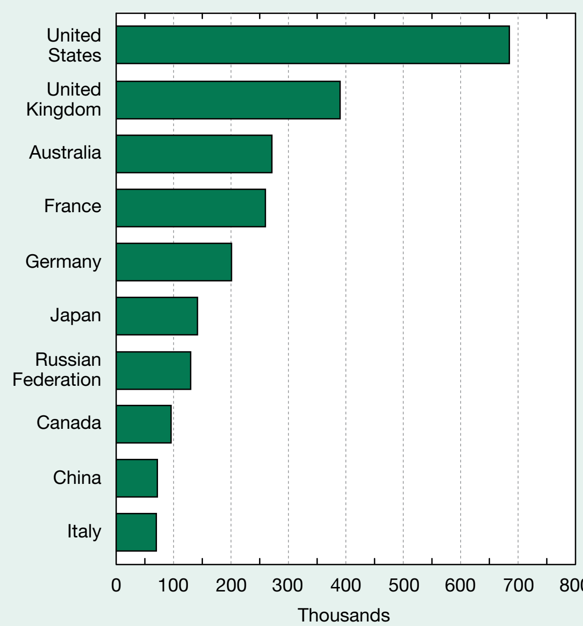
Figure O-12
Internationally mobile students enrolled in tertiary education, by selected country: 2010



NOTES: Data are based on the number of students who have crossed a national border and moved to another country with the objective of studying, i.e., mobile students. Data for Canada and the Russian Federation correspond to 2009. Data for Germany exclude advanced research programs (e.g., doctorate).

SOURCE: UNESCO Institute for Statistics, special tabulations (2013).

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Research Publications

Refereed journal articles are a tangible and readily measured output of research activity. Despite the growth in research capability abroad, the United States continues to be the world leader in the publication of S&E articles when publications are measured at the individual country level. In 2011, the United States accounted for 26% of the world's 828,000 articles.[6] Nonetheless, the U.S. share of the global total of refereed journal articles has been declining, dropping by 4 percentage points between 2001 and 2011. Similarly, shares for the EU and Japan fell from 35% to 31% and from 9% to 6%, respectively, between 2001 and 2011. This was due mainly to increased output of research articles in East and Southeast Asia and in developing countries, such as Brazil and India. China's share of refereed journal articles grew the fastest among larger developing economies during this time period, almost quadrupling from 3% to 11% of the world total (figure O-13).

Citations to refereed journal articles are an oft-used indicator of the quality and impact of research output. Researchers based in the United States continue to set the bar with respect to the production of influential research results. Between 2002 and 2012, 1.6%–1.8% of U.S.-authored S&E articles have been among the world's top 1% of cited articles, compared with 0.7%–0.9% of articles from the EU (figure O-14). The share of China's articles in the top 1% remained behind the United States and the EU but experienced a sixfold increase (0.1% to 0.6%) over the period. Overall, U.S.-authored articles represented 48% of the world's top 1% of cited articles during this time period.

Citation data can also signal the extent of collaboration among researchers, both nationally and across borders. The trend toward more collaboration varies among S&E fields, research institutions, and countries. Citation patterns, like coauthorship patterns, are strongly influenced by cultural, geographic, and language ties. Thus, U.S. articles are disproportionately cited by Canadian and UK articles. In comparison, U.S. authors cite Chinese articles much less than suggested by the overall citation trends. Within Europe and Asia (with the exception of Japan), cross-national citation is common, with most country pairs in each continent surpassing the expected number of citations.[7]

U.S. articles are highly cited across all broad scientific fields. Citations for U.S. engineering articles exhibited a slight increase between 2002 and 2012, and citations declined slightly for chemistry and social sciences. EU articles are cited more than expected in physics and agriculture. China underperformed on this measure across all science fields, with the notable exceptions of computer science and geosciences, in which China overperformed.

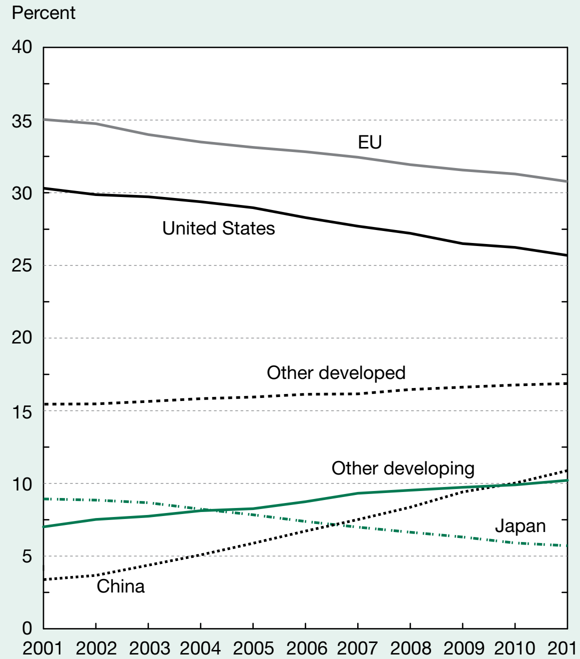
Innovation-Related Indicators

In addition to the research findings in published articles, patents are an important output often produced by S&E research. Although patents do not necessarily become commercialized or lead to practical innovations—some are accumulated to provide a basis for legal action to discourage competitors from innovating, and others are simply deemed not to be commercially viable—patent grants and applications can sometimes lead to new or significantly improved products or processes or new methods of organizing productive activities.

The United States Patent and Trademark Office (USPTO) accepts applications from and grants patents to inventors worldwide. Trends in USPTO patenting activity indicate changes in inventive activity in different parts of the world (figure O-15).

The USPTO granted more than 250,000 patents in 2012, of which 120,000 were to U.S. inventors. This represents the highest number worldwide. Japan (51,000) and the EU (36,000) posted the next-highest numbers of successful patent applications to the USPTO. Although the absolute number

Figure O-13
S&E articles, by global share of selected region/country: 2001–11



EU = European Union.

NOTES: Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles are classified by the year of publication, and are assigned to a country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a fractional-count basis (i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on the basis of the proportion of its participating institutions). Counts for all six groups sum to the world total. Data for Bulgaria, Hungary, and Romania are included with the EU and not with developing economies.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, and The Patent Board,™ special tabulations (2013) from Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/. See appendix table 5-26.

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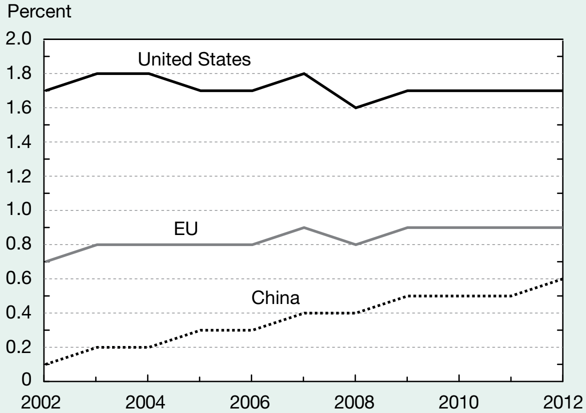
of USPTO patents granted to U.S. inventors increased from 87,000 to 120,000 between 2003 and 2012, the U.S. share declined by 5 percentage points (from 53% to 48%) in this period. This likely signals increased technological capabilities abroad, which, in a globalized marketplace, underscore the need for patent protection in foreign countries. Developing countries received 9,000 patents (less than 4% of total patents), with China and India receiving the bulk of the relatively small number of patents granted to these countries.

Data on the numbers of patents granted provide no indication of patent quality. *Triadic patents,* in which inventors simultaneously seek patent protection in three of the world's largest markets—the United States, the EU, and Japan—indicate patents expected to have high commercial value. In 2010, the number of these triadic patents was estimated to be about 49,000. The shares of the United States, the EU, and Japan stayed roughly equal (at around 30% each) during the period from 2000 to 2010. Although South Korea still produces far fewer patented inventions than the long-standing global leaders, the country made rapid and notable progress on this indicator in the last decade, doubling its filings from 2% to 4% of the global total (figure O-16).

Globally, there are indications that various economies receive the majority of their patent grants in certain technology areas (figure O-17). U.S. inventors accounted for nearly 70% of all U.S. patents granted in medical equipment and electronics, far higher than the overall U.S. share, indicating that U.S. inventors are very active in this area. In addition, the United States has slightly higher than average shares in information and communications technologies (ICT) and biotechnology and pharmaceuticals. EU inventors have a somewhat higher than average share in biotechnology and pharmaceuticals, receiving 21% of all U.S. patents in the area; an additional technology area where the EU has a slightly higher

Figure O-14
Share of U.S., EU, and China S&E articles that are in the world's top 1% of cited articles: 2002–12



EU = European Union.

NOTES: Article/citation counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles are classified by the year they entered the database, rather than their year of publication, and are assigned to a country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a fractional-count basis (i.e., for articles with collaborating institutions from multiple countries/regions, each country/region receives fractional credit on the basis of the proportion of its participating institutions). See appendix table 5-24 for countries included in the EU, which in this figure is treated as a single country. Citation counts are based on a 3-year period with a 2-year lag (e.g., citations for 2012 are references made in articles in the 2012 data tape to articles in the 2008–10 data tapes).

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, and The Patent Board,™ special tabulations (2013) from Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/. See appendix table 5-57.

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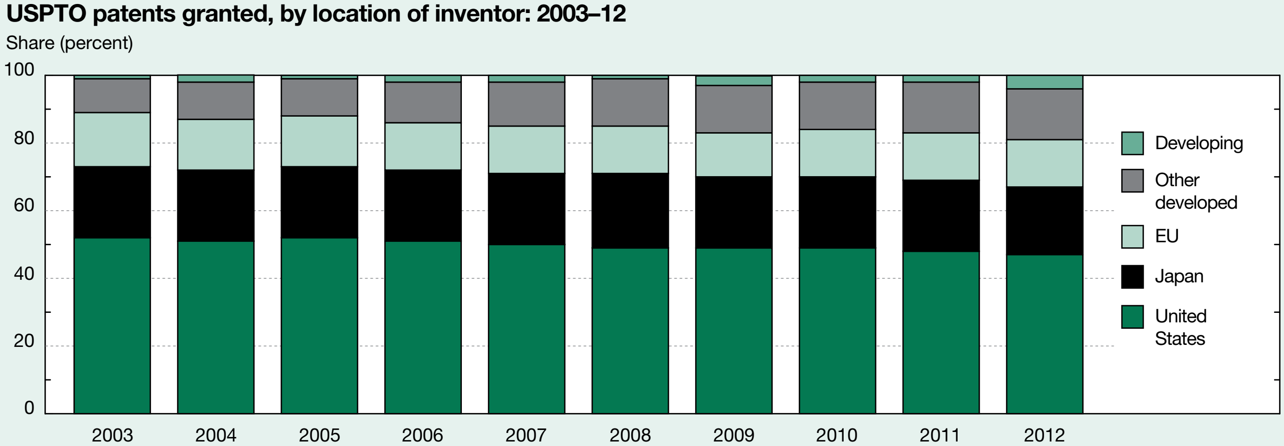
Figure O-15
USPTO patents granted, by location of inventor: 2003–12



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

NOTES: Technologies are classified by The Patent Board.™ Patent grants are fractionally allocated among countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ special tabulations (2013) from Proprietary Patent database. See appendix table 6-40.

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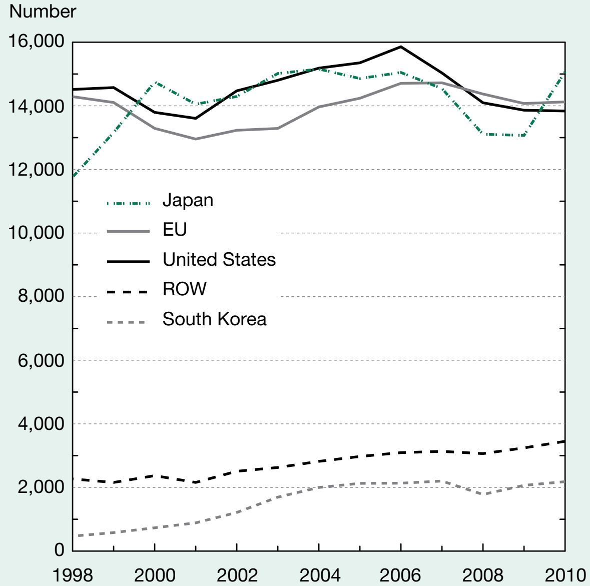
Figure O-16
Global triadic patent families, by selected region/country/economy: 1998–2010



EU = European Union; ROW = rest of world.

NOTES: Triadic patent families include patents applied in the U.S. Patent and Trademark Office, European Patent Office, and Japan Patent Office. Patent families are fractionally allocated among regions/countries/economies based on the proportion of the residences of all named inventors.

SOURCE: Organisation for Economic Co-operation and Development, Patents Statistics, http://stats.oecd.org/WBOS/index.aspx, Patents by Region database, accessed 15 January 2011. See appendix table 6-54.

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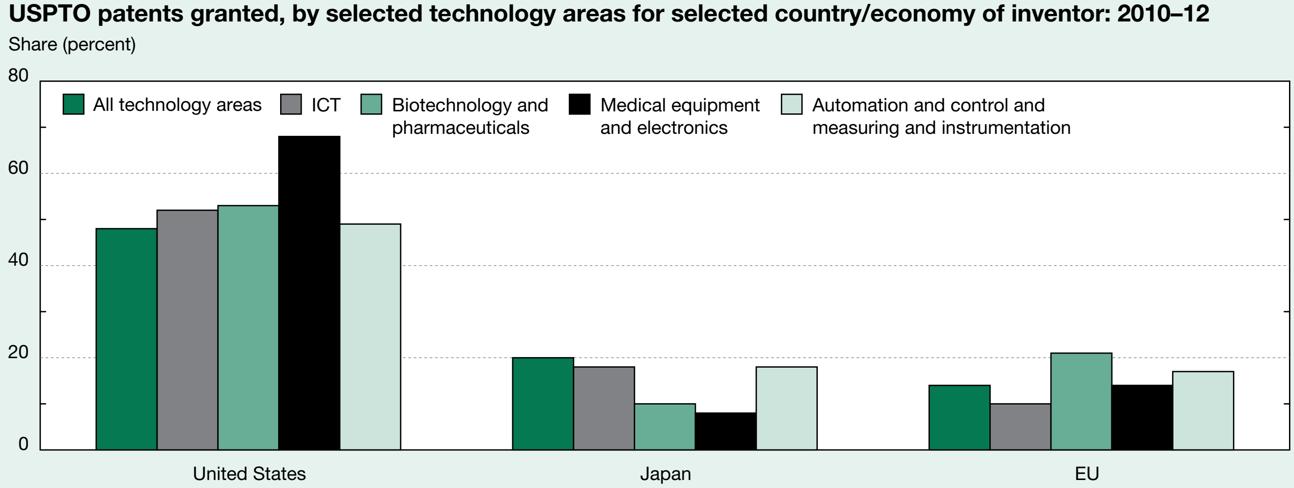
than average share is automation and control and measuring and instrumentation (17%).

KTI industries account for a large share of USPTO patent grants awarded to inventors in the United States. In 2011, HT manufacturers garnered 29,000 of the 58,000 patents granted to all U.S. manufacturing industries. U.S. commercial KI services industries accounted for 46% of the 43,000 patents issued to nonmanufacturing industries in 2011. Although HT manufacturing is a smaller part of the U.S. economy than KI services, the majority of inventions attributable to KTI industries occur on the manufacturing side.

In manufacturing, five of the six HT manufacturing industries—aircraft and spacecraft; communications; computers; pharmaceuticals; and testing, measuring, and control instruments—reported rates of product and process innovation that were at least double the manufacturing sector average. In KI services industries, software firms lead in incidence of innovation, with 69% of companies reporting the introduction of a new product or service, compared to the 9% average for all nonmanufacturing industries. Other KI services industries—such as computer systems design, data processing and hosting, and scientific R&D services—also report innovation at rates that are three to four times higher than the nonmanufacturing average.

Innovative activities and trade in intellectual property are strongly related. Intellectual property trade is measured by royalties and fees collected for licensing or franchising proprietary technologies. Although sometimes affected by different tax treatments, income from intellectual property broadly indicates which nations are producing intellectual products with commercial value. U.S. export income from royalties and fees has exhibited a strongly positive trend

Figure O-17
USPTO patents granted, by selected technology areas for selected country/economy of inventor: 2010–12



EU = European Union; ICT = information and communications technologies; USPTO = U.S. Patent and Trademark Office.

NOTES: Technologies are classified by The Patent Board.™ Patents are fractionally allocated among countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board,™ special tabulations (2013) from Proprietary Patent database. See appendix tables 6-40 and 6-43–6-53.

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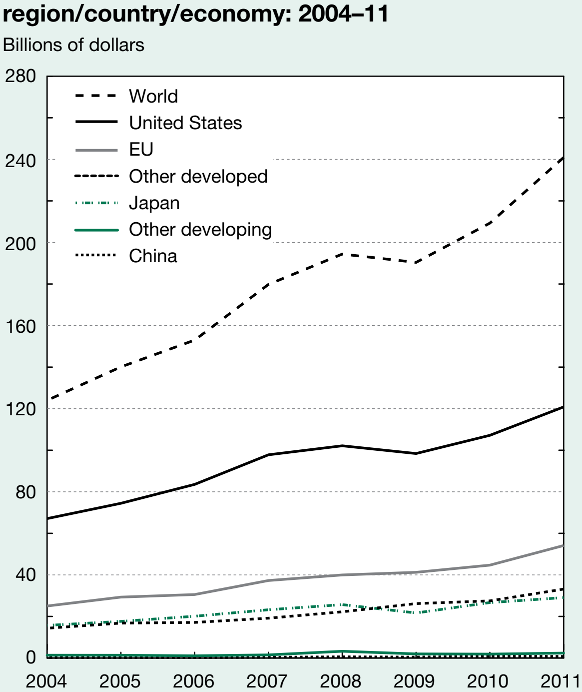
over the last decade (figure O-18). In 2011, the United States posted export income of $121 billion in royalties and fees. The EU exported intellectual property in the amount of $54 billion while accumulating a small trade deficit in this area. Like the United States, Japan, which exported $29 billion in royalties and fees, had a substantial trade surplus in this area. Three economies that import more rights to production than they export (and are, therefore, net importers of royalties and fees) are among countries that the World Bank has recently classified as developing: China, Russia (reclassified as developed in 2012), and Brazil.

The U.S. Science and Engineering Landscape

Changes in the major institutions that engage in S&E R&D and help prepare the workforce of the future usually occur gradually, typically over a longer time scale than changes in economic markets. This section describes consequential changes and continuities in the major institutions involved in U.S. S&E activity over the last two decades, focusing on institutional features that play important roles in R&D and in S&E education. Attention is devoted primarily to higher education, industry, and government, which are the largest funders and performers of R&D and the biggest employers of workers with S&E training. However, other institutions that play important niche roles (e.g., nonprofit funders and performers of research; federally funded research and development centers [FFRDCs]) are also mentioned. Other institutions that lay important foundations for a knowledge economy (e.g., K–12 education) are discussed in the body of the report.

Figure O-18
Global exports of royalties and fees, by selected region/country/economy: 2004–11



EU = European Union.

NOTES: EU exports do not include intra-EU exports. Developed countries are classified as high-income economies by the World Bank. Developing countries are classified as upper- and lower-middle income and low income by the World Bank. Sum of regions/countries/economies does not add up to total due to rounding and discrepancies.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 8 August 2013.

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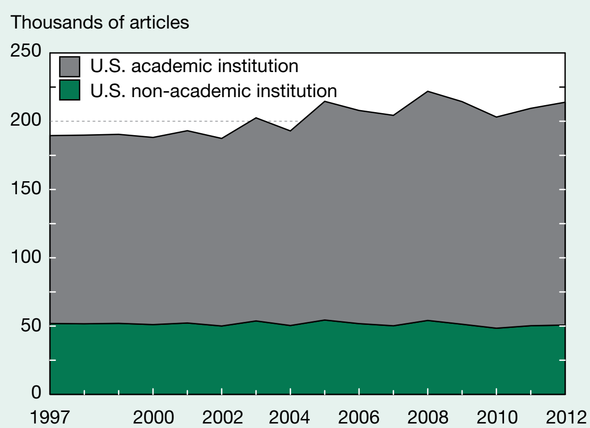
Cross-Sector Collaboration

Ironically, a focus on institutions highlights one of the most striking changes in the U.S. S&E landscape in recent years—the growth of cross-institution, cross-sector, and cross-national collaboration. Institutions and disciplines that formerly inhabited almost entirely separate worlds more frequently collaborate on projects and cross boundaries to enter previously unfamiliar territory.

Publication data show the clearest evidence of this trend. Although the distribution of S&E publication activity between academic and nonacademic institutions remained relatively stable between 1997 and 2012 (figure O-19), with academic institutions producing the large majority of

Figure O-19
U.S. academic and non-academic S&E articles: 1997–2012



NOTES: Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles are classified by the year they entered the database and are assigned to U.S. institution(s) based on the institutional address(es) listed in the article. Articles are credited on a fractional count basis; for articles with institutional addresses from multiple countries/U.S. institutions, each U.S. institution receives fractional credit on the basis of the proportion of its participating institutions.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, and The Patent Board,™ special tabulations (2013) from Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/. See appendix table 5-40.

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publications, the proportion of collaborative publications increased. The share of S&E articles with more than one named author grew, as did the percentages involving institutional and international coauthorships (figures O-20 and O-21).

From 1990 to 2012, the share of purely U.S. S&E articles with authors from multiple institutions grew from 34% to 62%. Collaborative publication was more common in the U.S. academic sector than in other U.S. institutional sectors. The share of purely U.S. academic articles with authors from multiple academic institutions rose from 16% in 1990 to 31% in 2012 (figure O-20).[8] Other U.S. institutional sectors showed a similar trend toward collaborative publication among multiple institutions during this period. The average number of authors on papers published by authors from U.S. academic institutions also increased considerably, rising from 3 authors in 1990 to 8 authors in 2012 (figure O-21).

Between 1997 and 2012, internationally coauthored articles grew from 16% to 25% of the world's total. In the United States, the trend toward more international collaboration was even stronger. The percentage of U.S. articles with coauthors from institutions in other countries almost doubled (from 19% to 35%) between 1997 and 2012. Worldwide in 2012, 59% of all S&E articles with only domestic authors were produced with coauthors at different institutions (43% in 1997). Collaborative research articles receive more citations than single-author articles, suggesting higher quality or greater impact.

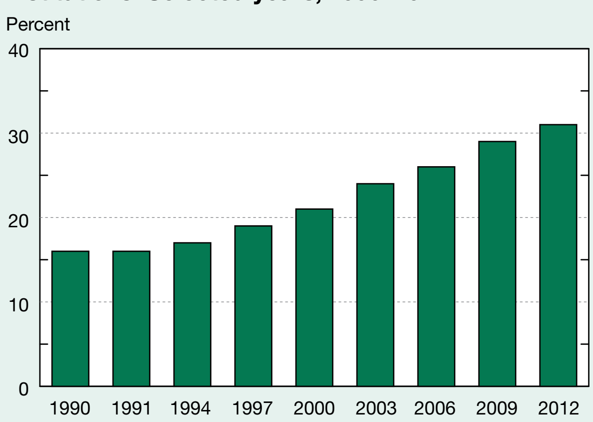
Publication data reveal increased collaboration between U.S. authors at academic institutions and other organizations that perform R&D, indicating a growing connection between the basic research performed in the academic sector and the more applied work characteristic of other sectors. In various institutional sectors—including industry, federal government, FFRDCs, and private nonprofit—the proportion of articles with academic sector coauthors increased by about 12–14 percentage points between 1997 and 2012.

The flow of funding among institutions also illustrates the trend toward collaborative research. Over the past 15 years, *pass-through funding,* in which funding for R&D at one university is shared with one or more collaborating institutions, has grown more rapidly than overall academic R&D expenditures. Between FY 2000 and FY 2009, the pass-through funds that universities provided to other universities grew by 171% (from $700 million to $1.9 billion), while overall academic R&D expenditures grew by only 82% (from $30.1 billion to $54.9 billion).

Moreover, a growing proportion of patents are citing S&E literature on their cover pages. This indicates an

Figure O-20

Share of articles authored at U.S. academic institutions that have authors from multiple U.S. institutions: Selected years, 1990–2012



NOTES: Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles are classified by the year they entered the database, rather than their year of publication, and are assigned to the U.S. academic sector on the basis of the institutional address(es) listed in the article. All article authors have U.S. academic institutional addresses.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, and The Patent Board,™ special tabulations (2013) from Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/.

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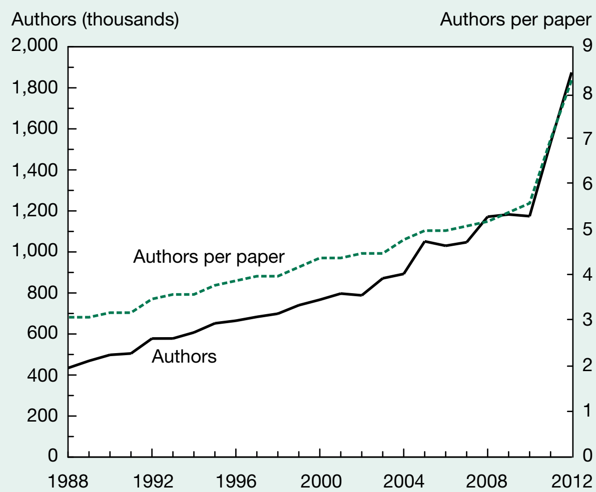
Figure O-21

Number of authors and authors per paper for U.S. academic institutions: 1988–2012



NOTES: Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles are classified by the year they entered the database, rather than their year of publication, and are assigned to the U.S. academic sector on the basis of the author institutional address(es) listed in the article. All articles have at least one U.S. academic institutional address. Authors counted are individual author names on each article, and an individual author name is counted each time it appears in the dataset.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, and The Patent Board,™ special tabulations (2013) from Thomson Reuters, SCI and SSCI, http://thomsonreuters.com/products_services/science/.

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increasing connection between higher education and the institutions that translate research findings into commercial innovations. Of patents awarded to both U.S. and foreign assignees, 12% cited S&E articles in 2003, and that share grew to 15% in 2012.

Just as academic research is increasingly interconnected both nationally and globally, business R&D has also been developing more international and interorganizational linkages. The rise in these kinds of linkages has coincided with the decline of large research organizations, such as Bell Labs, that performed fundamental research inside major corporations and with a concomitant drop in research publications attributed to industry (from 15,614 to 11,779 between 1990 and 2012).

U.S. Higher Education

Institutions of higher education are responsible for S&E education and training and perform the majority of U.S. basic research. In these respects, the functions of the higher education system have remained largely unchanged in recent decades.

The organization of higher education, however, has undergone significant modifications, including changes in the opportunity structure for research doctorate holders. Over the past 20 years, there has been a declining ratio of tenured to nontenured positions, even as the professoriate has aged substantially.[9] Growth in the numbers of individuals in other positions—including academic postdoctorates and nontenured full- and part-time positions—has been substantial.

Between 1995 and 2010, the proportion of S&E faculty in academia reporting research as their primary job activity edged up slightly (from 33% to 36%), and the share of those identifying teaching as their primary activity fell from 54% to 47%. Further evidence of the growing importance of research in the U.S. academic sector can be seen in the growth of research expenditures in general and in revenues from federal appropriations, grants, and contracts.

In public very high research universities,[10] inflation-adjusted research expenditures grew by about 150%, and revenues from federal awards grew by about 190% in the same period. In private very high research universities, the corresponding growth rates were approximately 160% and 140% (figure O-22).

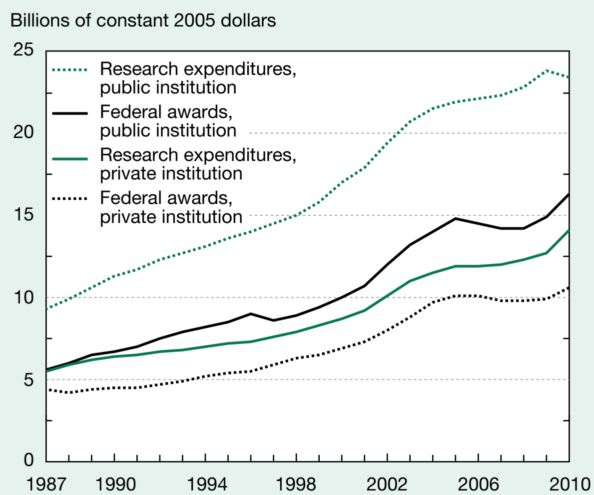
Historically, the training of the next generation of highly skilled researchers in S&E has been concentrated in doctorate-granting institutions with very high research activity. It still is, but to a lesser extent than it once was. In 2011, these institutions awarded 74% of doctoral degrees, 42% of master's degrees, and 38% of bachelor's degrees in S&E fields. That is down from 94% (doctoral), 55% (master's), and 45% (bachelor's) in 1998. The change suggests a growing role in advanced S&E education for higher education institutions that are less centrally research- and S&E-oriented.

In addition, higher education institutions that are primarily oriented toward teaching, such as community colleges, play an important role in preparing students for advanced training in S&E. One-fifth of all U.S. citizens or permanent residents who received a doctoral degree from 2007 to 2011 had earned some college credit from a community or 2-year college. Moreover, the share of bachelor's degree recipients with at least some credit from community colleges increased from 43% in 1999 to 49% in 2010 (figure O-23).

Revenue and expenditure patterns for higher education institutions have also undergone significant changes over the last two decades. Between 1987 and 2010, state and local appropriations per full-time equivalent (FTE) enrolled student at public universities fell by more than 25% on average after adjusting for inflation. At the same time, inflation-adjusted net student tuition per FTE student more than doubled at these universities, in effect replacing public sources of funding with private ones. Tuition and fees for public colleges and universities grew faster than median household income during this period (figure O-24).

To acquire revenue to support research and other operating activities, higher education institutions in the United States increasingly tapped sources such as higher tuition rates that generate revenues from students from more-affluent families, foreign students who pay full tuition, and outside grant support for research activities. Increasing grant receipts, however, do not necessarily cover the full costs of grant administration, especially in S&E areas, such as biomedical research, for which universities must

Figure O-22
Federal awards and research expenditures at very high research activity institutions, by institutional control: 1987–2010



NOTES: Gross domestic product implicit price deflators are used to convert current dollars to constant 2005 dollars. Very high research activity institutions are designated by the 2005 Carnegie classification code. See The Carnegie Classification of Institutions of Higher Education, http://classifications.carnegiefoundation.org/index.php.

SOURCES: IPEDS Analytics: Delta Cost Project Database: 1987–2010 and National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2013) of the Higher Education Research and Development Survey.

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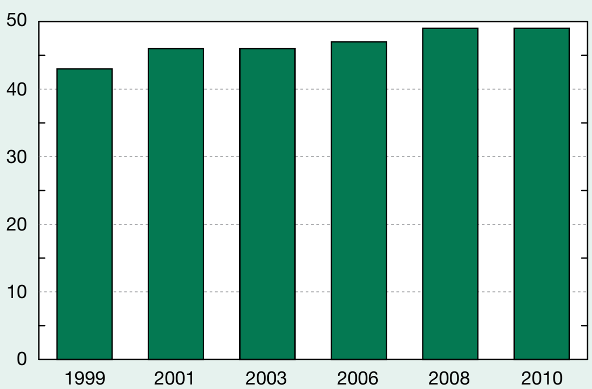
bear the significant costs of monitoring compliance with research regulations.

Finally, among various long-term changes, one feature of the higher education research landscape shows remarkable continuity. The bulk of R&D expenditures in the United States are concentrated among a small number of research-intensive institutions, and the extent of this concentration has remained very consistent over the last two decades, even as the identity of the institutions in the top groups has changed. In FY 2012, the top 10 institutions in terms of R&D performance accounted for 18.0% (18.8% in FY 1989), the top 20 for 30.6% (32.5%), and the top 100 for 78.8% (82.0%).

Figure O-23
Community college attendance among recent S&E bachelor's recipients: 1999–2010



NOTES: Recent graduates are those who earned degrees in the 2 academic years preceding the survey year or, for the 2006 survey year, in the 3 preceding academic years. For 2006, recent graduates are those who earned degrees between 1 July 2002 and 30 June 2005.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2010) of the National Survey of Recent College Graduates.

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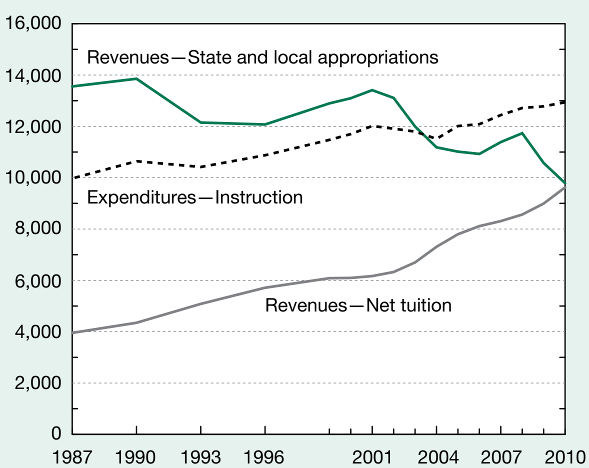
Figure O-24
Selected average revenues and expenditures at public very high research universities: 1987–2010



NOTE: Data are per full-time equivalent student.

SOURCE: IPEDS Analytics: Delta Cost Project Database, 1987–2010, special tabulations (2013).

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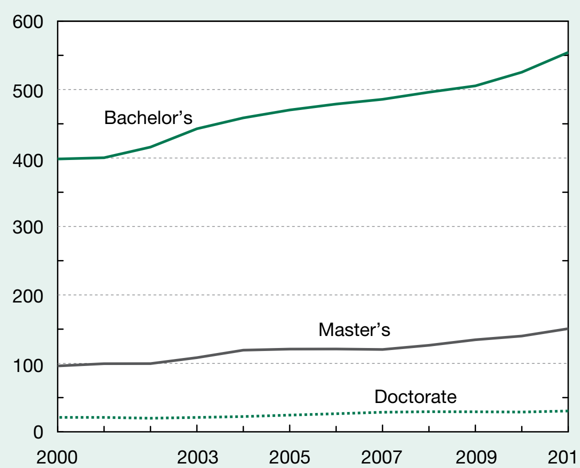
Degree Production

With the growth of a knowledge economy over recent decades, a larger number of U.S. students are getting S&E degrees and eventually finding jobs in S&E occupations. Between 2000 and 2011, there were sizeable increases in the number of earned S&E degrees at the bachelor's (+39.1%), master's (+56.6%), and doctoral levels (+35.5%) (figure O-25). These increases were similar to the corresponding increases for degrees in all fields in the same period—38.2% (bachelor's), 60.1% (master's), and 33.2% (doctoral).

As the number of S&E bachelor's degrees has grown steadily over the past 15 years (with a new peak of over half a million in 2011 [figure O-26]), increasing proportions of the graduates earning those degrees have been women or members of racial and ethnic minorities (figure O-27). Since the late 1990s, about 57% of all bachelor's degrees and half of all S&E degrees have been awarded to women. Percentages of S&E degrees awarded to women are highest

Figure O-25
S&E degrees, by level: 2000–11



NOTES: Data are based on degree-granting institutions eligible to participate in Title IV federal financial aid programs and do not match previously published data from *Science and Engineering Indicators 2008* and earlier years that were based on accredited higher education institutions. S&E doctorates exclude other health sciences because of changes in doctoral categories in the source data.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System, http://webcaspar.nsf.gov.

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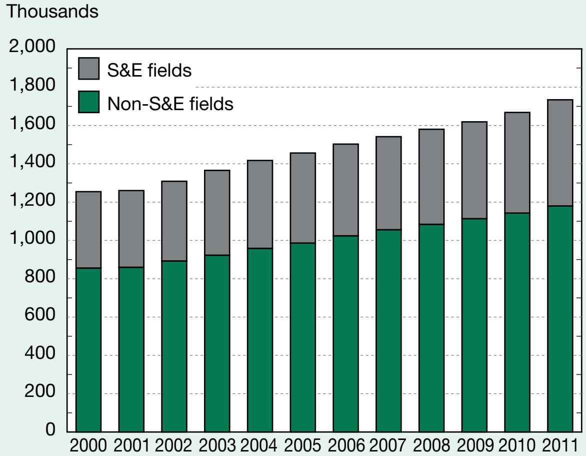
Figure O-26
Bachelor's degrees, by broad field of degree: 2000–11



SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System, http://webcaspar.nsf.gov.

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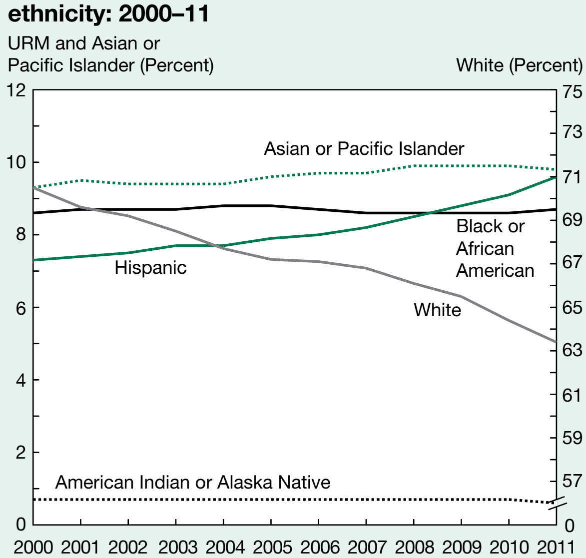
Figure O-27
Share of S&E bachelor's degrees among U.S. citizens and permanent residents, by race and ethnicity: 2000–11



URM = underrepresented minorities (black, Hispanic, and American Indian or Alaska Native).

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian or Pacific Islander, black or African American, and white refer to individuals who are not of Hispanic origin. Percentages do not sum to 100 because data do not include individuals who did not report their race and ethnicity.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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in the biological, agricultural, and social sciences and in psychology. At the same time, for all racial and ethnic groups, the total number of bachelor's degrees earned, the number of S&E bachelor's degrees earned, and the number of bachelor's degrees in most S&E fields (except computer science) have generally increased since 2000.

For over 20 years, about one-third of U.S. bachelor's degrees have been awarded in S&E fields. Likewise, the distribution of degrees across S&E fields remained remarkably similar between 2000 and 2011. Percentages of bachelor's degrees in S&E were almost unchanged in engineering (about 14% in both years), biological and agricultural sciences (21%), and psychology (18%). Physical sciences (3.7% in 2000; 3.5% in 2011) and mathematics (2.9% in 2000; 3.3% in 2011) also did not exhibit major changes. Social sciences experienced a slight increase (28.5% in 2000; 31.1% in 2011) and computer sciences a small decrease (9.4% in 2000; 7.9% in 2011).

Demographics of the U.S. S&E Labor Force

Although the demographics of persons receiving S&E training and entering the S&E labor force remain quite different from those of the general U.S. population, there has been some general movement toward more diversity of participation in S&E occupations. Proportions of workers in minority groups have increased, while the percentage of whites has dropped from 84% in 1993 to 70% in 2010.

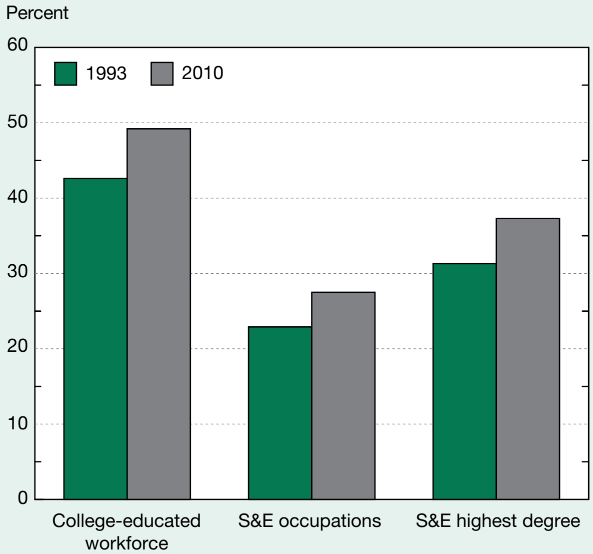
While women represent half of the college-educated workforce, they are underrepresented in the S&E workforce. In 2010, women accounted for only 37% of employed individuals with a highest degree in an S&E field and 28% of employed individuals in S&E occupations. Yet, these percentages represent increases since 1993, when the comparable figures were 31% and 23%, respectively (figures O-28 and O-29).

S&E participation has also risen over time among racial and ethnic minorities, particularly among Asians but also, to a lesser degree, among Hispanics and blacks (figure O-30). Despite this increase, participation varies substantially across groups. In 2010, Asians worked in S&E occupations at much higher rates (19%) than their representation in the general U.S. population (5%), whereas historically underrepresented racial and ethnic groups, particularly blacks and Hispanics, represented a much smaller proportion of the S&E workforce than their share of the U.S. population. In total, Hispanics, blacks, and American Indians or Alaska Natives account for 26% of the U.S. population age 21 and over but only for 10% of workers in S&E occupations and for 13% of S&E highest degree holders. In comparison, in 1993, Hispanics and blacks accounted for 7% of workers in S&E occupations, 8% of S&E highest degree holders, and 9% of the college-degreed workforce.

The share of workers holding a bachelor's degree or above in S&E occupations who are foreign born has increased over the last decade. Among college-educated S&E workers, the foreign-born share increased from 22.4% in 2000 to 26.2% in 2011 (figure O-31). The percentage of workers with a doctorate who are foreign born increased from 37.6% in 2000 to 43.2% in 2011. For holders of bachelor's and master's degrees, the changes were, respectively, from 16.5% to 19.0% and from 29.0% to 34.3% between 2000 and 2011.

Among foreign-born individuals with S&E doctorates living in the United States in 2010, slightly more than

Figure O-28
Women in the workforce and in S&E: 1993 and 2010



SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) and National Survey of College Graduates (NSCG) (1993 and 2010), http://sestat.nsf.gov.

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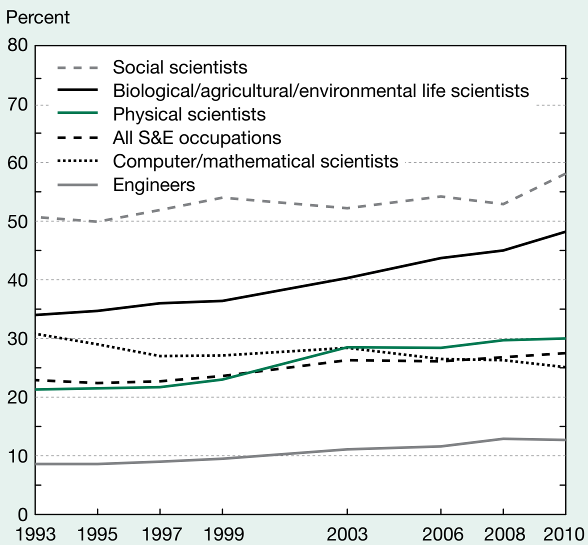
Figure O-29
Women in S&E occupations: 1993–2010



NOTE: National estimates were not available from the Scientists and Engineers Statistical Data System (SESTAT) in 2001.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (1993–2010), http://sestat.nsf.gov.

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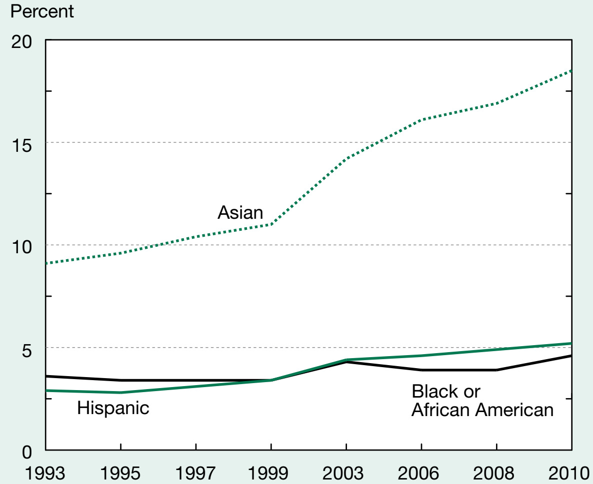
Figure O-30
Share of workers in S&E occupations, by selected race and ethnicity: Selected years, 1993–2010



NOTES: Before 2003, Asian included Native Hawaiians and Other Pacific Islanders. Hispanic may be any race. Asian and black or African American refer to individuals who are not of Hispanic origin.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (1993–2010), http://sestat.nsf.gov.

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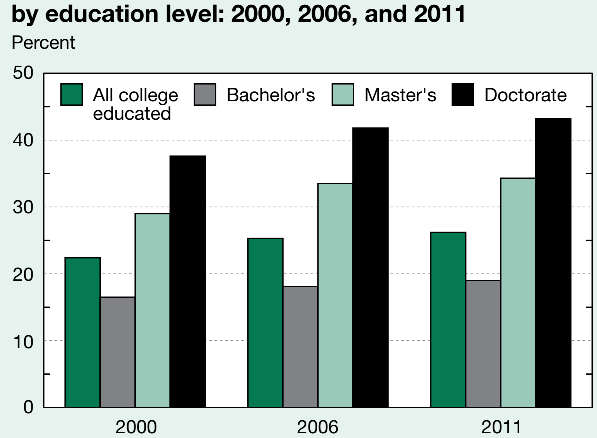
Figure O-31
Foreign-born workers in S&E occupations, by education level: 2000, 2006, and 2011



NOTES: All college educated includes professional degrees not broken out separately. These data include all S&E occupations except postsecondary teachers because these occupations are not separately identifiable in the source data files.

SOURCES: Census Bureau, 2000 Decennial Census Public Use Microdata Sample (PUMS), and American Community Survey (2006, 2011).

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one-third were born in China (23%) and India (13%) (figure O-32). After rising for most of the 2000–09 decade, the number of foreign recipients of U.S. S&E doctoral degrees declined in 2009 and 2010. Newer data indicate a slight increase, suggesting that the decline may have been temporary.

R&D Funding

Of the more than $420 billion of U.S. R&D funding, over 90% comes from either the business sector (63% in 2011) or the federal government (30% in 2011). These proportions have been relatively stable over the last decade (69% and 25%, respectively, in 2000). Consistent with the growing commercial relevance of systematic knowledge, business sector funding as a proportion of overall R&D funding increased rapidly for over 30 years beginning in 1965. In the last two decades, however, federal funding has also increased substantially, and the ratio between U.S. federal and business sector R&D funding has been relatively stable, with U.S. federal funding being somewhat less than half the size of business sector spending on R&D since the mid-1990s. Thus, although federal funding as a proportion of national R&D had declined during the decades following World War II, the federal government has continued to fund a large and generally stable share of national R&D over the last decade (figure O-33).

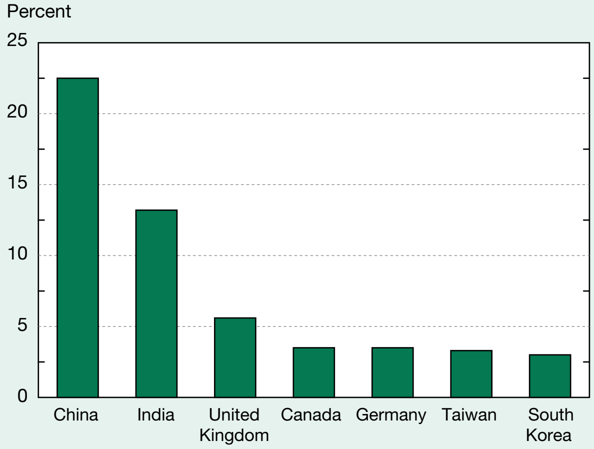
During the last two decades, the division in national R&D among basic research, applied research, and development has also been fairly stable (18%, 19%, and 63%, respectively, in 2011). Different institutions tend to perform different kinds of R&D projects. In 2011, the business sector was the largest performer of R&D activities in the United States (70%) because it performed most of U.S. applied research (57%) and development (88%). It executes relatively little basic research (17% in 2011). The academic sector, which performed only 15% of national R&D in 2011, in contrast, accounted for most U.S. basic research (55%).

In many respects, federal funding patterns show substantial continuity. Thus, the Department of Defense has continually accounted for more than half of annual federal R&D spending. Likewise, federal funding consistently has been the main source of funding for academic R&D. Over the last decade, the federally funded proportion of R&D at public academic institutions increased from 52% (1999) to 58% (2012). At private institutions, it remained roughly constant, at or around 72% (figure O-34). For all academic institutions, the share of academic R&D expenditures that is funded by the institutions themselves has increased substantially over the last four decades. It grew from about 12% in 1972 to approximately 19% in 1990 and has remained relatively stable since then.

Federal R&D spending over the last two decades has changed substantially in one respect: health-related R&D has grown sharply, going from 12% of total federal R&D budget authority in FY 1980 to 22% in FY 2011. A corresponding major shift has occurred in the distribution of academic R&D expenditures among S&E fields, which has moved away from physical sciences and toward the life sciences. Data on research space at academic institutions and publications likewise reflect a more dominant role for life sciences in academic R&D.

During the international financial crisis that started in late 2008, the three institutional sectors mainly responsible

Figure O-32
Foreign-born individuals with highest degree in S&E living in the United States, by place of birth: 2010



NOTE: Only countries/economies with shares of 3% or more are shown.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (2010), http://sestat.nsf.gov.

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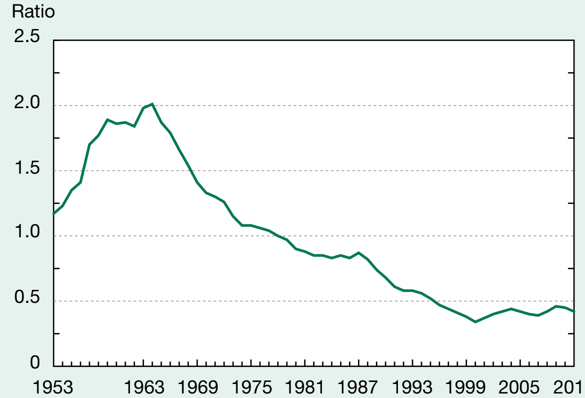
Figure O-33
Ratio of U.S. federal-to-nonfederal funding for R&D: 1953–2011



NOTE: Federal R&D/gross domestic product ratios represent the federal government as a funder of R&D by all performers; the nonfederal ratios reflect all other sources of R&D funding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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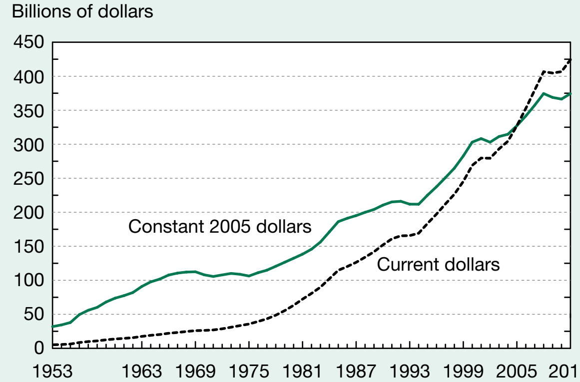
for R&D funding and performance—business, universities and colleges, and the federal government—faced budgetary challenges. Many businesses were unable to secure credit or were unwilling to make investments in view of uncertainty about the length and the intensity of the economic downturn. Universities and colleges faced steep budget cuts, prompted by declining state appropriations or shrinking endowments. Along with many governments across the world, the federal government took on unexpected and unprecedented financial commitments to guarantee the integrity of the international and national financial systems.

Consequently, R&D investments in all three sectors were curtailed and broke away from their long-term growth trend. In the United States, for the first time in 50 years, R&D expenditures remained stagnant in 2009 (figure O-35). The main reason for this was a sharp reduction in business R&D. The overall national impact was tempered by the infusion of American Recovery and Reinvestment Act of 2009 (ARRA) R&D funding during the depths of the downturn. After ARRA funding subsided, business R&D growth led a rebound in overall national R&D. Figure O-36 illustrates the expenditures by various R&D funding sectors over the 5 years ending in 2011 (figure O-36).

While R&D expenditures have recovered to some extent, the deviation from the overall long-term trend remains discernible in the data. Adjusted for inflation (in 2005 dollars), R&D expenditures in the United States for 2011 ($374.4 billion) were about the same as in 2008 ($374.5 billion).

Figure O-35
U.S. total R&D expenditures: 1953–2011



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-2.

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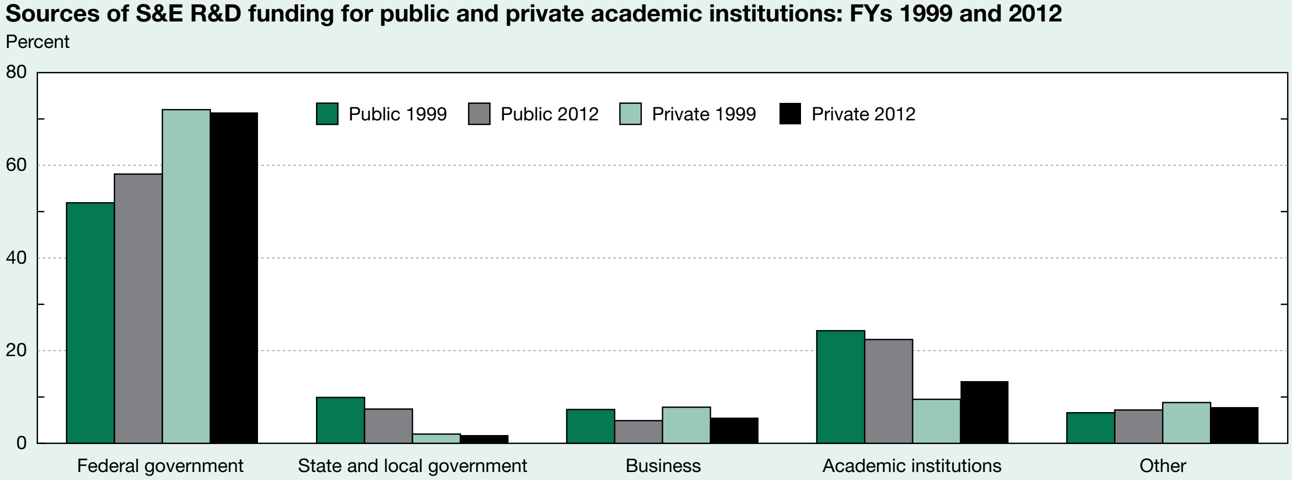
Figure O-34
Sources of S&E R&D funding for public and private academic institutions: FYs 1999 and 2012



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Academic Research and Development Survey and the Higher Education Research and Development Survey (various years).

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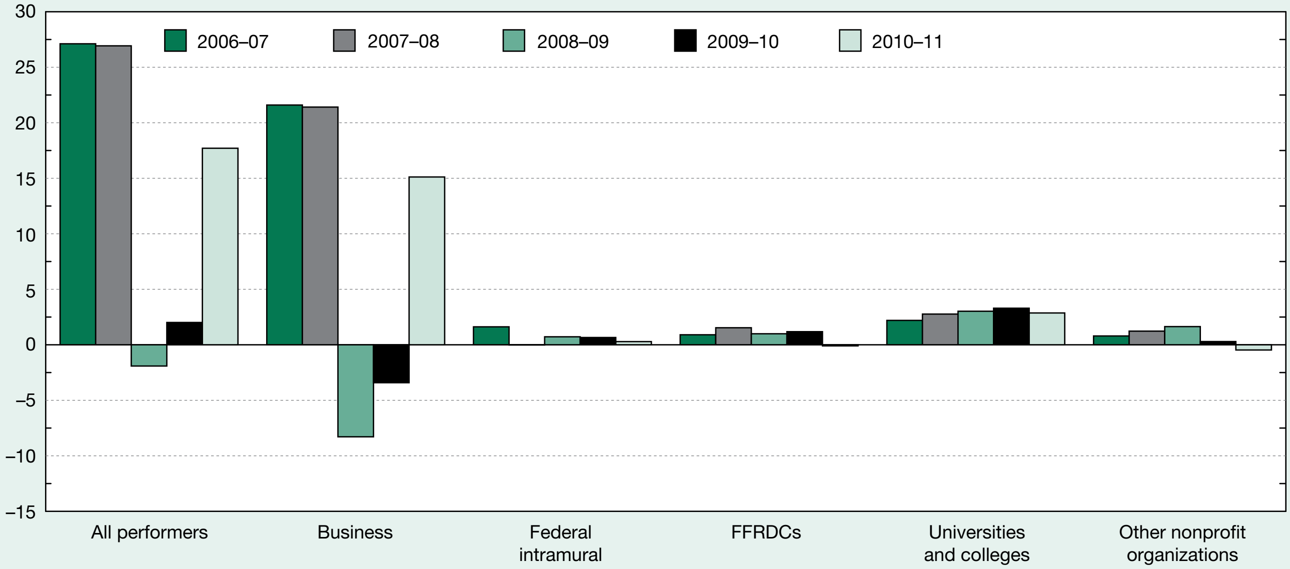
Figure O-36
Year-to-year changes in U.S. R&D expenditures, by performing sector: 2006–11



FFRDC = federally funded R&D center.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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Conclusion

In recent decades, the implications of investment in science and engineering and in knowledge- and technology-intensive industries for economic prosperity have become increasingly important. This is indicated by the rise in knowledge- and technology-intensive production and trade and by increased investments in R&D across the world.

The global economic downturn had a significant impact on S&E-related trends, especially in developed economies. Its effects included increased funding uncertainty affecting R&D activities and changes in institutions of higher learning, such as more reliance on nontenured positions. During the downturn, economic activity involving S&E increased in the developing world, continuing the gradual shift in the world's knowledge-based economic activity toward developing nations and away from developed ones. The increase was pronounced in Asia but also notable in other parts of the developing world. Knowledge-intensive services in developing countries grew rapidly, especially in China.

U.S. knowledge- and technology-intensive industries, as well as the U.S. economy generally, weathered the global economic downturn better than comparable industries and economies in the EU and Japan. Smaller, more recently developed economies in South Korea and Taiwan also withstood the downturn relatively well.

Concurrent with the downturn, several emerging economies demonstrated significant growth in scientific output, as measured by publications and patents. The growth in publication output in China was striking, and the influence of China's publications also increased. In addition, rapid growth (6%–9% average annually) in three other Asian locations—South Korea, Taiwan, and Singapore—also reduced the global share of S&E publication by the United States, the EU, and Japan.

Recently developed economies are becoming better positioned to challenge the S&E leadership of developed economies. Economies such as South Korea, Taiwan, and Singapore, with their emphasis on high-quality education, are poised to narrow the gap. China, with a per capita income comparable to other developing countries, is unique among developing countries in having a global presence in knowledge- and technology-intensive economic activity and R&D performance that is comparable to or exceeds that of most long-standing developed countries.

As the world economy has changed, the U.S. S&E enterprise has also undergone substantial changes in the last two decades. The recent economic downturn disturbed the continuity of trends that had characterized the major institutions that fund and perform U.S. R&D and that provide advanced training in S&E. Such breaks in long-term patterns included lower R&D investments by businesses as well as slightly decreased stay rates of foreign recipients of advanced S&E degrees. However, many of those developments appear to have been temporary, and there are signs of a return to pre-downturn patterns and trends.

Nevertheless, the ongoing economic recovery has brought with it indications of emerging changes in S&E education and R&D. Potentially disruptive developments include the emergence of massive open online courses as an avenue for trying to reduce the cost of higher education and the continuing R&D budget uncertainty that accompanies a difficult fiscal environment.

As more countries around the world develop R&D and human capital infrastructure to sustain a knowledge-oriented economy, the United States, not surprisingly, is playing a less dominant role in many areas of S&E-related activity. However, it remains the world's leading nation in numerous indicators of S&E activity, such as high-value patenting, that can have a large impact on innovation and economic growth. Moreover, the increasing interconnectedness of both the global economy and the international scientific community may provide opportunities for improvements in U.S. S&E and the U.S. economy and also for increased sharing of the gains of international R&D.

Notes

1. Countries classified by the World Bank as high income are developed countries, while those classified in the other income levels—upper middle income, lower middle income, and low income—are classified as developing. Russia, which the World Bank recently classified as a developed country, reported a substantially higher proportion (54%) of KTI activity in its economy in 2012 than the United States. However, large year-to-year fluctuations in Russian estimates (e.g., from 30.7% in 2005 to 38.9% in 2006) strongly suggest that these data are not reliable.

2. The East and Southeast Asia region includes China, Indonesia, Japan, Malaysia, Singapore, South Korea, Taiwan, and Thailand.

3. The rapid decline in this measure for China in 2008–09 is due to a methodological change. Since 2009, China has collected data on researchers using the international statistical system definition of researcher in the OECD *Frascati Manual*, whereas earlier Chinese data often used a more expansive United Nations Educational, Scientific and Cultural Organization (UNESCO) concept (see [OECD 2012:29]).

4. Changes in data collection practices in South Korea and China make comparisons of recent data with pre-2006 data (for South Korea) and pre-2009 data (for China) problematic.

5. The Population White Paper published in early 2013 estimates that the number of Singaporeans in "Professional, Managerial, Executive and Technical (PMET) jobs" (NPTD 2013:4), which are roughly equivalent to S&E occupations, is expected to rise by nearly 50% to about 1.25 million, compared to 850,000 today.

6. The article counts, coauthorships, and citations discussed here are derived from publications data recorded by the Science Unit of Thomson Reuters in the Science Citation Index and Social Sciences Citation Index (http://www.thomsonreuters.com/business_units/scientific/). Chapter 5 (sidebar "Bibliometric Data and Terminology") provides details about how publication indicators are tabulated.

7. If a country receives 10% of the citations in the worldwide scientific literature, its expected number of citations by any given country would be 10% of that country's total citations. Similarly, if a country is credited with authorship of 10% of the world's internationally coauthored articles, it would be expected to coauthor 10% of the international articles attributed to any other country. A more detailed explanation of citation and coauthorship indexes can be found in chapter 5 under the sidebar "Normalizing Coauthorship and Citation Data."

8. In these data, articles are attributed to different U.S. academic institutions only when the authors are from different universities or colleges, not when they come from different units of the same university or college (e.g., the engineering school and the economics department). In contrast, chapter 5 treats all articles whose authors report different institutional addresses as instances of interinstitutional collaboration, even when the addresses are part of the same university. Using the less stringent chapter 5 collaboration indicator, the increase in the proportion of U.S. academic articles involving interinstitutional collaboration shows a similar trend, rising from 34% in 1990 to 51% in 2012. International data in the overview use the chapter 5 collaboration indicator; international data unifying different addresses that can be considered part of the same institution are not currently available.

9. Full-time, tenure-track faculty positions as either senior or junior faculty continue to be the norm in academic doctoral employment. Such positions constituted about 90% of academic doctoral positions in the early 1970s but had dropped to about 80% by the mid-1990s and to about 70% by 2010.

10. The Carnegie Classification of Institutions of Higher Education considers doctorate-granting universities that award at least 20 doctoral degrees per year to be *research universities*. The 2010 Carnegie Classification includes three subgroups of research universities based on the level of research activity: very high research activity (108 institutions), high research activity (99 institutions), and doctoral/research universities (90 institutions).

Glossary

European Union (EU): As of June 2013, the EU comprised 27 member nations: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Croatia joined the EU in July 2013. Unless otherwise noted, Organisation for Economic Co-operation and Development data on the EU include all 28 members; data on the EU from other sources are limited to the 27 nations that were members as of June 2013.

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

Knowledge- and technology-intensive (KTI) industries: They consist of high-technology manufacturing and knowledge-intensive service industries.

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

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Errata

The following errors were discovered after publication of the print and PDF versions of *Science and Engineering Indicators 2014*. These errors have been corrected in the online version of the volume.

Updated 21 April 2014

Science and Engineering Indicators 2014
Overview

Page O-8. The title to figure O-10 listed the years covered incorrectly. The correct range is 2000–10.