Chapter 4.

Research and Development: National Trends and International Comparisons

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Highlights

Recent Trends in U.S. R&D Performance

R&D performed in the United States totaled $427.8 billion (current dollars) in 2011, $435.3 billion in 2012, and $456.1 billion in 2013. In 2008, just ahead of the onset of the main economic effects of the national/international financial crisis and the Great Recession, U.S. R&D totaled $407.0 billion. The total of U.S. R&D performance returned to current dollar increases in 2011, 2012, and 2013.

- Inflation-adjusted growth in total U.S. R&D averaged only 0.8% annually over the 2008–13 period, behind the 1.2% annual average for U.S. gross domestic product (GDP). Even so, the single-year metrics for 2010–11 and 2012–13 were markedly more favorable than this 5-year average: 2.7% in real growth for total R&D in 2010–11 versus 1.6% for GDP; 3.2% for R&D in 2012–13 versus 2.2% for GDP.
- By comparison, the growth of U.S. R&D averaged 3.9% annually in 2003–08, ahead of GDP at 2.2%, and over 1993–2003, U.S. R&D growth averaged 3.9% compared with GDP at 3.4%. On this basis, the R&D growth figures in 2010–11 and 2012–13 were more like those before 2008, but the longstanding U.S. trend of substantial real growth annually in R&D, well ahead of the pace of GDP, still has not returned.

The business sector continued to account for most of U.S. R&D performance and U.S. R&D funding.

- The business sector performed $322.5 billion of R&D in 2013, or 71% of the U.S. total, drawing on business, federal, and other sources of R&D funding. The business sector itself provided $297.3 billion of funding for R&D in 2013, or 65% of the U.S. total, most of which supported R&D performed by business. The level of business R&D noticeably declined in 2009 and 2010, compared with the 2008 level but returned to an expansionary path in 2011, 2012, and 2013. Even with these declines, business R&D performance has continued to account for most of the nation's R&D growth over the last 10 years.
- The academic sector was the second-largest performer of U.S. R&D, accounting for $64.7 billion in 2013, or about 14% of the national total.
- The federal government was the second-largest funder of U.S. R&D, accounting for an estimated $121.8 billion, or 27% of U.S. total R&D performance in 2013.

Most of U.S. basic research is conducted at universities and colleges and is funded by the federal government. However, the largest share of U.S. total R&D is development, which is mainly performed by the business sector. The business sector also performs the majority of applied research.

- In 2013, basic research was about 18% ($80.5 billion) of total U.S. R&D performance, applied research was about 20% ($90.6 billion), and development was about 63% ($285 billion).
- Universities and colleges historically have been the main performers of U.S. basic research, and they accounted for about 51% of all U.S. basic research in 2013. The federal government remained the largest funder of basic research, accounting for about 47% of all such funding in 2013.
- The business sector was the predominant performer of applied research, accounting for 56% of all U.S. applied research in 2013. Business also provided 51% of the funding for the applied research total, with most of this support remaining within the sector. The federal government accounted for 37% of the funding.
- Development was by far the largest component of U.S. R&D. The business sector performed 88% of it in 2013 and provided 81% of the funding. Federal funding accounted for only 18% of this, with the business

sector (especially defense-related industries) and federal intramural laboratories being the largest recipients.

Cross-National Comparisons of R&D Performance

Worldwide R&D performance totaled an estimated $1.671 trillion in 2013, up from $1.269 trillion in 2008 and $836 billion in 2003. Fifteen countries/economies expended $19 billion or more on R&D in 2013, accounting for 86% of the global total. The top rankings at present are dominated by the United States and China.

- The United States remained the largest R&D-performing country in 2013, with total expenditures of $456.1 billion, a 27% share of the global total, and an R&D/GDP ratio of 2.7%. China was a decisive second, with R&D expenditures of $336.5 billion, a 20% global share, and an R&D/GDP ratio of 2.0%.
- Japan ($160.2 billion, 10% global share, ratio of 3.5%) and Germany ($101.0 billion, 6% global share, ratio of 2.9%) were the comparatively distant third and fourth. The other 11 countries/economies in the top 15 were South Korea, France, Russia, the United Kingdom, India, Taiwan, Brazil, Italy, Canada, Australia, and Spain—with the annual national R&D expenditure totals ranging from about $69 billion (South Korea) down to $19 billion (Spain).
- Total global R&D doubled (current dollars) from 2003 to 2013. About 20% of this increase reflected the growth of U.S. R&D over this period, 16% from the European Union (EU) as a whole (including Germany, France, and the United Kingdom, as well as 5%–6% each from Japan and South Korea). Nonetheless, the largest contributor by far was China, accounting for nearly 34% of the decade increase. The pace of growth over the decade in China's overall R&D remained exceptionally high, at just under 20% annually (or around 17% adjusted for inflation).
- Regionally, the U.S. share of worldwide R&D was notably higher in 2003 (35%) but continued to decline over the subsequent 10 years (down to 27% in 2013). The EU also exhibited a decline over the same period: from 25% of the global total in 2003, down to 20% in 2013. The expansion was clearly within the economies of East/Southeast and South Asia—including China, Japan, South Korea, India, and Taiwan—which represented 27% of the global R&D total in 2003, rising to about 40% in 2013.

U.S. Business R&D

The business sector is by far the largest performer in the U.S. R&D system. R&D is performed across a wide range of manufacturing and nonmanufacturing sectors. R&D intensity is concentrated, however, in a few industries.

- The R&D performed domestically by U.S. businesses occurs mainly in five business sectors: chemicals manufacturing (particularly the pharmaceuticals industry); computer and electronic products manufacturing; transportation equipment manufacturing (particularly the automobiles and aerospace industries); information (particularly the software publishing industry); and professional, scientific, and technical services (particularly the computer systems design and scientific R&D services industries).
- In 2013, these five business sectors accounted for 82% of the $322.5 billion of total domestic business R&D performance that year. Similarly, in 2008, the five sectors accounted for 84% of the business total.
- Considering U.S. business as a whole, domestic R&D is mainly funded through performing companies' own funds: 82% in 2013 (and similar shares for recent years). For the remaining 18%, where the R&D is performed by companies but funded by others, the largest source of funding is the federal government, whose funding accounted for about 9% of the business R&D performance total in 2013. Other companies

located domestically provided about 4% of the funding; foreign companies also provided about 4% of the funding. Nonfederal governments and both domestic and foreign nonprofit organizations also were sources, but at very small levels. (Some notable departures from these aggregate average shares occur when specific sectors and industries are considered.)

- Large companies (those with 25,000 or more domestic employees) accounted for 37% of all U.S. business R&D performance in 2013. Small companies (those with fewer than 500 domestic employees) accounted for 16%. This distribution of business R&D performance share by size has not greatly changed in recent years.

Recent Trends in Federal Support for U.S. R&D

Federal funding for the R&D performed by federal departments and agencies, as well as most of the other major U.S. R&D performers, increased annually (in both current and constant dollar terms) from the late 1990s through FY 2010. In the several years since, however, the levels of this federal support have dropped noticeably.

- Federal obligations for the total of R&D and R&D plant were $129 billion in FY 2008, $145 billion in FY 2009, and $147 billion in FY 2010. But the years thereafter have been mostly marked by funding declines: FYs 2011 and 2012 were down $6–$7 billion from the FY 2010 peak and then declined further to $127 billion in FY 2013. In FY 2014, the total increased to $131 billion. Nonetheless, the drop from the FY 2010 level to that in FY 2014 is a current dollar decline of 11%—and when inflation is factored in, it is steeper still, at 17%.
- Fifteen federal departments and 12 other agencies engage in and/or fund R&D in the United States. Seven of these departments/agencies reported R&D obligations in FY 2013 in excess of $1 billion: the U.S. Department of Agriculture (USDA), the Department of Commerce (DOC), the Department of Defense (DOD), the Department of Energy (DOE), the Department of Health and Human Services (HHS), the National Science Foundation (NSF), and the National Aeronautics and Space Administration (NASA). These together accounted for 97% of all federal obligations for R&D that year.
- DOD has historically accounted for well over half of annual federal R&D funding. Health-related R&D accounts for the majority of federal nondefense R&D funding. DOD and HHS have borne the brunt of the federal R&D funding decline since FY 2010, with the other nondefense categories being notably less affected.

Federal Programs to Promote the Transfer and Commercialization of Federal R&D

The federal government has been active since the early 1980s in establishing policies and programs to improve the transfer and economic exploitation of the results of federally funded R&D.

- The data show continued active use by the federal departments/agencies accounting for the largest portion of federal R&D (including USDA, DOC, DOD, DOE, HHS, and NASA) of the technology transfer authorities provided by the Stevenson-Wydler Technology Innovation Act of 1980 and the subsequent amplifying legislation.
- Federal funding to small, entrepreneurial companies engaged in R&D with eventual commercialization objectives, through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, is now considerably larger than when these programs were first initiated in the early 1980s and the mid-1990s, respectively. At its start in FY 1983, the SBIR program (across all

participating agencies) made 789 awards (all Phase I) for a total of $38 million in funding; in FY 2013, 4,452 awards (Phases I and II) were made, with funding totaling $1.772 billion. For STTR, the program started in FY 1995, with a single Phase I award for $100,000. In FY 2013, 640 STTR awards (Phases I and II) were made, with funding totaling $206 million.

- Furthermore, beyond these well-known programs and authorities with essentially federalwide application, particular departments/agencies have their own technology transfer and early-stage development programs more narrowly directed at their own mission objectives. Notable here are DOC's Hollings Manufacturing Extension Partnership, DOE's Advanced Research Projects Agency–Energy, and NSF's Industry/University Cooperative Research Centers Program.

Introduction

Chapter Overview

The discovery of new knowledge, technological advances that improve on what we can already do or expand the horizon of the possible, and their creative exploitation have become ever more essential for success in the competitive global economy. The strength of a country's overall R&D enterprise—from both the public and private realms of this system—serves as an important marker of current and future national economic advantage.

This chapter identifies the key recent developments in the current performance and funding of the U.S. R&D system. The discussion covers the sectors mainly responsible for present U.S. R&D performance and funding: the business sector, federal government, nonfederal government, universities and colleges, and other nonprofit organizations. At numerous points, the chapter directly contrasts these U.S. R&D indicators with broadly comparable data from the world's other major economies.

Chapter Organization

This chapter is organized into five principal sections on the following discussion topics: the recent trends (particularly over the last 5 to 10 years) in overall U.S. R&D performance, comparison of U.S. R&D performance to that of other leading countries, the U.S. business sector's large role in the nation's overall R&D activity, the federal government's roles in supporting and conducting U.S. R&D, and an examination of federal programs and policies promoting the transfer and commercialization of federal R&D.

Recent Trends in U.S. R&D Performance

The U.S. R&D system consists of the R&D activities of a number of differing performers and sources of funding. Included here are private businesses, the federal government, other government (nonfederal) organizations, universities and colleges, and nonprofit organizations. The organizations that perform R&D often receive significant levels of outside funding; furthermore, those that fund R&D may also be significant performers. This section discusses the current levels and notable recent trends in overall U.S. R&D performance and the sources funding these activities. (Definitions for key terms in this section appear in this chapter's glossary. The sidebar Measured and Unmeasured R&D discusses the main sources for the indicator data and analyses in this section of the chapter.)

Measured and Unmeasured R&D

The statistics on U.S. R&D discussed in this section reflect the National Science Foundation's (NSF's) periodic National Patterns of R&D Resources reports and data series, which provide a comprehensive account of total U.S. R&D performance. The National Patterns data, in turn, derive from six major NSF surveys of the organizations that perform the bulk of U.S. R&D:

- Business R&D and Innovation Survey
- Higher Education Research and Development Survey
- Survey of Federal Funds for Research and Development
- Survey of R&D Expenditures at Federally Funded R&D Centers
- Survey of State Government Research and Development
- Survey of Research and Development Funding and Performance by Nonprofit Organizations

The National Patterns analysis integrates R&D spending and funding data from these separate surveys into U.S. R&D performance totals, which are then reported on a calendar year basis and for the main performing sectors and funding sources.

Because of practical constraints in the surveys, some elements of R&D performance are omitted from the U.S. totals. In evaluating R&D performance trends over time and in international comparisons, it is important to be aware of these omissions.

The U.S. business R&D estimates are derived from a survey of R&D-performing companies with five or more employees. No estimates of R&D performance currently are available for companies with fewer than five employees. (NSF is in the process of designing and implementing the Survey of Microbusiness Innovation Science and Technology, which will collect data from companies with fewer than five employees.)

Until recently, the U.S. statistics for business R&D did not include social science R&D, and likewise, R&D in the humanities and other non-S&E fields (such as law) were excluded from the U.S. academic R&D statistics. Other countries include both of these R&D components in their national statistics, making their national R&D expenditures relatively larger when compared with those of the United States. Both of these shortfalls are now addressed in the U.S. statistics. NSF's Business R&D and Innovation Survey—which replaced the previous Survey of Industrial Research and Development, starting with the 2008 data year—includes social science R&D. Also, the Higher Education Research and Development Survey—which replaced the previous Survey of Research and Development Expenditures at Universities and Colleges, starting with the 2010 academic fiscal year—directly includes non-S&E R&D expenditures in the reported academic R&D totals. (The academic R&D totals reported by the National Patterns statistics have been revised back to 2003 to include the non-S&E R&D expenditures.)

The statistics for academic R&D track research expenditures that are separately accounted for in both sponsored research and institutionally funded research. U.S. universities do not report funds for research that are not separately accounted for, such as estimates of faculty time spent on research beyond formally tracked research projects. This can be a limitation in international R&D comparisons because such estimates are often included in the national statistics of other countries.

Likewise, the activity of individuals performing R&D on their own time and not under the auspices of a corporation, university, or other organization is omitted from official U.S. R&D statistics.

Statistics on R&D performed by state governments are collected in a biennial NSF/U.S. Census Bureau survey. Although these data represent small amounts (typically totaling only several hundred million dollars annually), they are now included in the National Patterns totals. Finally, NSF has not fielded a full survey on R&D performance by nonprofit organizations since 1998—the National Patterns performance figures for this sector in the national R&D totals are estimated.

U.S. Total R&D and R&D Intensity

R&D performed in the United States totaled $456.1 billion (current dollars) in 2013 (Table 4-1), compared with $435.3 billion in 2012 and $427.8 billion in 2011. In 2008, just ahead of the onset of the main economic effects of the national/international financial crisis and the Great Recession, U.S. R&D totaled $407.0 billion.

Table 4-1 **U.S. R&D expenditures, by performing sector and source of funds: 2008–13**

Sector	2008	2009	2010	2011	2012	2013[a]
	Current $millions					
All performing sectors	406,952	405,136	408,197	427,833	435,347	456,095
Business	290,680	282,393	278,977	294,092	302,251	322,528
Federal government	45,649	47,363	49,955	52,668	51,318	49,859
Federal intramural[b]	29,839	30,560	31,970	34,950	34,017	33,026
FFRDCs	15,810	16,804	17,985	17,718	17,301	16,833
Nonfederal government	343	405	490	493	468	467
Universities and colleges	53,917	56,972	60,374	62,446	63,284	64,680
Other nonprofit organizations[c]	16,363	18,002	18,401	18,134	18,026	18,561
All funding sources	406,952	405,136	408,197	427,833	435,347	456,095
Business	258,131	246,770	248,314	266,606	275,892	297,279
Federal government	119,113	127,180	127,559	128,039	124,956	121,808

Sector	2008	2009	2010	2011	2012	2013[a]
Nonfederal government	4,257	4,287	4,287	4,355	4,105	4,113
Universities and colleges	11,640	11,917	12,105	12,951	14,136	15,240
Other nonprofit organizations[c]	13,811	14,983	15,932	15,882	16,258	17,655
	Constant 2009 $millions					
All performing sectors	410,043	405,136	403,270	414,122	413,961	427,323
Business	292,888	282,393	275,610	284,667	287,403	302,182
Federal government	45,995	47,363	49,352	50,981	48,797	46,714
Federal intramural[b]	30,066	30,560	31,584	33,830	32,346	30,943
FFRDCs	15,930	16,804	17,768	17,150	16,451	15,771
Nonfederal government	345	405	484	477	445	438
Universities and colleges	54,327	56,972	59,645	60,445	60,176	60,600
Other nonprofit organizations[c]	16,487	18,002	18,179	17,552	17,141	17,390
All funding sources	410,043	405,136	403,270	414,122	413,961	427,323
Business	260,092	246,770	245,317	258,062	262,339	278,525
Federal government	120,017	127,180	126,019	123,936	118,817	114,124
Nonfederal government	4,289	4,287	4,235	4,216	3,904	3,853
Universities and colleges	11,728	11,917	11,959	12,536	13,442	14,278
Other nonprofit organizations[c]	13,916	14,983	15,739	15,373	15,459	16,542

FFRDC = federally funded R&D center.

[a] Data for 2013 include some estimates and may later be revised.

[b] Includes expenditures of federal intramural R&D and costs associated with administering extramural R&D.

[c] Some components of the R&D performed by other nonprofit organizations are projected and may later be revised.

NOTES: Data are based on annual reports by performers, except for the nonprofit sector. Expenditure levels for academic, federal government, and nonfederal government performers are calendar-year approximations based on fiscal year data.

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

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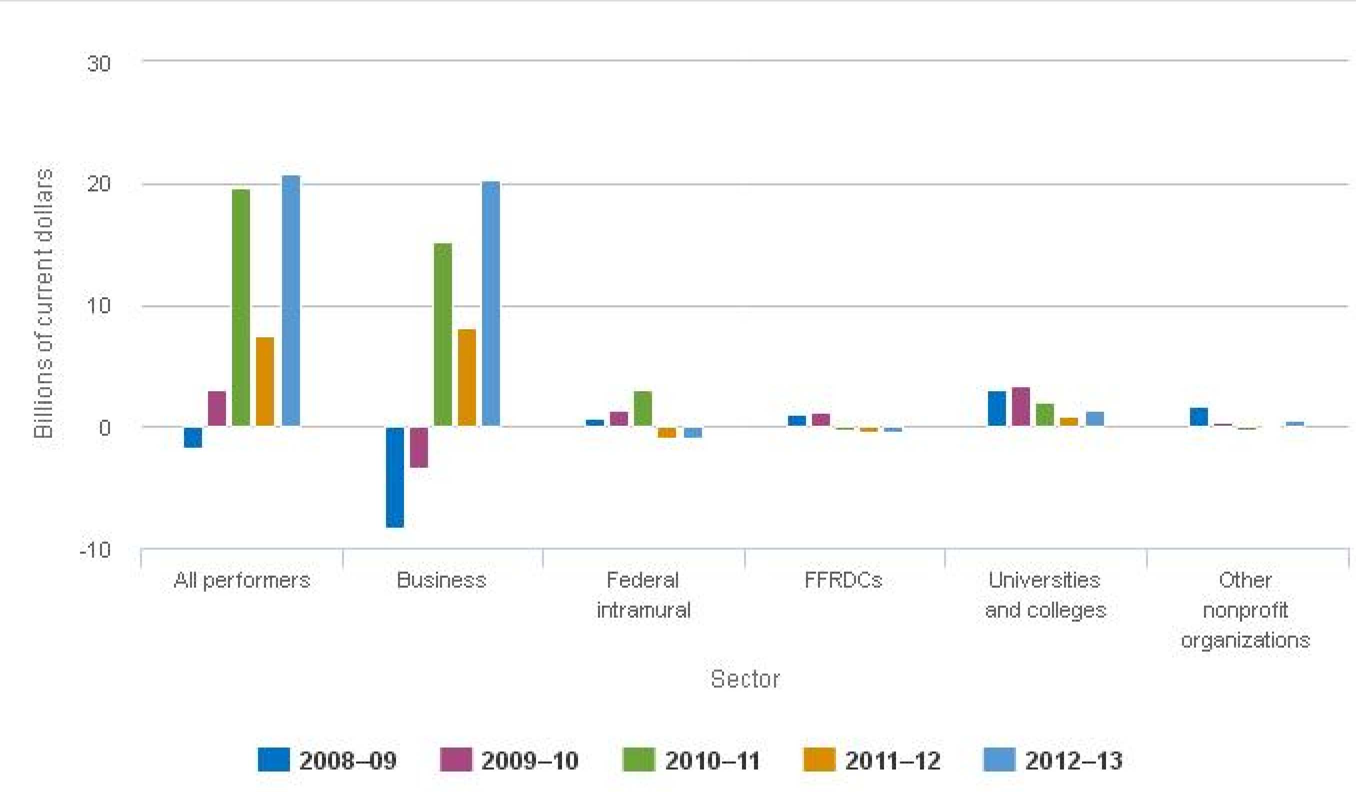
In 2013, U.S. total R&D increased by $20.7 billion over the year-end 2012 level (Figure 4-1). This was in addition to increases of $7.5 billion in 2012 and $19.6 billion in 2011—in contrast to the several billion dollar decline in 2009 and little gain in 2010. As the figure indicates, much of the increase in the U.S. total in these most recent years owes to the return of sizable yearly increases in business R&D performance.

Figure 4-1

Year-to-year changes in U.S. R&D expenditures, by performing sector: 2008–13



FFRDC = federally funded R&D center.

NOTES: Data are calculated from R&D expenditure data reported for performers in table 4-1. Expenditures by nonfederal government performers are negligible, and specific bars for this sector are excluded.

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

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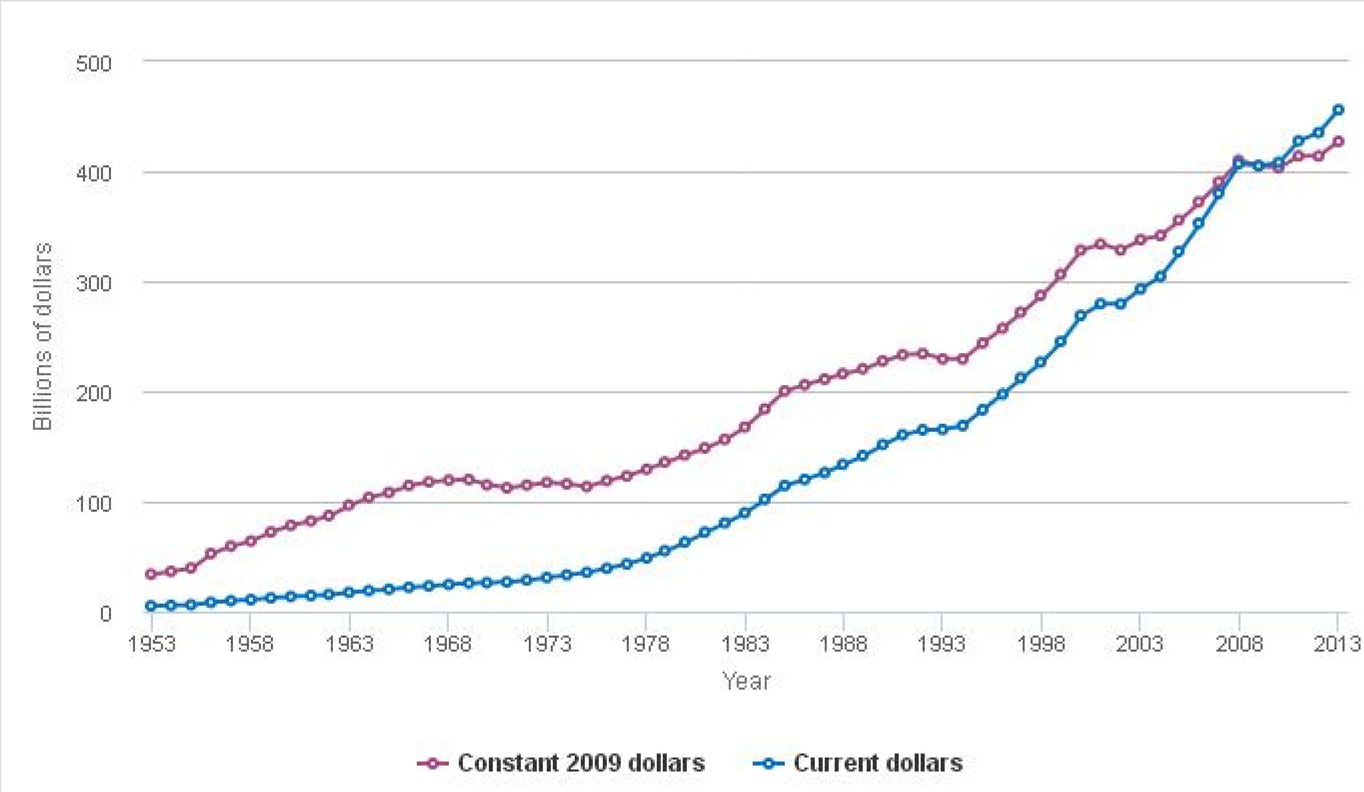
National Science Foundation (NSF) statistics on U.S. R&D performance go back to 1953 (see Appendix Table 4-1, Appendix Table 4-2, Appendix Table 4-3, Appendix Table 4-4, Appendix Table 4-5, Appendix Table 4-6, Appendix Table 4-7, Appendix Table 4-8, and Appendix Table 4-9). From then to 2013, the total of U.S. R&D performance has exhibited sizable growth, whether judged in current or inflation-adjusted dollar terms (Figure 4-2; Appendix Table 4-1).[i] Annual growth in the U.S. R&D total over this 60-year period averaged 7.8% in current dollars, or 4.3% when adjusted for inflation. (As a comparative yardstick, a 7% average annual rate of growth yields a doubling of the quantity in 10 years.) Additionally, the expansion rate for R&D substantially outpaced that for U.S. gross domestic product (GDP) over the same period, which was 6.5% annually in current dollars or 3.1% adjusted for inflation.

[i] In this chapter, dollars adjusted for inflation (i.e., constant dollars) are based on the GDP implicit price deflator (currently in 2009 dollars) as published by the Department of Commerce's Bureau of Economic Analysis (http://www.bea.gov/iTable/index_nipa.cfm). A 1953–2013 time series for this deflator appears in Appendix Table 4-1. Note that GDP deflators are calculated on an economy-wide scale and do not explicitly focus on R&D.

Figure 4-2

U.S. total R&D expenditures: 1953–2013



NOTE: Data for 2013 include some estimates and may later be revised.

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

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Average annual growth of U.S. R&D over the more recent period of 2008–13 has been less favorable than these long-run rates and their relationships. The expansion of U.S. total R&D over this 5-year period has averaged only 2.3% (or 0.8%, when adjusted for inflation) and was behind the pace of GDP expansion (which averaged 2.6% annually in current dollars, or 1.2% when adjusted for inflation) (Table 4-2).

Table 4-2 **Annual rates of growth in U.S. R&D expenditures, total and by performing sectors: 1993–2013**

(Percent)

	Longer-term trends			Most recent 5 years				
Expenditures and gross domestic product	1993–2003	2003–08	2008–13	2008–09	2009–10	2010–11	2011–12	2012–13
				Current $				
Total R&D, all performers	5.9	6.8	2.3	-0.4	0.8	4.8	1.8	4.8
Business	5.7	7.7	2.1	-2.9	-1.2	5.4	2.8	6.7

	Longer-term trends			Most recent 5 years				
Expenditures and gross domestic product	1993–2003	2003–08	2008–13	2008–09	2009–10	2010–11	2011–12	2012–13
Federal government	4.3	4.2	1.8	3.8	5.5	5.4	-2.6	-2.8
Federal intramural[a]	4.2	3.6	2.1	2.4	4.6	9.3	-2.7	-2.9
FFRDCs	4.4	5.2	1.3	6.3	7.0	-1.5	-2.4	-2.7
Nonfederal government	NA	NA	6.4	NA	20.9	0.6	-5.1	-0.1
Universities and colleges	7.4	5.1	3.7	5.7	6.0	3.4	1.3	2.2
Other nonprofit organizations b	9.6	4.5	2.6	10.0	2.2	-1.5	-0.6	3.0
Gross domestic product	5.3	5.0	2.6	-2.0	3.8	3.7	4.2	3.7
	Constant 2009$							
Total R&D, all performers	3.9	3.9	0.8	-1.2	-0.5	2.7	0.0	3.2
Business	3.8	4.8	0.6	-3.6	-2.4	3.3	1.0	5.1
Federal government	2.4	1.4	0.3	3.0	4.2	3.3	-4.3	-4.3
Federal intramural[a]	2.3	0.9	0.6	1.6	3.4	7.1	-4.4	-4.3
FFRDCs	2.5	2.4	-0.2	5.5	5.7	-3.5	-4.1	-4.1
Nonfederal government	NA	NA	4.9	NA	19.4	-1.4	-6.8	-1.6
Universities and colleges	5.5	2.3	2.2	4.9	4.7	1.3	-0.4	0.7
Other nonprofit organizations b	7.6	1.7	1.1	9.2	1.0	-3.4	-2.3	1.5
Gross domestic product	3.4	2.2	1.2	-2.8	2.5	1.6	2.3	2.2

NA = not available.

FFRDC = federally funded R&D center.

[a] Includes expenditures of federal intramural R&D and costs associated with administering extramural R&D.

[b] Some components of the R&D performed by other nonprofit organizations are projected and may later be revised.

NOTES: Longer-term trend rates are calculated as compound annual growth rates. Data for 2013 include some estimates and may later be revised. As a further aid to interpretation, the National Science Foundation's data series on U.S. R&D performance dates back to 1953. The average annual rate of growth of total R&D for the 1953–2013 period was 7.8%, compared with 6.5% for U.S. gross domestic product over the same period. Adjusted for inflation, these average annual rates were, respectively, 4.3% and 3.1%.

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

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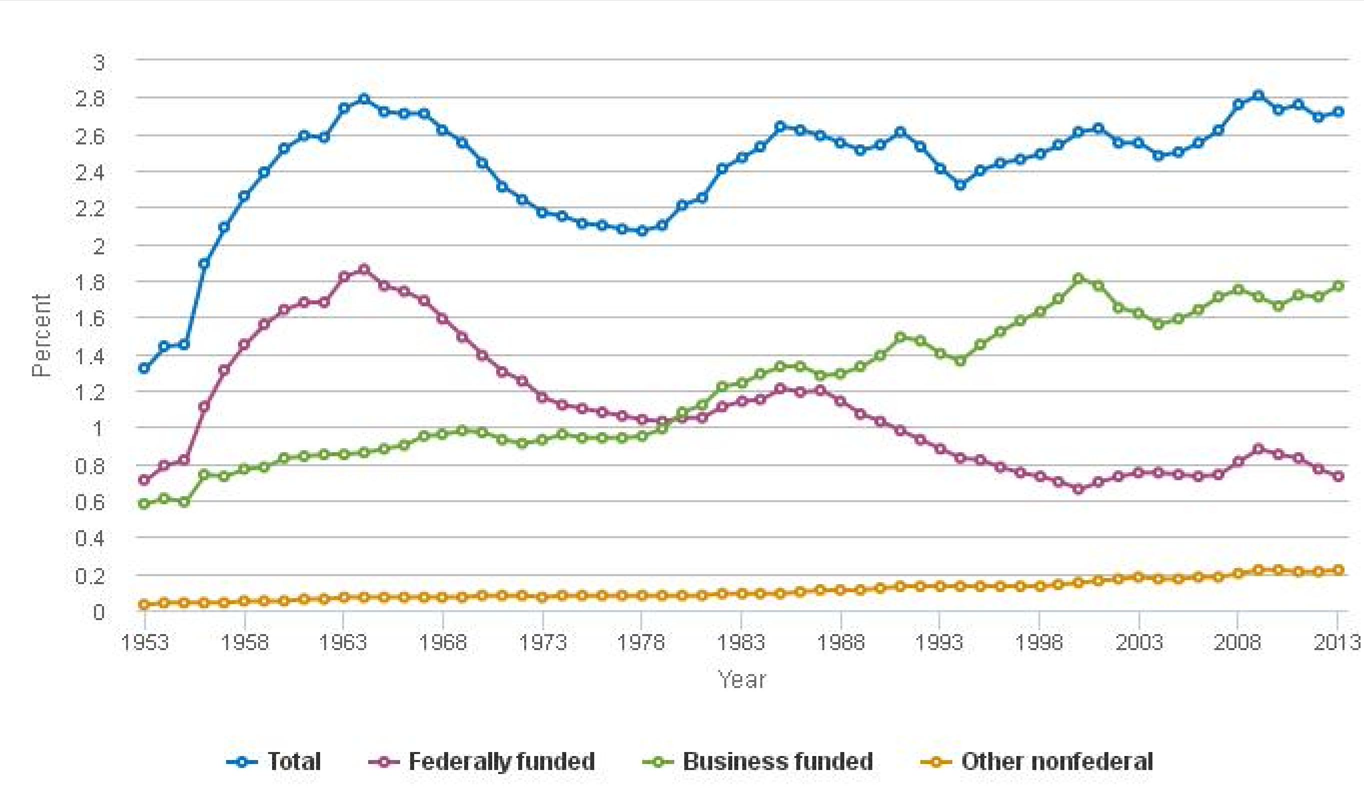
The 2008–10 period was a challenging time for U.S. R&D expansion—and the little change in U.S. R&D levels throughout this period weighed down the 5-year averages. With the business sector routinely accounting for two-thirds or more of the U.S. R&D total, the declines in its R&D performance in the 2008–10 period were clearly a significant factor in the stagnant pace of expansion in the national R&D totals over this period (Table 4-1; Figure 4-1).

By comparison, the pace of expansion in the second half of the 2008–13 period has been more favorable—but issues remain. The year-over-year increases in U.S. total R&D in 2010–11 ($20 billion) and 2012–13 ($21 billion) approximate the $15–$20 billion (or more) annual increases that prevailed from the mid-1990s to 2008 (Figure 4-1; Appendix Table 4-1). Further, the growth in total U.S. R&D well outpaced the growth of GDP in 2011 and 2013 (Table 4-2). Business R&D returned in these same 2 years to the comparatively high rates of expansion that have prevailed on average since the early 1990s (Table 4-2). Even so, the 2011–12 increase in the U.S. total was relatively weak—matching only the pace of inflation and well behind the expansion of GDP. Additionally, the data show absolute declines (both current and constant dollars) in federal government R&D performance (federal intramural and federally funded R&D centers [FFRDCs]) in 2012 and 2013. The data also suggest a slowing pace of growth of R&D performed by universities and colleges in 2012 and 2013—the result of the more challenging federal budget environment for R&D support. The data for 2014 and 2015—not yet available—will be of more than normal interest in gauging what new trends may be emerging.

A consequence of these shifting growth rates is that the R&D intensity of the national economy (the ratio of R&D expenditures to GDP), which reached a long-term peak in 2009, has been declining somewhat more recently (Figure 4-3; Appendix Table 4-1). (The ratio of total national R&D expenditures to GDP is often reported as a measure of the intensity of a nation's overall R&D effort and is widely used as an international benchmark for comparing countries' R&D systems.)

Figure 4-3

Ratio of U.S. R&D to gross domestic product, by roles of federal, business, and other nonfederal funding for R&D: 1953–2013



NOTES: Data for 2013 include some estimates and may later be revised. The federally funded data represent the federal government as a funder of R&D by all performers; the business-funded data have a similar function. The Other nonfederal category includes R&D funded by all other sources—mainly universities and colleges, nonfederal government, and other nonprofit organizations. The gross domestic product data used reflect the U.S. Bureau of Economic Analysis's comprehensive revisions of the national income and product accounts of July 2013.

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

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(Note: The Department of Commerce's Bureau of Economic Analysis [BEA] introduced a comprehensive set of revisions to the U.S. national income and product accounts in July 2013—including explicitly recognizing R&D as investment in the measure of U.S. GDP. These changes resulted in modest revisions to the U.S. GDP time series back to 1929. The R&D/GDP ratio data NSF reports here reflect BEA's revised GDP data series, both in the present and the past, and differ somewhat from data reported in previous editions of *Science and Engineering Indicators*. For further information, see the sidebar R&D in the U.S. National Income and Product Accounts.)

U.S. expenditures on R&D totaled 2.76% of GDP in 2011, 2.69% in 2012, and 2.72% in 2013. These numbers are lower, but only somewhat, than the 2.81% that prevailed in 2009—which was the highest level of this ratio since the start of the time series in 1953. Over the 10-year period from 2003 to 2013, the ratio has fluctuated to some degree from year to year, between a low of 2.48% in 2004 and the high of 2.81% in 2009. The apparent trend since the later 1990s is a generally rising R&D/GDP ratio (Figure 4-3). Whether the somewhat lower levels arising since 2009 represent merely a short-term reversal or something more permanent remains to be seen.

Most of the rise of the R&D/GDP ratio over the past several decades has come from the increase of nonfederal spending on R&D, particularly that by the business sector (Figure 4-3). This reflects the growing role of business R&D in the national R&D system and, in turn, the growing prominence of R&D-derived goods and services in the national and global economies. By contrast, the ratio of federal R&D spending to GDP declined from the mid-1980s to the late 1990s, notably from cuts in defense-related R&D. The gradual uptick through 2009 was the result of increased federal spending on biomedical and national security R&D and the one-time incremental funding for R&D provided by the American Recovery and Reinvestment Act of 2009 (ARRA).

R&D in the U.S. National Income and Product Accounts

Comprehensive revisions of the U.S. GDP and related national income and product accounts (NIPA), released by BEA in July 2013, included a change to treat R&D as a fixed investment with long-term benefits. R&D investment is now recognized in the NIPA in a new asset category called "intellectual property products," or intangible assets, along with software and entertainment, literary, and artistic originals. Before this change, the NIPA considered R&D as an expense or as an intermediate input cost in the business sector and as consumption in the government and nonprofit sectors (BEA 2013). This update is one of several NIPA changes aimed at capturing the role of intangible assets in economic growth. NSF's regular surveys of U.S. R&D expenditures serve as the primary data source for the R&D component of these revisions. (For a further discussion, see NSF's recent InfoBrief on this topic: http://www.nsf.gov/statistics/2015/nsf15315/.)

As a part of these July 2013 revisions (and for all subsequent releases), BEA provided a revised time series for GDP and its components going back to 1929. After these comprehensive revisions, GDP levels are somewhat higher in this revised time series than previously reported. An implication is that the R&D/GDP ratios previously reported by NSF in *Indicators* and related publications on U.S. R&D are somewhat smaller because of this higher reported GDP. For example, the U.S. R&D/GDP ratio for 2000, previously reported as 2.70%, is now 2.61% under the revised NIPA, or what was 2.84% in 2011 under the previous methodology is revised to 2.76%. The U.S. R&D statistics reported throughout in this chapter now fully reflect BEA's revised GDP data series.

Performers of R&D

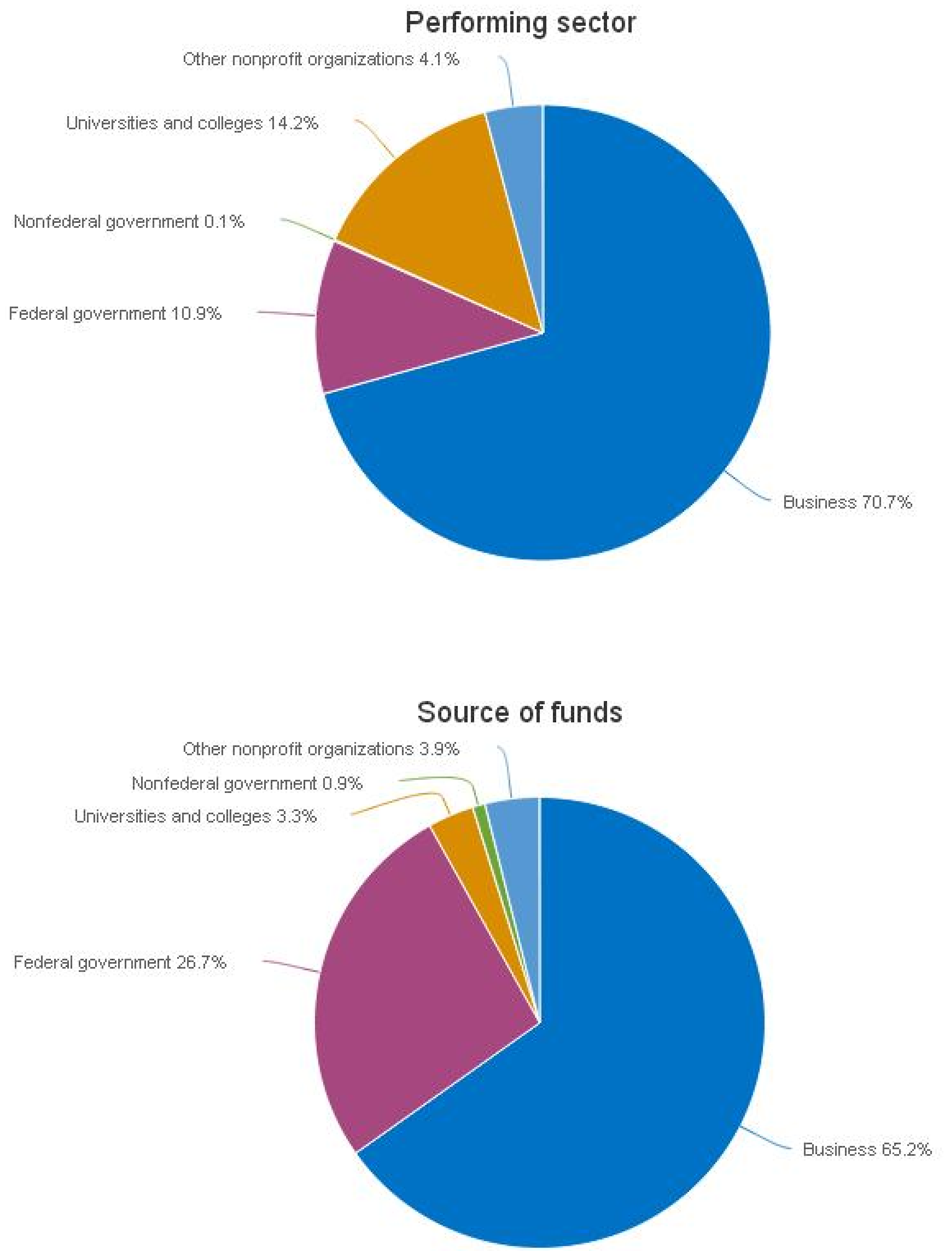
NSF tracks the R&D spending patterns of the major performers in the overall U.S. R&D system. Included here are businesses, the intramural R&D activities of federal agencies, FFRDCs, nonfederal government organizations (mainly state government), universities and colleges, and other nonprofit organizations.

Business Sector

In 2013, the business sector continued to be the largest performer of U.S. R&D, conducting $322.5 billion, or almost 71%, of the national total (Table 4-1; Figure 4-4). The 2013 level of business R&D performance was markedly above the 2012 level ($302.3 billion) and, along with the increases of 2011–12 and 2010–11, suggests this sector's return to annual R&D growth and reversal of the declines in 2009 and 2010. Over the 5-year period of 2008–13, business R&D performance grew an average of 2.1% annually, although somewhat behind the 2.3% rate of growth of overall U.S. R&D (Table 4-2).

Figure 4-4

Shares of U.S. total R&D expenditures, by performing sector and source of funds: 2013



NOTES: U.S. R&D expenditures totaled $456.1 billion in 2013. The federal government performing sector includes federal agencies and federally funded R&D centers.

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

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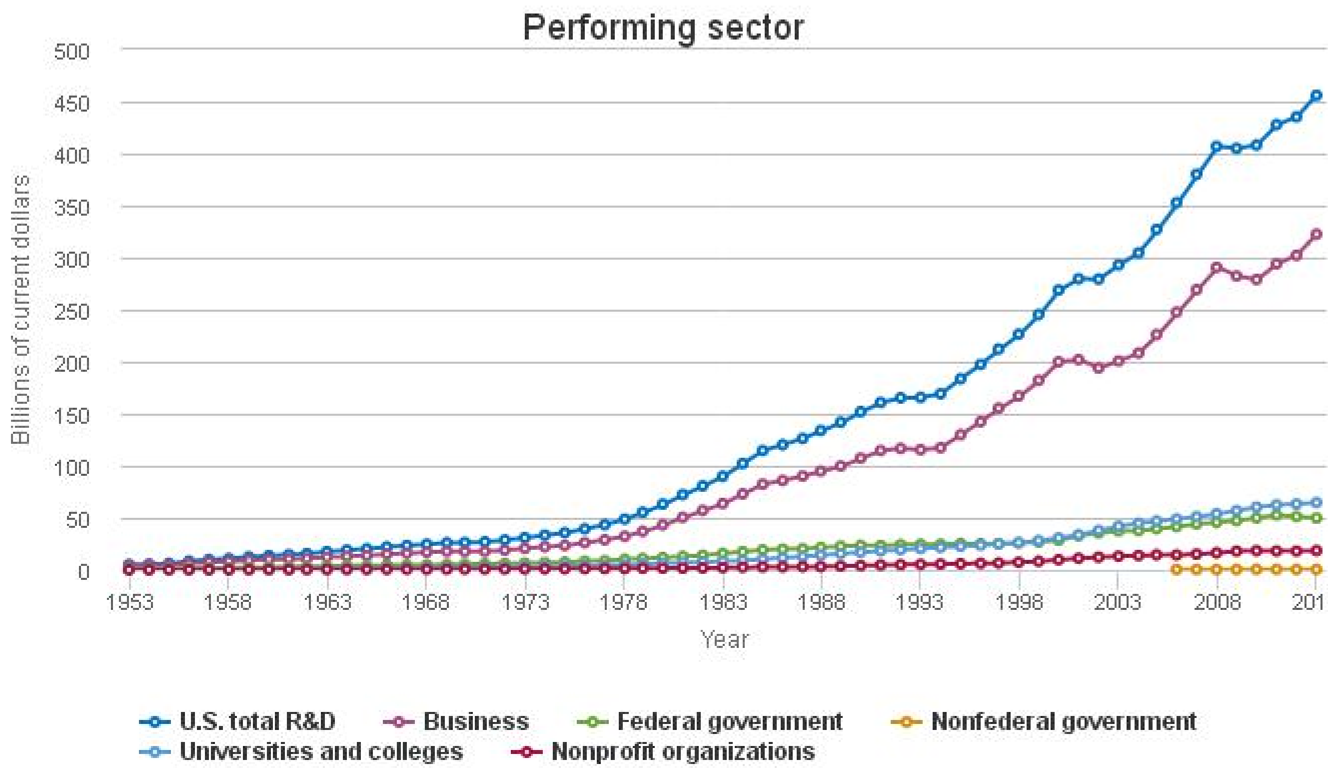
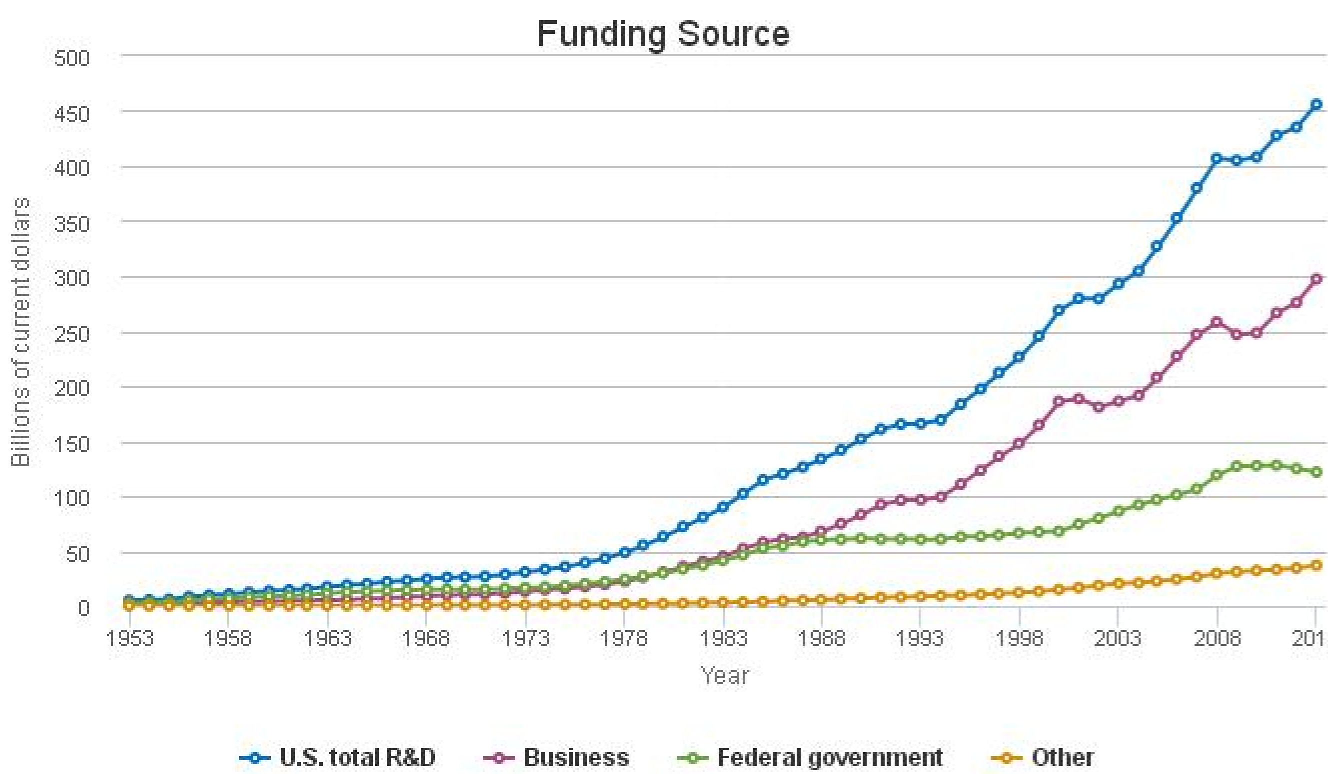
The business sector has long been prominent in the composition of national R&D, with its annual share ranging between 68% and 74% over the 20-year period of 1993–2013 (Figure 4-5 and Figure 4-6; Appendix Table 4-2).

Figure 4-5

U.S. R&D, by performing sector and source of funds: 1953–2013





NOTES: Data for 2013 include some estimates and may later be revised. Some components of the R&D performed by other nonprofit organizations are projected and may later be revised. Federal performers of R&D include federal agencies and federally funded R&D centers. Performance by nonfederal government includes mainly state and local governments (data in this series are not available before 2006). Other funding includes support from universities and colleges, nonfederal government, and nonprofit organizations.

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

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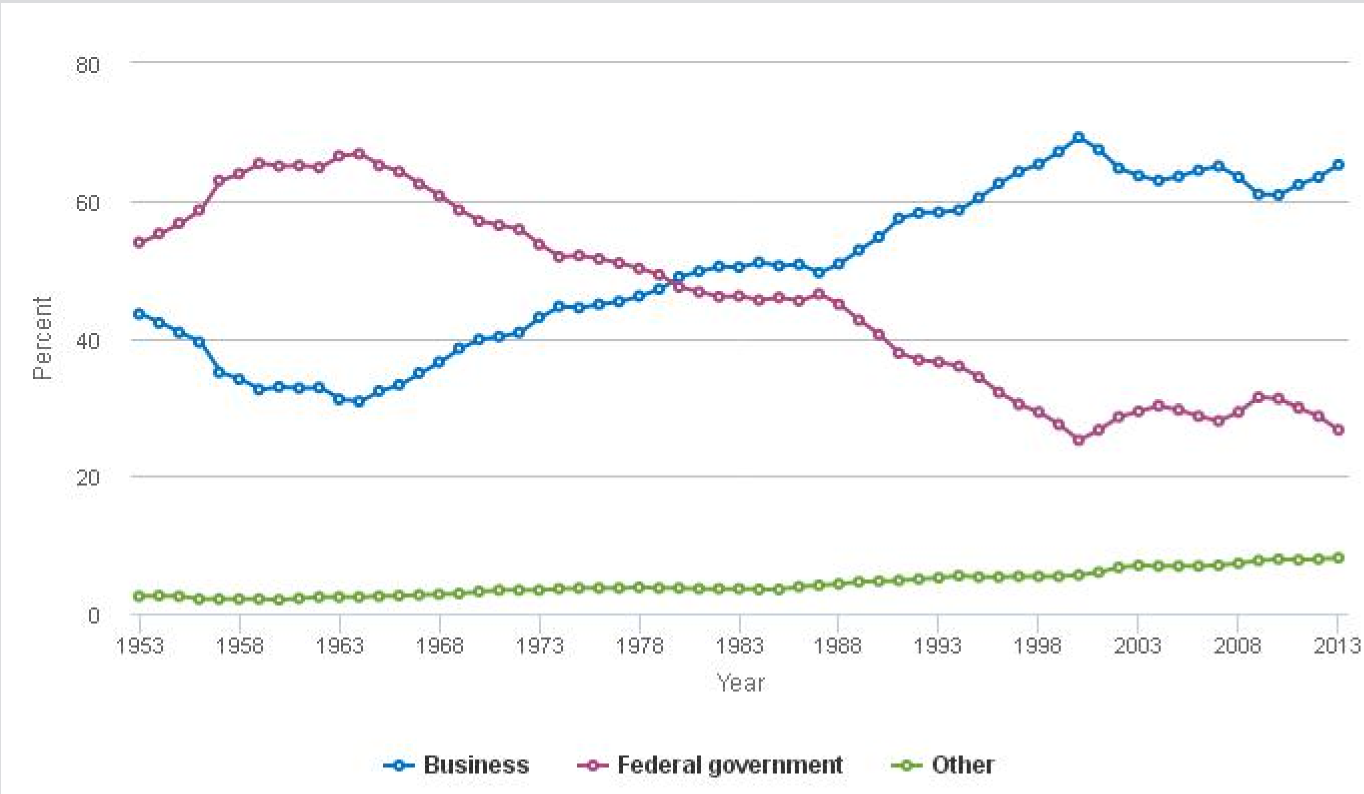
Figure 4-6

U.S. total R&D expenditures, by source of funds: 1953–2013



NOTES: Data for 2013 include some estimates and may later be revised. Other includes nonfederal government, universities and colleges, other nonprofit organizations, and other not elsewhere classified.

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

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Universities and Colleges

Academia is the second-largest performer of U.S. R&D. Universities and colleges performed $64.7 billion, or 14%, of U.S. R&D in 2013 (Table 4-1; Figure 4-4).[i] The total of academic R&D performance has increased by several billion dollars each year since 2008. Annual growth of R&D in this sector has averaged 3.7% over the period of 2008–13, well ahead of the rate of total national R&D (Table 4-2).

Over the 20-year period of 1993–2013, the academic sector's share in U.S. R&D has ranged between 11% and 15% annually. Importantly, universities and colleges have a special niche in the nation's R&D system: They performed just over half (51%) of the nation's basic research in 2013.

Federal Agencies and FFRDCs

R&D performed by the federal government includes the activities of agency intramural laboratories and FFRDCs. Federal intramural R&D performance includes the spending for both agency laboratory R&D and for agency activities to plan and administer intramural and extramural R&D projects. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the federal government. An FFRDC is operated to provide R&D capability to serve agency mission objectives or, in some cases, to provide major facilities at universities for research and associated training purposes. (There were 40 FFRDCs in 2013.)[ii] Each FFRDC is administered by an industrial firm, a university, a nonprofit institution, or a consortium.[iii]

The federal government conducted $49.9 billion, or 11%, of U.S. R&D in 2013 (Table 4-1; Figure 4-4). Of this amount, $33.0 billion (7% of the U.S. total) was intramural R&D performed by federal agencies in their own research facilities, and $16.8 billion (4%) was R&D performed by the 40 FFRDCs.

The federal total in 2013 was down by about $1.4 billion over the 2012 level, and the 2012 level was lower than the 2011 level by a similar amount, with the declines affecting both federal intramural and the FFRDCs (Table 4-1). From 2008 to 2011, the story was much the opposite: year-over-year increases of $1–$2 billion in the federal total. This reversal reflected both the waning of the ARRA incremental funding after 2010 and the more challenging budget environment for increases in R&D funding after 2011. In 1993, the federal performance share was about 15%, but it gradually declined in subsequent years.

This volume of the federal government's R&D performance is small compared with that of the U.S. business sector. Even so, the $49.9 billion performance total in 2013 exceeded the total national R&D expenditures of every country except China, Japan, Germany, South Korea, and France.[iv]

Other Nonprofit Organizations and Nonfederal Government

R&D performed in the United States by nonprofit organizations other than universities and nonprofit-administered FFRDCs is estimated at $18.6 billion in 2013 (Table 4-1). This was 4% of U.S. R&D in 2013, a share that has been largely the same since the late 1990s (Figure 4-4).

NSF started to track the annual intramural R&D performance of state agencies in 2006. The total of this for all 50 states and the District of Columbia in 2013 is estimated to be $467 million—a small share (about 0.1%) of the U.S. total.

Geographic Location of R&D

The sidebar Location of R&D Performance, by State summarizes the leading geographic locations of U.S. R&D performance. For additional R&D indicators at the state level, see the State Data Tool.

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[i] The data for academic R&D reported in this chapter adjust the academic fiscal year basis of NSF's Higher Education Research and Development Survey data to calendar year and net out pass-throughs of research funds from one academic institution to another. Accordingly, the academic data reported in this chapter may differ from those cited in chapter 5.

[ii] NSF maintains a current Master Government List of Federally Funded R&D Centers. For information on the current FFRDC count, along with its history, see http://www.nsf.gov/statistics/ffrdclist/.

[iii] The R&D data cited are for all the FFRDCs as an aggregate. For data on the individual FFRDCs, see NSF's annual FFRDC Research and Development Surveys at http://www.nsf.gov/statistics/srvyffrdc/.

[iv] Furthermore, this figure does not include federal government investments in R&D infrastructure and equipment, which support the maintenance and operation of unique research facilities and the conduct of research activities that would be too costly or risky for a single company or academic institution to undertake.

Location of R&D Performance, by State

Distribution of R&D expenditures among the U.S. states

In 2012, the 10 states with the largest R&D expenditure levels accounted for about 64% of U.S. R&D expenditures that can be allocated to the states: California, Massachusetts, Texas, Maryland, New York, Michigan, Washington, New Jersey, Illinois, and Pennsylvania (Table 4-A).[*] California alone accounted for 24% of the U.S. total, almost 4 times as much as Massachusetts, the next highest state. The top 20 states accounted for 84% of the R&D total; the 20 lowest-ranking states accounted for around 5% (Appendix Table 4-10 and Appendix Table 4-11).

The states with the biggest R&D expenditures are not necessarily those with the greatest intensity of R&D. Among those with the highest R&D/GDP ratios in 2012 were New Mexico, Massachusetts, Maryland, California, and Washington (Table 4-A). New Mexico is the location of a number of major government research facilities. Massachusetts benefits from both leading research universities and thriving high-technology industries. Maryland is the site of many government research facilities and growing research universities. California has relatively high R&D intensity and benefits from the presence of Silicon Valley, other high-technology industries, federal R&D, and leading research universities, but it is still fourth on this list. Washington State is home to government research facilities, leading research universities, and high-technology industries.

U.S. R&D performance, by sector and state

The proportion of R&D performed by each of the main R&D-performing sectors (business, universities and colleges, federal intramural R&D facilities, and FFRDCs) varies across the states, but the states that lead in total R&D also tend to be well represented in each of these sectors (Table 4-A).

In 2012, R&D performed by the business sector accounted for about 71% of the U.S. total R&D that could be allocated to specific states. Of the top 10 states in total R&D performance, 9 are also in the top 10 in industry R&D. Ohio, 10th in business sector R&D, surpasses Maryland in the business R&D ranking.

University-performed R&D accounts for 16% of the allocable U.S. total. Only New Jersey and Washington fall out of the top 10 of total R&D states, replaced by North Carolina and Florida.

Federal R&D performance (including both intramural R&D facilities and FFRDCs)—about 11% of the U.S. total—is more concentrated geographically than that in other sectors. Only five jurisdictions—Maryland, California, New Mexico, Virginia, and the District of Columbia—account for 61% of all federal R&D performance.[†] This figure rises to 78% when the other 5 of the top 10 performers—Massachusetts, Alabama, Tennessee, Illinois, and Washington—are included.

Federal R&D accounts for the bulk of total R&D in several states, including New Mexico (85%), which is home to the nation's two largest FFRDCs (Los Alamos and Sandia National Laboratories), and Tennessee (41%), which is home to Oak Ridge National Laboratory. The high figures for Maryland (58%), the District of Columbia (66%), and Virginia (38%) reflect the concentration of federal facilities and federal R&D administrative offices in the national capital area.

* The latest data available on the distribution of U.S. R&D performance by state are for 2012 (Appendix Table 4-10). Total U.S. R&D expenditures that year are estimated at $435.3 billion. Of this total, $410.9

billion could be attributed to one of the 50 states or the District of Columbia. This state-attributed total differs from the U.S. total for a number of reasons: Some business R&D expenditures cannot be allocated to any of the 50 states or the District of Columbia because respondents did not answer the question related to location, nonfederal sources of nonprofit R&D expenditures (about $12 billion in 2012) could not be allocated by state, state-level university R&D data have not been adjusted for double-counting of R&D passed from one academic institution to another, and state-level university and federal R&D performance data are not converted from fiscal to calendar years.

† Federal intramural R&D includes costs associated with the administration of intramural and extramural programs by federal personnel, as well as actual intramural R&D performance. This is a main reason for the large amount of federal intramural R&D in the District of Columbia.

Table 4-A Top 10 states in U.S. R&D performance, by sector and intensity: 2012

	All R&D[a]		Sector ranking			R&D intensity (R&D/GDP ratio)		
Rank	State	Amount (current $millions)	Business	Universities and colleges	Federal intramural and FFRDCs[b]	State	R&D/GDP (%)	GDP (current $billions)
1	California	97,531	California	California	Maryland	New Mexico	6.62	89.2
2	Massachusetts	24,129	Massachusetts	New York	California	Massachusetts	5.59	431.9
3	Texas	20,673	New Jersey	Texas	New Mexico	Maryland	5.45	336.5
4	Maryland	18,354	Texas	Maryland	Virginia	California	4.59	2,125.7
5	New York	18,249	Michigan	Pennsylvania	District of Columbia	Washington	4.52	390.9
6	Michigan	17,844	Washington	Massachusetts	Massachusetts	Delaware	4.31	60.7
7	Washington	17,678	Illinois	North Carolina	Alabama	Michigan	4.28	416.8
8	New Jersey	17,630	New York	Illinois	Tennessee	Connecticut	3.57	242.9
9	Illinois	16,736	Pennsylvania	Michigan	Illinois	New Hampshire	3.55	66.1
10	Pennsylvania	13,210	Ohio	Florida	Washington	New Jersey	3.33	528.8

FFRDC = federally funded R&D center; GDP = gross domestic product.

[a] Includes in-state total R&D performance of the business sector, universities and colleges, federal agencies, FFRDCs, and federally financed nonprofit R&D.

[b] Includes costs associated with administration of intramural and extramural programs by federal personnel and actual intramural R&D performance.

NOTES: Small differences in parameters for state rankings may not be significant. Rankings do not account for the margin of error of the estimates from sample surveys.

SOURCES:	National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series). State GDP data are from the U.S. Bureau of Economic Analysis. See appendix table 4-10. *Science and Engineering Indicators 2016*

Sources of R&D Funding

Funds that support the conduct of R&D in the United States come from a variety of sources, including businesses, federal and nonfederal government agencies, academic institutions, and other nonprofit organizations. For the most part, the mix of funding sources varies by performer.

R&D Funding by Business

The business sector is the predominant source of funding for the R&D performed in the United States. In 2013, business sector funding accounted for $297.3 billion, or 65% of the $456.1 billion of total U.S. R&D performance (Table 4-1; Figure 4-4).

Nearly all of the business sector's funding for R&D (98%) is directed toward business R&D performance (Table 4-3).[i] The small remainder goes to higher education, other nonprofit organizations, and FFRDC performers.

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[i]R&D funding by business in this section refers to nonfederal funding for domestic business R&D plus business funding for FFRDCs and U.S. academic and nonprofit R&D performers.

Table 4-3 **U.S. R&D expenditures, by performing sector, source of funds, and type of work: 2013**

	Source of funds ($millions)						
Performing sector and type of work	Total	Business	Federal government	Nonfederal government	Universities and colleges	Other nonprofit organizations	Percent distribution by performer
R&D	456,095	297,279	121,808	4,113	15,240	17,655	100.0
Business	322,528	292,153	29,362	194	*	819	70.7
Federal government	49,859	180	49,448	50	*	181	10.9
Federal intramural	33,026	0	33,026	0	0	0	7.2
FFRDCs	16,833	180	16,422	50	*	181	3.7
Nonfederal government	467	*	193	274	*	*	0.1
Universities and colleges	64,680	3,502	36,867	3,594	15,240	5,477	14.2
Other nonprofit organizations	18,561	1,444	5,939	*	*	11,178	4.1
Percent distribution by funding source	100.0	65.2	26.7	0.9	3.3	3.9	na

	Source of funds ($millions)						
Performing sector and type of work	Total	Business	Federal government	Nonfederal government	Universities and colleges	Other nonprofit organizations	Percent distribution by performer
Basic research	80,460	21,213	37,826	2,317	9,384	9,720	100.0
Business	19,508	18,203	1,196	21	*	88	24.2
Federal government	9,531	52	9,413	14	*	52	11.8
Federal intramural	5,355	0	5,355	0	0	0	6.7
FFRDCs	4,176	52	4,058	14	*	52	5.2
Nonfederal government	NA	*	NA	NA	*	*	NA
Universities and colleges	41,275	2,156	24,148	2,213	9,384	3,373	51.3
Other nonprofit organizations	10,029	802	3,021	*	*	6,207	12.5
Percent distribution by funding source	100.0	26.4	47.0	2.9	11.7	12.1	na
Applied research	90,629	46,290	33,357	1,340	4,801	4,841	100.0
Business	51,013	44,738	6,028	47	*	200	56.3
Federal government	15,103	82	14,915	23	*	83	16.7
Federal intramural	8,337	*	8,337	*	0	*	9.2
FFRDCs	6,766	82	6,578	23	*	83	7.5
Nonfederal government	NA	*	NA	NA	*	*	NA
Universities and colleges	18,608	1,103	9,845	1,132	4,801	1,726	20.5
Other nonprofit organizations	5,671	366	2,472	*	*	2,833	6.3
Percent distribution by funding source	100.0	51.1	36.8	1.5	5.3	5.3	na

	Source of funds ($millions)						
Performing sector and type of work	Total	Business	Federal government	Nonfederal government	Universities and colleges	Other nonprofit organizations	Percent distribution by performer
Development	285,007	229,776	50,625	456	1,054	3,096	100.0
Business	252,007	229,212	22,137	126	*	532	88.4
Federal government	25,225	46	25,120	13	*	46	8.9
Federal intramural	19,334	*	19,334	*	0	*	6.8
FFRDCs	5,890	46	5,786	13	*	46	2.1
Nonfederal government	NA	*	NA	NA	*	*	NA
Universities and colleges	4,797	242	2,874	249	1,054	379	1.7
Other nonprofit organizations	2,861	276	446	*	*	2,139	1.0
Percent distribution by funding source	100.0	80.6	17.8	0.2	0.4	1.1	na

NOTES: * = small to negligible amount, included as part of the funding provided by other sectors; na = not applicable; NA = not available.

FFRDC = federally funded R&D center.

Data for 2013 include some estimates and may later be revised. Some components of R&D performance and funding by other nonprofit organizations are projected and may later be revised.

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

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The business sector's predominant role in the nation's R&D funding began in the early 1980s, when the support it provided started to exceed 50% of all U.S. R&D funding (Figure 4-5 and Figure 4-6). This business sector share moved up annually until reaching 69% in 2000. However, this share has declined somewhat in the years since, to around 61% in 2009 and 2010, but rebounded to 65% in 2013.

R&D Funding by the Federal Government

The federal government is the second-largest source of overall funding for U.S. R&D. It is a major source for most U.S. performer sectors except businesses, where the federal role, although not negligible, is substantially overshadowed by the business sector's own funds.

Funds from the federal government accounted for $121.8 billion, or 27%, of U.S. total R&D in 2013 (Table 4-1; Figure 4-4). This funding was mainly directed to federal, business, and higher education performers, but other nonprofit organizations were also recipients (Table 4-3).

Federal funding accounted for all of the $33.0 billion of federal intramural R&D performance in 2013 and mostly all of the $16.8 billion of R&D performed by FFRDCs. (Nonfederal support for FFRDC R&D has been around $0.4 billion or so in recent years, or less than 1% of total support; see Appendix Table 4-2).

Federal funding to the business sector accounted for $29.4 billion of business R&D performance in 2013, or 9% of the sector's R&D total that year (Table 4-3). Federal funds to academia supported $36.9 billion (57%) of the $64.7 billion spent on academic R&D in 2013. For the R&D performed by other nonprofit organizations, $5.9 billion (about 32%) of this sector's $18.6 billion of performance was supported by federal funds.

The federal government was once the leading sponsor of the nation's R&D, funding some 67% of all U.S. R&D in 1964 (Figure 4-6). The federal share decreased in subsequent years to 49% in 1979, on down to a historical low of 25% in 2000. However, changing business conditions and expanded federal funding for health, defense, and counterterrorism R&D pushed the federal funding share above 31% in 2009 and 2010. But the federal share has declined somewhat in the subsequent years, reaching 27% in 2013—reflecting again the particularly challenging federal budget environment in the most recent years. Similarly, through the early 1960s, the federal government had funded more than half of the nation's business-performed R&D. This share then declined in subsequent years to around 9% in 2000, increasing again to 12%–14% from 2008 to 2010, but going back down to 9% by 2013 (Appendix Table 4-2).

R&D Funding from Other Sources

The balance of R&D funding from other sources is small: $37.0 billion in 2013, or about 8% of all U.S. R&D performance that year. Of this amount, $15.2 billion (3%) was academia's own institutional funds, most all of which remain in the academic sector; $4.1 billion (1%) was from state and local governments, primarily supporting academic research; and $17.7 billion (4%) was from other nonprofit organizations, the majority of which funds this sector's own R&D. In addition, some funds from the nonprofit sector support academic R&D.

The share of R&D funding from these sources has been marginally increasing over the 2008–13 period (Figure 4-5). In 2008, these other sources accounted for slightly more than 7% of U.S. total R&D, growing to about 8% in 2013.

R&D, by Type of Work

R&D encompasses a wide range of activities: from research yielding fundamental knowledge in the physical, life, and social sciences; to research addressing national defense needs and such critical societal issues as global climate change, energy efficiency, and health care; to the development of platform or general-purpose technologies that can enable the creation and commercial application of new and improved goods and services. The most widely applied classification of these activities characterizes R&D as "basic research," "applied research," or "(experimental) development" (Office of Management and Budget 2012; Organisation for Economic Co-operation and Development [OECD] 2002; NSF 2006). (For definitions of these terms, see this chapter's glossary).

This trio of categories has been criticized as reinforcing the idea that creating new knowledge and innovation is a linear process beginning with basic research, followed by applied research and then development, and ending with the production and diffusion of new technology. However, alternative classifications that involve measurable distinctions, capture major differences in types of R&D, and are widely deemed to be superior by the global science and technology statistical and policy communities have yet to emerge. Despite the recognized limitations of the basic research-applied research-development classification framework, it remains useful in providing indications of differences in the motivation, expected time horizons, outputs, and types of investments associated with R&D projects.

The most recent type-of-work cross-section in NSF's R&D expenditures and funding data covers 2013.[i] Basic research activities accounted for $80.5 billion (18%) of the $456.1 billion of total U.S. R&D that year. Applied research was $90.6 billion (20%); development was $285.0 billion (63%) (Table 4-3). (For years earlier than 2013, see Appendix Table 4-3, Appendix Table 4-4, and Appendix Table 4-5.)

Basic Research

Universities and colleges continued to be the primary performers of U.S. basic research in 2013, accounting for 51% of the $80.5 billion of basic research performance that year (Table 4-3). The business sector performed about 24%, the federal government (agency intramural laboratories and FFRDCs) performed 12%, and other nonprofit organizations performed 13%.

The federal government remains the largest source of funding for basic research, accounting for about 47% of the $80.5 billion funding total in 2013 (Table 4-3). The business sector was also a substantial funder, providing 26% of the total.

Applied Research

The business sector performed 56% of the $90.6 billion of applied research in 2013 (Table 4-3). Universities and colleges accounted for 21%, the federal government (federal agency intramural laboratories and FFRDCs) accounted for 17%, and nonprofit organizations for 6%.

The business sector provided 51% of the funding for applied research in 2013, with the vast majority remaining within the sector (Table 4-3). The federal government accounted for about 37%, spread broadly across the performers, with the largest amounts going to universities and colleges, federal intramural laboratories, and FFRDCs.

Development

The business sector predominates in development, performing 88% of the $285.0 billion the United States devoted to development in 2013 (Table 4-3).[ii] The federal government (agency intramural laboratories, FFRDCs) accounted for another 9%—much of it defense related, with the federal government being the main consumer. By contrast, academia and other nonprofit organizations perform very little development, respectively 2% and 1% of the total in 2013.

The business sector provided 81% of the funding for the $285.0 billion of U.S. development in 2013, most of which remained in the sector (Table 4-3). Federal funding accounted for about 18% of the development total—with the business sector (especially defense-related industries) and federal intramural laboratories being the largest recipients.

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[i] The arithmetic is straightforward, based on the data in Appendix Table 4-2, Appendix Table 4-3, Appendix Table 4-4, and appendix table 4-5, to calculate similar type-of-R&D shares for years earlier than 2013. Nonetheless, care must be taken in describing the trends for these shares over time. Although NSF's sectoral surveys of R&D expenditures have consistently used the OECD Frascati Manual's type-of-R&D definitions, the survey instruments

have occasionally been revised to improve the reliability of the responses received, most notably in the academic, business, and FFRDC R&D expenditure surveys. Accordingly, some differences observed in the shares directly calculated from the appendix table time series data more nearly reflect the effects of these improvements in the type-of-R&D survey questions than changes in the type-of-R&D shares among R&D performers.

[ii] The OECD notes that in measuring R&D, the greatest source of error is typically the difficulty of locating the dividing line between experimental development and the further downstream activities needed to realize an innovation (OECD 2002, paragraph 111). Most definitions of R&D set the cutoff at the point when a particular product or process reaches "market readiness." At this point, the defining characteristics of the product or process are substantially set—at least for manufactured goods, if not also for services—and further work is primarily aimed at developing markets, engaging in preproduction planning, and streamlining the production or control system.

Cross-National Comparisons of R&D Performance

Data on R&D expenditures and intensity by country and region provide a broad picture of the global distribution of R&D capabilities and activities and changes under way. Data provided periodically by the OECD (covering its 34 member countries and 7 selected nonmembers) and by the United Nations Educational, Scientific and Cultural Organization's (UNESCO's) Institute for Statistics (covering more than 100 other countries) are useful for this comparative task (OECD 2015; UNESCO 2015).

Cross-national comparisons of R&D expenditures and funding necessarily involve currency conversions. The analysis in this section follows the international convention of converting all foreign currencies into U.S. dollars via purchasing power parity (PPP) exchange rates. (For a discussion of this methodology, see sidebar, Comparing International R&D Expenditures.)

Comparing International R&D Expenditures

Comparisons of international R&D statistics are hampered by the lack of R&D-specific exchange rates. Two approaches are commonly used: (1) express national R&D expenditures as a percentage of GDP, or (2) convert all expenditures to a single currency. The first method is straightforward but permits only gross comparisons of R&D intensity. The second method permits absolute level-of-effort comparisons and finer-grain analyses but entails selecting an appropriate method of currency conversion. The choice is between market exchange rates (MERs) and PPPs, both of which are available for a large number of countries over an extended period.

MERs represent the relative value of currencies for cross-border trade of goods and services but may not accurately reflect the cost of nontraded goods and services. They are also subject to currency speculation, political events, wars or boycotts, and official currency intervention. PPPs were developed to overcome these shortcomings (Ward 1985). They take into account the cost differences of buying a similar market basket of goods and services covering tradables and nontradables. The PPP basket is assumed to be representative of total GDP across countries. PPPs are the preferred international standard for calculating cross-country R&D comparisons and are used in all official R&D tabulations of the OECD.*

Because MERs tend to understate the domestic purchasing power of developing countries' currencies, PPPs can produce substantially larger R&D estimates than MERs for these countries. For example, China's R&D expenditures in 2010 (as reported to the OECD) were $178 billion in PPP terms but only $104 billion using MERs.

However, PPPs for large developing countries such as China and India are often rough approximations and have other shortcomings. For example, structural differences and income disparities between developing and developed countries may result in PPPs based on markedly different sets of goods and services. In addition, the resulting PPPs may have very different relationships to the cost of R&D in different countries.

R&D performance in developing countries often is concentrated geographically in the most advanced cities and regions in terms of infrastructure and level of educated workforce. The costs of goods and services in these areas can be substantially greater than for the country as a whole.

* Recent research raises some unresolved questions about the use of GDP PPPs for deflating R&D expenditures. In analyzing the manufacturing R&D inputs and outputs of six industrialized OECD countries, Dougherty and colleagues (2007:312) concluded that "the use of an R&D PPP will yield comparative costs and R&D intensities that vary substantially from the current practice of using GDP PPPs, likely increasing the real R&D performance of the comparison countries relative to the United States."

Country and Regional Patterns in Total National R&D

The global total of R&D expenditures continues to rise at a significant pace. NSF's latest estimate puts the worldwide total at $1.671 trillion (current PPP dollars) in 2013.[i] The corresponding estimate for 5 years earlier in 2008 was $1.269 trillion. Ten years earlier, in 2003, it was $836 billion. By these figures, the annual increase in total global R&D averaged 5.7% over the 5-year period and 7.2% over the decade, doubling in size. (As a point of comparison, U.S. GDP totaled $16.768 trillion in 2013.)

Global R&D performance continues to remain concentrated in three geographic regions: North America, Europe, and the southern and eastern areas of Asia (Figure 4-7). North America (United States, Canada, and Mexico) accounted for 29% ($492 billion) of worldwide R&D performance in 2013; Europe, including (but not limited to) the EU (see "Glossary" for a list of the EU member countries), accounted for 22% ($367 billion); the combination of the East/Southeast and South regions of Asia (including China, Japan, South Korea, India, and Taiwan) accounted for 40% ($660 billion). The remaining 9% of global R&D comes from the regions of Central and South America, Central Asia, the Middle East, Australia and Oceania, and Africa.

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[i] The figures cited here for total global R&D in 2003, 2008, and 2013 are NSF estimates. R&D expenditures for all countries are denominated in U.S. dollars, based on PPPs. These estimates are based on data from the OECD's (2015) *Main Science and Technology Indicators* (Volume 2015/1) and from R&D statistics for additional countries assembled by UNESCO's Institute for Statistics (as of late February 2015). Presently, no database on R&D spending is comprehensive and consistent for all nations performing R&D. The OECD and UNESCO databases together provide R&D performance statistics for 154 countries, although the data are not current or complete for all. NSF's estimate of total global R&D reflects 93 countries, with reported annual R&D expenditures of $50 million or more, which accounts for most of current global R&D.

Figure 4-7

Global R&D expenditures, by region: 2013

PPP = purchasing power parity.

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

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics estimates, August 2015. Based on data from the Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1), and the United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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The geographic concentration of R&D is more sharply apparent when the profiles of specific countries/economies are considered (Table 4-4). The United States remains the largest R&D performer ($457 billion in 2013), accounting for 27% of the global total. China was the second-largest performer ($336 billion) in 2013, accounting for about 20% of the global total. Japan is third at 10% ($160 billion); Germany is fourth at 6% ($101 billion). South Korea ($69 billion), France ($55 billion), Russia ($41 billion), the United Kingdom ($40 billion), and India ($36 billion) make up a third tier of performers—each accounting for 2% to 4% of the global R&D total. Taiwan, Brazil, Italy, Canada, Australia, and Spain make up a fourth tier, with annual R&D expenditures ranging from $19 billion to $31 billion; each accounting for 1% to 2% of the global total. The United States and China together account for about 47% of the global R&D total in 2013, the top 9 countries account for 78%, and all of the 15 countries mentioned account for 87% of the global total.

Table 4-4 **International comparisons of gross domestic expenditures on R&D and R&D share of gross domestic product, by region/country/economy: 2013 or most**

recent year

Region/country/economy	GERD (PPP $millions)	GERD/GDP (%)
North America		
United States (2013)[a]	456,977.1	2.73
Canada (2013)	24,565.4	1.62
Mexico (2013)	11,543.1	0.50
South America		
Brazil (2011)	27,430.0	1.21
Argentina (2013)	5,437.9	0.58
Chile (2013)	1,494.2	0.39
Colombia (2012)	859.6	0.17
Europe		
Germany (2013)	100,991.4	2.85
France (2013)	55,218.2	2.23
United Kingdom (2013)	39,858.8	1.63
Italy (2013)	26,520.4	1.25
Spain (2013)	19,133.4	1.24
Netherlands (2013)	15,377.4	1.98
Sweden (2013)	14,151.3	3.30
Switzerland (2012)	13,251.4	2.96
Austria (2013)	10,603.4	2.95
Belgium (2013)	10,603.4	2.28
Poland (2013)	7,918.1	0.87
Denmark (2013)	7,513.4	3.06
Finland (2013)	7,175.6	3.32
Czech Republic (2013)	5,812.9	1.91
Norway (2013)	5,513.8	1.65
Portugal (2013)	3,942.7	1.36
Ireland (2012)	3,271.5	1.58
Hungary (2013)	3,249.6	1.41
Ukraine (2011)	2,404.1	0.74
Greece (2013)	2,213.4	0.78
Slovenia (2013)	1,537.8	2.59
Romania (2013)	1,452.9	0.39

Region/country/economy	GERD (PPP $millions)	GERD/GDP (%)
Slovak Republic (2013)	1,190.6	0.83
Belarus (2011)	984.0	0.70
Serbia (2012)	841.3	0.99
Bulgaria (2012)	749.1	0.64
Croatia (2012)	672.4	0.75
Lithuania (2012)	656.1	0.90
Estonia (2013)	592.2	1.74
Luxembourg (2013)	571.5	1.16
Middle East		
Turkey (2013)	13,315.1	0.95
Israel (2013)	11,032.9	4.21
Iran (2008)	5,969.6	0.75
United Arab Emirates (2011)	1,755.3	0.49
Saudi Arabia (2009)	503.2	0.07
Africa		
South Africa (2012)	4,870.7	0.76
Egypt (2011)	2,200.5	0.43
Morocco (2010)	1,108.1	0.73
Tunisia (2009)	1,042.4	1.10
Kenya (2010)	646.3	0.98
Nigeria (2007)	644.0	0.22
Central Asia		
Russian Federation (2013)	40,694.5	1.12
South Asia		
India (2011)	36,195.5	0.81
Pakistan (2011)	1,526.9	0.33
East and Southeast Asia		
China (2013)	336,495.4	2.08
Japan (2013)	160,246.8	3.47
South Korea (2013)	68,937.0	4.15
Taiwan (2013)	30,511.2	2.99
Singapore (2012)	8,176.9	2.00
Malaysia (2011)	4,902.9	1.07
Thailand (2009)	1,339.9	0.25

Region/country/economy	GERD (PPP $millions)	GERD/GDP (%)
Indonesia (2009)	794.9	0.08
Australia and Oceania		
Australia (2011)	20,955.6	2.13
New Zealand (2013)	1,828.5	1.17
Selected country groups		
European Union (2013)	342,431.5	1.91
OECD (2013)	1,128,468.2	2.36
G20 (2013)	1,551,393.7	2.00

G20 = Group of Twenty; GDP = gross domestic product; GERD = gross expenditures (domestic) on R&D; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

[a] Data for the United States in this table may differ slightly from those cited earlier in the chapter. Data here reflect international standards for calculating GERD, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D.

NOTES: Year of data is listed in parentheses. Foreign currencies are converted to dollars through PPPs. Countries in this table have an annual GERD of $500 million or more. Countries are grouped according to the regions described by *The World Factbook*, www.cia.gov/library/publications/the-world-factbook/. No countries in the Central America and Caribbean region had annual GERD of $500 million or more. Data for Israel are civilian R&D only. See sources below for GERD statistics on additional countries.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); OECD, *Main Science and Technology Indicators* (2015/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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The 2013 R&D total for the EU as a whole was $342 billion—only somewhat greater than China's level for the year. Among the EU countries, Germany is by far the largest R&D performer: $101 billion in 2013. France ($55 billion), the United Kingdom ($40 billion), and Italy ($27 billion) are next in order.

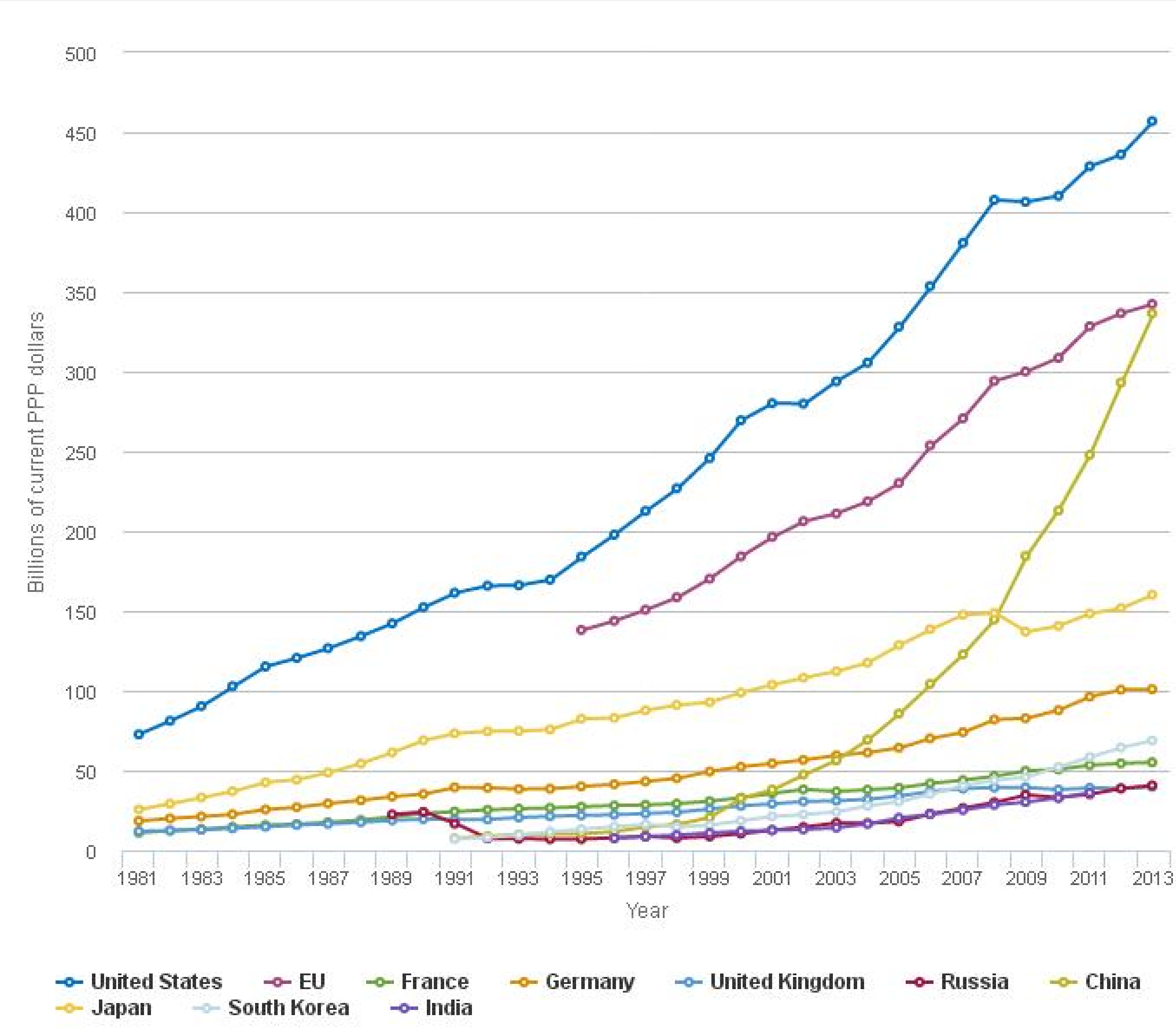
The generally vigorous pace at which total global R&D has doubled over a decade and continues to grow is certainly one of the prominent developments—a direct reflection of the escalating knowledge-intensiveness of the economic competition among the world's nations (see chapter 6 for a further discussion). Nonetheless, another major trend comprises the substantially growing levels of R&D performance in the regions of East/Southeast and South Asia compared with the other major R&D-performing areas. R&D performed in the North American region accounted for 38% of the global total in 2003 but, as noted earlier, declined to 29% in 2013. Europe accounted for 27% in 2003 but 22% in 2013. The East/Southeast and South Asian areas comprised 27% of the global total in 2003 but rose to a striking 40% in 2013. The present regional growth trends in R&D performance suggest that the growing primacy of Asia is unlikely to soon end.

Total global R&D increased some $836 billion (current dollars) from 2003 to 2013—as noted earlier, the 2003 total was $836 billion, rising to $1.671 trillion in 2013. Over this 10-year period, China alone accounted for 34% ($280 billion) of the global increase. The United States accounted for 20% ($163 billion) and the EU for 16% ($134 billion). The increases of several other major Asian R&D performers were also noticeable: Japan accounted for 6% of the increase ($48 billion), and South Korea accounted for 5% ($45 billion).

China continues to exhibit the world's most dramatic R&D growth pattern (Figure 4-8). The pace of its increase in R&D performance over the past 10 years (2003–13) remains exceptionally high, averaging 19.5% annually over this period (or 17.2% per year, when adjusted for inflation). The rate of growth in South Korea's R&D has also been quite high, averaging 11.1% annually over the same 10-year period. Japan's growth rate has been slower, at 3.6% annually.

Figure 4-8

Gross domestic expenditures on R&D, by the United States, the EU, and selected other countries: 1981–2013



NA = not available.

EU = European Union; PPP = purchasing power parity.

NOTES: Data are for the top nine R&D-performing countries and the EU. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary 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. Data for Germany for 1981–90 are for West Germany.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015. See appendix table 4-12.

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Although the United States remains well atop the list of the world's R&D-performing nations, its pace of growth in R&D performance has averaged 4.5% over the same 2003–13 period, and its share of global R&D has declined from 35% to 27%. Total R&D by EU nations has been growing over the same 10 years at an annual average rate of 5.0%—with Germany at 5.7%, France at 4.1%, and the United Kingdom at 2.5%. The EU countries accounted for 25% of total global R&D in 2003 but dropped to 20% of global R&D in 2013.

Country and Regional Patterns in National R&D Intensity

As discussed earlier in this chapter, the U.S. R&D/GDP ratio has exhibited over the preceding 10 years both an extended period of increase, reaching a historical peak, and a gradual drop in the most recent years (Figure 4-3). The U.S. R&D/GDP ratio peaked at 2.81% in 2009, but dropped to 2.72% by 2013.

At the 2013 level, the United States is 11th among the economies tracked by the OECD and UNESCO data. Israel and South Korea are essentially tied for the top spot, with ratios of 4.2% each. (Although Israel's data exclude expenditures for defense R&D, whereas South Korea's include them.) Israel has long been at the top of the R&D/GDP indicator ranking (Table 4-4). But South Korea's upward movement has been particularly rapid; furthermore, it is one of the world's largest R&D performers, with annual R&D expenditures many times that of Israel. Japan is third, at 3.5%. Several smaller countries/economies with comparatively high R&D/GDP ratios follow: Finland (3.3%), Sweden (3.3%), Denmark (3.1%), Taiwan (3.0%), Switzerland (3.0%), and Austria (3.0%). Germany is 10th at 2.9%.

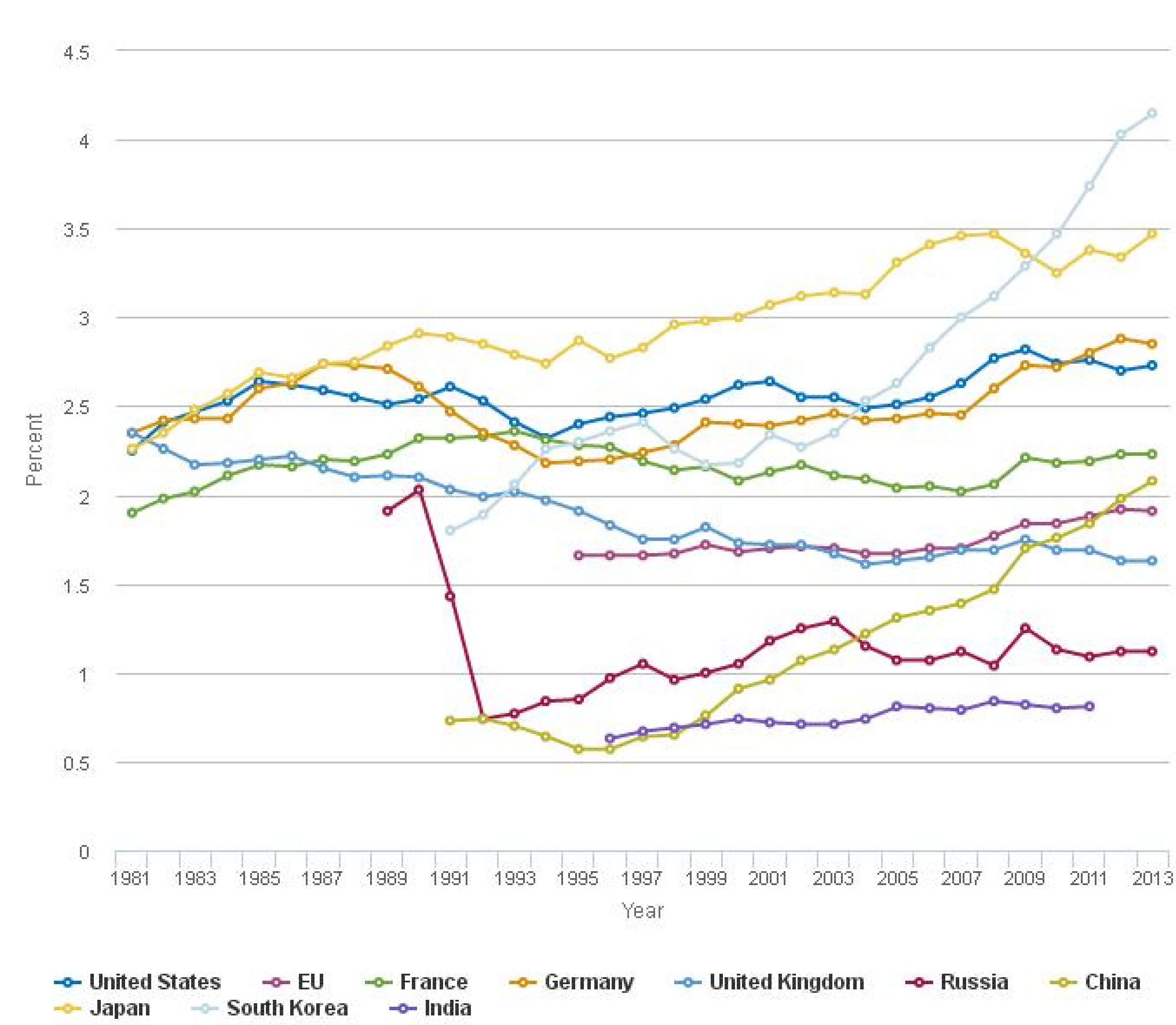
The other top R&D performers include France at 2.2%, China at 2.0%, the United Kingdom at 1.6%, Russia at 1.1%, and India at 0.8%.

The U.S. rank in this indicator has been falling in recent years. The U.S. rank was 10th in 2011 (as reported in *Science and Engineering Indicators 2014*). It was eighth in 2009 (as reported in *Science and Engineering Indicators 2012*).

The ratio has been rising gradually for the EU as a whole over the past decade: from about 1.7% in 2003 to 1.9% in 2013 (Figure 4-9). For the largest R&D performers among the EU countries, ratios for Germany and France have gradually risen, but the United Kingdom has exhibited little to no growth.

Figure 4-9

Gross domestic expenditures on R&D as a share of gross domestic product, by the United States, the EU, and selected other countries: 1981–2013



NA = not available.

EU = European Union; GDP = gross domestic product.

NOTES: Data are for the top nine R&D-performing countries and the EU. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary 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. Data for Germany for 1981–90 are for West Germany.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015. See appendix table 4-12.

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Among the large Asian R&D performers, Japan's R&D/GDP ratio has moved mainly upward in the last 10 years: 3.1% in 2003 to 3.5% in 2013—to a degree, reflecting sluggish GDP growth. The high risers—across all the 11 countries considered here—have been China and South Korea. China's ratio doubled over the period: from just over 1.0% in 2003 to slightly above 2.0% in 2013 (Appendix Table 4-12). South Korea's ratio increased from 2.4% in 2003 to 4.2% in 2013.

Comparisons of the Composition of Country R&D Performance

The business sector is the predominant R&D performer for nearly all of the current top 11 R&D-performing nations (Table 4-5). For the United States, the business sector accounted for 71% of gross expenditures on R&D in 2013. The shares are even higher in the leading Asian R&D performers: China, where the business sector accounted for 77% of the country's total in 2013; Japan, where it accounted for 76%; and South Korea, where it accounted for 79%. Germany, at 68% in 2013, was closer to the level of the United States. France and the United Kingdom were somewhat lower, both at about 65% in 2013. Russia's business sector accounted for about 61% of the country's total R&D in 2013. The exception is India, where the country's business sector accounts for a much smaller share of the national R&D total—36% in 2011 (the most recent year for which data are available).

Table 4-5 **Gross expenditures on R&D for selected countries, by performing sector and source of funds: 2013 or most recent year**

(Country)

		Share of total (%)			
R&D performance	GERD (PPP $billions)	Business	Government	Higher education	Private nonprofit
United States (2013)[a]	457.0	70.6	11.2	14.2	4.1
China (2013)	336.5	76.6	16.2	7.2	na
Japan (2013)	160.3	76.1	9.2	13.5	1.3
Germany (2013)	101.0	67.8	14.7	17.5	**
South Korea (2013)	68.9	78.5	11.2	9.2	1.2
France (2013)	55.2	64.8	13.2	20.8	1.4
Russia (2013)	40.7	60.6	30.3	9.0	0.1
United Kingdom (2013)	39.9	64.5	7.3	26.3	1.9
India (2011)	36.2	35.5	4.1	60.5	na
		Share of total (%)			
R&D source of funds	GERD (PPP $billions)	Business	Government	Other domestic	From abroad
United States (2013)[a]	457.0	60.9	27.7	6.9	4.5
China (2013)	336.5	74.6	21.1	NA	0.9
Japan (2013)	160.3	75.5	17.3	6.7	0.5
Germany (2013)	101.0	66.1	29.2	0.4	4.3
South Korea (2013)	68.9	75.7	23.9	1.1	0.3

		Share of total (%)			
R&D performance	GERD (PPP $billions)	Business	Government	Higher education	Private nonprofit
France (2013)	55.2	55.4	35.0	2.0	7.6
Russia (2013)	40.7	28.2	67.6	1.2	3.0
United Kingdom (2013)	39.9	46.6	27.0	5.8	20.7
India (2011)	36.2	NA	NA	NA	NA

** = included in data for other performing sectors; na = not applicable; NA = not available.

GERD = gross expenditures on R&D; PPP = purchasing power parity.

[a] Data for the United States in this table reflect international standards for calculating GERD, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D. The data for U.S. funding from abroad include funding for business R&D and academic R&D.

NOTES: This table includes the top nine R&D-performing countries. Percentages may not add to total because of rounding. Data years are listed in parentheses.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2014/2); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 February 2015.

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R&D performed by the government accounted for about 11% of the national total in the United States in 2013. This primarily includes activities by the federal government but also includes the small amount of R&D by nonfederal government (state) performers. The share ranged from 4% to 30% across the other eight countries. The government share in Russia was the highest, at 30% in 2013; the lowest was India, at 4%. The United Kingdom (7%) and Japan (9%) were on the lower end. The other countries arrayed around the United States included China (16%), Germany (15%), France (13%), and South Korea (11%).

R&D performed by the higher education sector ranged from 7% to 61% of total national R&D across these countries. This sector's performance share for the United States was about 14% in 2013. China had the lowest share that year, at 7%. South Korea and Russia were both near that level, each with 9%. Japan and Germany were near the United States, with, respectively, 14% and 18% in 2013. France (21%) and the United Kingdom (26%) were noticeably higher. India was again the exception, with the higher education sector being the predominant performer, at 61% (data for 2011).

With the exception of Russia, business sectors were the predominant source of R&D funding (Table 4-5). (Comparable data on R&D funding sources are not available for India.) For the United States, the business sector (domestic) accounted for about 61% of all U.S. R&D in 2013. China, Japan, and South Korea had substantially higher percentages, at 75%, 76%, and 76%, respectively. Germany's share was higher than that of the United States, at 66%; the United Kingdom was somewhat less, at 47%. At 28%, Russia's share of business-funded R&D was far lower.

Government was the second major source of R&D funding for these countries—but again, Russia was the particularly noticeable exception. For the United States, government (federal and nonfederal) accounted for 28% of the nation's R&D in 2013. Germany and the United Kingdom had similar shares: 29% and 27%, respectively. France was higher, at 35%. Japan (17%), China (21%), and South Korea (24%) are below the U.S. share. The 68% government funding role for Russia in 2013 was by far the highest share and the exception among this group of leading R&D performers.

Funding from abroad refers to funding from businesses, universities, governments, nonprofits, and other organizations located outside of the country. Among the top R&D-performing countries, the United Kingdom is the most notable in this category, with 21% of R&D funding coming from abroad in 2013. France is also comparatively high, at nearly 8%. Germany and the United States are both around 4%, and the rest are much lower. (For the United States, the funding from abroad reflects foreign funding for domestic R&D performance mainly by the business and higher education sectors.)

Another dimension for comparing these top R&D-performing countries is the levels and shares of overall national annual R&D performance devoted to basic research, applied research, and (experimental) development. (Note: Type-of-R&D data are not available for Germany.) With regard to basic research, the countries range between 5% and 24% in the portion of annual R&D that falls under this heading (Table 4-6). For the United States, this share is on the high side of the range: 17% of its overall R&D in 2012, which amounted to $73.1 billion of basic research performance that year. France often shows a higher share; in 2011, this share was 24%, but this amounted to $13.0 billion of basic research performance, which was well below the U.S. level. Among top R&D-performing countries, China's basic research share is the lowest, at slightly less than 5% in 2012; however, this still amounted to about $14 billion of basic research performance that year.

Table 4-6 **Gross expenditures on R&D for selected countries, by type of work: 2012 or most recent year**

Country	GERD (PPP $billions)	Basic	Applied	Experimental development	Other nec
		PPP $billions			
United States (2012)[a]	436.1	73.1	90.6	271.7	0.0
China (2012)	293.1	14.1	33.1	245.9	0.0
Japan (2011)	148.4	18.3	31.2	92.1	6.8
Germany (2012)	100.7	NA	NA	NA	NA
South Korea (2011)	58.4	10.6	11.9	36.0	0.0
France (2011)	53.4	13.0	19.7	18.6	2.0
Russia (2012)	40.7	5.9	NA	NA	NA
United Kingdom (2011)	39.1	5.8	18.9	14.5	0.0
India (2009)	30.3	4.8	6.8	7.1	11.6
		Share of total (%)			
United States (2012)[a]	--	16.8	20.8	62.3	0.0
China (2012)	--	4.8	11.3	83.9	0.0
Japan (2011)	--	12.3	21.0	62.1	4.6
Germany (2012)	--	NA	NA	NA	NA
South Korea (2011)	--	18.1	20.3	61.7	0.0
France (2011)	--	24.4	36.9	34.8	3.8

Country	GERD (PPP $billions)	Basic	Applied	Experimental development	Other nec
Russia (2012)	--	14.4	NA	NA	NA
United Kingdom (2011)	--	14.9	48.2	37.0	0.0
India (2009)	--	16.0	22.3	23.5	38.3

NA = not available.

GERD = gross expenditures on R&D; nec = not elsewhere classified; PPP = purchasing power parity.

[a] Data for the United States in this table reflect international standards for calculating GERD, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D.

NOTES: This table includes the top nine R&D-performing countries. Percentages may not add to total because of rounding. Data years are listed in parentheses.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2014/2); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 February 2015.

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The shares for applied research for these countries ranged between 11% (China) and 48% (United Kingdom), with the U.S. share nearly in the middle, at 21%. Nonetheless, in terms of overall volume, the United States dominates this category, with $90.6 billion of applied research spending in 2012. The second and third countries in this category are comparatively far back: China, at $33.1 billion, and Japan, at $31.2 billion.

With regard to (experimental) development, China exhibits the highest share by far: nearly 84% of its R&D total in 2012, which was $245.9 billion of spending in this category that year. For the United States, the development share that year was 62%, totaling $271.7 billion of spending in this category. Japan and South Korea also exhibit comparatively high shares for development, both near 62% in 2011; however, the dollar amounts of their performances were well below the levels for China and the United States.

U.S. Business R&D

Businesses have been the predominant performers of U.S. R&D for a long time (back into the 1950s). In 2008, the business sector accounted for $290.7 billion (71.4%) of the $407.0 billion total of U.S. total R&D (Table 4-7). In 2013, the business share was $322.5 billion (70.7%) of the $456.1 billion U.S. total. Year-to-year increases and declines in the level of business R&D performance greatly influence the U.S. R&D total. Indeed, the slowed growth and declines of U.S. R&D in the 2009–11 period owe much to the slowed growth and declines of the level of domestic business R&D in these years (see Figure 4-1).[i]

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[i] See Archibugi, Filippetti, and Frenz (2013) and references therein for studies on the relationship of R&D, innovation, and business cycles.

Table 4-7 **Funds spent for business R&D performed in the United States: 2008–13**

Sector	2008	2009	2010	2011	2012	2013
	Current $millions					
U.S. total R&D	406,952	405,136	408,197	427,832	435,375	456,094
All business R&D[a]	290,680	282,393	278,977	294,093	302,250	322,528
Paid for by the company	232,505	224,920	221,706	238,768	247,280	264,913
From company-owned, U.S.-located units	225,848	221,104	218,187	235,426	242,674	259,908
From foreign subsidiaries	6,657	3,816	3,519	3,342	4,606	5,005
Paid for by others	58,176	57,473	57,271	55,324	54,970	57,615
Federal	36,360	39,573	34,199	31,309	30,621	29,362
Domestic companies	12,181	9,567	11,013	11,124	11,624	13,450
Foreign companies	8,876	7,648	11,013	12,007	12,093	13,791
Foreign parent[b]	NA	NA	7,102	7,438	8,486	10,445
Unaffiliated companies	NA	NA	3,913	4,569	3,607	3,346
All other organizations[c]	759	685	1,046	884	632	1,013
	Source of funds as a percentage of all business R&D					
All business R&D[a]	100.0	100.0	100.0	100.0	100.0	100.0
Paid for by the company	80.0	79.6	79.5	81.2	81.8	82.1
From company-owned, U.S.-located units	77.7	78.3	78.2	80.1	80.3	80.6
From foreign subsidiaries	2.3	1.4	1.3	1.1	1.5	1.6

Sector	2008	2009	2010	2011	2012	2013
Paid for by others	20.0	20.4	20.5	18.8	18.2	17.9
Federal	12.5	14.0	12.3	10.6	10.1	9.1
Domestic companies	4.2	3.4	3.9	3.8	3.8	4.2
Foreign companies	3.1	2.7	3.9	4.1	4.0	4.3
Foreign parent[b]	NA	NA	1.7	1.7	1.9	2.3
Unaffiliated companies	NA	NA	1.0	1.1	0.8	0.7
All other organizations[c]	0.3	0.2	0.4	0.3	0.2	0.3

NA = not available.

[a] Includes companies located in the United States that performed or funded R&D. Data in this table represent an aggregate of all industries in the North American Industry Classification System codes 21–33 and 42–81.

[b] Includes foreign parent companies of U.S. subsidiaries.

[c] Includes U.S. state government agencies and laboratories, foreign agencies and laboratories, and all other organizations located inside and outside the United States.

NOTES: Detail may not add to total because of rounding. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. This table excludes data for federally funded R&D.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (annual series).

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The business sectors of the U.S. economy are diverse, with wide differences in the goods and services provided across industries and in the various production inputs required, including roles for R&D. Historically, companies in manufacturing industries have accounted for two-thirds or more of U.S. business R&D, with the balance accounted for by companies in nonmanufacturing industries. As it turns out, however, the peaks in current U.S. business R&D stem from a relative handful of industries, classified in both the manufacturing and nonmanufacturing sectors.

Key Characteristics of Domestic Business R&D Performance

NSF's annual Business R&D and Innovation Survey (BRDIS) provides data on all for-profit, nonfarm companies that are publicly or privately held and have five or more employees in the United States.[i] U.S. business R&D is the R&D performed by companies in the domestic United States, including that paid for by the company itself (from company-owned, U.S.-located units or from company subsidiaries located overseas) and that paid by others (such as other companies—domestic or foreign, including foreign parents of U.S. subsidiaries; the federal government; nonfederal government—domestic or foreign; nonprofit or other organizations—domestic or foreign).

Presently, most domestic R&D performance occurs in five business sectors: chemicals manufacturing (North American Industry Classification System [NAICS] 325—which includes the pharmaceuticals industry); computer and electronic products manufacturing (NAICS 334); transportation equipment manufacturing (NAICS 336—which includes the automobiles and aerospace industries); information (NAICS 51—which includes the software publishing industry); and professional, scientific, and technical (PST) services (NAICS 54—which includes the computer systems design and scientific R&D services industries) (Table 4-8).[ii] Although a sector's R&D performance total is influenced by both its overall economic size and the intensity of its R&D need (usually measured as dollars of R&D performance divided by total product sales), these are all sectors and industries with R&D intensities higher than others in the national economy (Table 4-9).

[i] BRDIS does not collect data for companies with fewer than five employees. See the sidebar, earlier in this chapter, "Measured and Unmeasured R&D."

[ii] The industry-level data presented in this section are obtained by classifying a company's total R&D into a single industry, even if R&D activities occur in multiple lines of business. For example, if a company has $100 million in R&D expenses—$80 million in pharmaceuticals and $20 million in medical devices—the total R&D expense of $100 million is assigned to the pharmaceuticals industry because it is the largest component of the company's total R&D expense (Shackelford 2012). However, most companies performed R&D in only one business activity area. In 2010, 86% of companies reported domestic R&D performed by and paid for by the company related to only one business activity. See also Shackelford (2012) for an in-depth analysis of the relationship between business codes and industry codes.

Table 4-8 **Funds spent for business R&D performed in the United States, by source of funds and selected industry: 2013**

			Paid for by others				
					Companies		
Industry and NAICS code	All R&D	Paid for by the company	Total	Federal	Domestic	Foreign a	All other organizations b
	Millions of dollars						
All industries, 21–33, 42–81	322,528	264,913	57,615	29,362	13,450	13,791	1,012
Manufacturing industries, 31–33	221,476	181,170	40,306	22,958	5,174	11,427	747
Chemicals, 325	61,664	54,285	7,379	356	1,389	5,594	40
Pharmaceuticals and medicines, 3254	52,426	45,891	6,534	167	1,343	4,987	37
Other 325	9,238	8,394	845	189	46	607	3
Machinery, 333	12,650	12,092	558	128	110	309	11
Computer and electronic products, 334	67,205	57,364	9,841	4,866	1,748	2,720	507
Electrical equipment, appliances, and components, 335	4,136	3,660	475	129	83	259	4
Transportation equipment, 336	45,972	25,165	20,807	17,312	1,328	1,676	491
Automobiles, trailers, and parts, 3361–63	16,729	14,081	2,647	304	565	1,772	6
Aerospace products and parts, 3364	27,114	10,042	17,072	15,927	758	D	D

			Paid for by others				
					Companies		
Industry and NAICS code	All R&D	Paid for by the company	Total	Federal	Domestic	Foreign a	All other organizations b
Other 336	2,129	1,042	1,088	1,081	5	D	D
Manufacturing nec, other 31–33	29,849	28,604	1,246	167	516	540	23
Nonmanufacturing industries, 21–23, 42–81	101,052	83,742	17,310	6,404	8,276	2,364	266
Information, 51	57,207	56,039	1,168	203	447	512	6
Software publishers, 5112	35,333	34,296	1,037	173	386	474	4
Other 51	21,874	21,743	131	30	61	38	2
Finance and insurance, 52	4,308	4,298	10	0	10	0	0
Professional, scientific, and technical services, 54	31,017	15,617	15,400	6,033	7,610	1,525	232
Computer systems design and related services, 5415	9,268	8,107	1,161	809	175	157	20
Scientific R&D services, 5417	14,201	2,838	11,363	3,288	6,841	1,127	107
Other 54	7,548	4,672	2,876	1,936	594	241	105
Nonmanufacturing nec, other 21–23, 42–81	8,520	7,788	732	168	209	327	28
	Percentage of sector/industry totals						
All industries, 21–33, 42–81	100.0	82.1	17.9	9.1	4.2	4.3	0.3
Manufacturing industries, 31–33	100.0	81.8	18.2	10.4	2.3	5.2	0.3
Chemicals, 325	100.0	88.0	12.0	0.6	2.3	9.1	0.1
Pharmaceuticals and medicines, 3254	100.0	87.5	12.5	0.3	2.6	9.5	0.1
Other 325	100.0	90.9	9.1	2.0	0.5	6.6	0.0
Machinery, 333	100.0	95.6	4.4	1.0	0.9	2.4	0.1
Computer and electronic products, 334	100.0	85.4	14.6	7.2	2.6	4.0	0.8
Electrical equipment, appliances, and components, 335	100.0	88.5	11.5	3.1	2.0	6.3	0.1

Industry and NAICS code	All R&D	Paid for by the company	Paid for by others				
					Companies		
			Total	Federal	Domestic	Foreign a	All other organizations b
Transportation equipment, 336	100.0	54.7	45.3	37.7	2.9	3.6	1.1
Automobiles, trailers, and parts, 3361–63	100.0	84.2	15.8	1.8	3.4	10.6	0.0
Aerospace products and parts, 3364	100.0	37.0	63.0	58.7	2.8	D	D
Other 336	100.0	48.9	51.1	50.8	0.2	D	D
Manufacturing nec, other 31–33	100.0	95.8	4.2	0.6	1.7	1.8	0.1
Nonmanufacturing industries, 21–23, 42–81	100.0	82.9	17.1	6.3	8.2	2.3	0.3
Information, 51	100.0	98.0	2.0	0.4	0.8	0.9	0.0
Software publishers, 5112	100.0	97.1	2.9	0.5	1.1	1.3	0.0
Other 51	100.0	99.4	0.6	0.1	0.3	0.2	0.0
Finance and insurance, 52	100.0	99.8	0.2	0.0	0.2	0.0	0.0
Professional, scientific, and technical services, 54	100.0	50.3	49.7	19.5	24.5	4.9	0.7
Computer systems design and related services, 5415	100.0	87.5	12.5	8.7	1.9	1.7	0.2
Scientific R&D services, 5417	100.0	20.0	80.0	23.2	48.2	7.9	0.8
Other 54	100.0	61.9	38.1	25.6	7.9	3.2	1.4
Nonmanufacturing nec, other 21–23, 42–81	100.0	91.4	8.6	2.0	2.5	3.8	0.3

D = suppressed to avoid disclosure of confidential information.

NAICS = North American Industry Classification System; nec = not elsewhere classified.

[a] Includes foreign parent companies of U.S. subsidiaries.

[b] Includes U.S. state government agencies and laboratories, foreign agencies and laboratories, and all other organizations located inside and outside the United States.

NOTES: Detail may not add to total because of rounding. Statistics are representative of companies located in the United States that performed or funded R&D. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Excludes data for federally funded R&D centers.Detail may not add to total because of rounding. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Excludes data for federally funded R&D centers.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey, 2013.
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Table 4-9 **Sales and R&D intensity for companies that performed or funded R&D, by selected industry: 2013**

Industry and NAICS code	Domestic net sales (US$millions)[a]	R&D intensity (%)[b]
All industries, 21–33, 42–81	9,654,952	3.5
Manufacturing industries, 31–33	5,902,677	3.9
Chemicals, 325	1,361,379	4.5
Pharmaceuticals and medicines, 3254	511,393	10.3
Other 325	849,986	1.0
Machinery, 333	370,969	3.4
Computer and electronic products, 334	643,383	10.6
Electrical equipment, appliances, and components, 335	142,537	2.9
Transportation equipment, 336	1,113,141	4.3
Automobiles, trailers, and parts, 3361–63	694,029	2.6
Aerospace products and parts, 3364	355,687	7.6
Other 336	63,425	4.4
Manufacturing nec, other 31–33	2,271,268	1.6
Nonmanufacturing industries, 21–23, 42–81	3,752,275	2.8
Information, 51	1,048,039	5.5
Software publishers, 5112	394,356	9.0
Other 51	653,683	3.4
Finance and insurance, 52	646,362	0.7
Professional, scientific, and technical services, 54	371,322	8.4
Computer systems design and related services, 5415	110,779	8.4[i]
Scientific R&D services, 5417	70,480	20.3
Other 54	190,063	4.0
Nonmanufacturing nec, other 21–23, 42–81	1,686,552	0.7

i = more than 50% of value imputed.

NAICS = North American Industry Classification System; nec = not elsewhere classified.

	[a] Includes domestic net sales of companies that perform or fund R&D, transfers to foreign subsidiaries, and export sales to foreign companies; excludes intracompany transfers and sales by foreign subsidiaries.
	[b] R&D intensity is domestic R&D paid for by the company and others and performed by the company divided by domestic net sales.
NOTES:	Detail may not add to total because of rounding. Statistics are representative of companies located in the United States that performed or funded R&D. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Excludes data for federally funded R&D centers. The Business R&D and Innovation Survey does not include companies with fewer than five employees.Detail may not add to total because of rounding. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. This table excludes data for federally funded R&D.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey, 2013.
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In 2013, these five business sectors accounted for $263.1 billion (82%) of the $322.5 billion business R&D performance total that year (Table 4-8). Corresponding data for earlier years are much the same: In 2008, the five sectors accounted for $244.9 billion (84%) of the $290.6 billion business R&D performance total (Appendix Table 4-13). Computer and electronic products accounted for about 21% of the business R&D performance total in 2013. From 2012 back to 2008, its share was in the 20%–22% range. Chemicals accounted for 19% of the business R&D total in 2013—most of which arose in the pharmaceuticals and medicines industry. Chemicals' share ranged from 19% to 21% in the previous years. The information sector accounted for about 18% of the business R&D performance total in 2013—nearly two-thirds of which was in software publishing. The information sector represented only 13% of the business R&D total in 2008, but its share has been rising since then. Transportation equipment (mainly the automobiles and aerospace industries) accounted for 14% in 2013 but had a higher share, at 17%, in 2008. Finally, the PST sector represented nearly 10% of the business R&D total in 2013—about half of this is from the scientific R&D services industry, but R&D is also sizable in the computer systems design and related services industry. The PST sector's share of the total was 13% in 2008 and has been gradually declining.

Looking at U.S. business R&D as a whole, performance is funded mainly by companies' own funds: 82% in 2013—the vast majority of this came from companies' units owned and located in the United States (81%), but a small amount (less than 2%) came from companies' foreign subsidiaries (Table 4-7). The 18% remainder comes from R&D performed by the company but paid for by others. Here the federal government is the largest of these "paid for by" sources: about 9% of the business R&D performance total in 2013. Companies other than the performer, both domestic and foreign (including foreign parents), account for about 4% each of the 2013 total. The "all other organizations" category spans a diverse group: state government agencies and laboratories, foreign agencies and laboratories, and any other domestic and foreign funding organizations. But this grouping accounts for a nearly negligible share: 0.3% in 2013. The relative shares of all these funding sources are not substantially different in looking back yearly to 2008 (Table 4-7).

Nonetheless, there are some noteworthy differences when more narrowly defined sectors and industries are considered, particularly for the five top R&D-performing sectors (and their main industries) previously discussed. R&D performance funded through a company's own funds was highest (in 2013) in the information sector, where the own funds share was 98%. By contrast, the own funds share was 55% in the transportation equipment sector and 50% in the PST sector. Even lower shares are evident when specific industries are considered: 20% in scientific R&D services are own funds, and 37% in aerospace products and parts are own funds.

The federal funding share is greatest in the transportation equipment sector (38%), particularly in this sector's aerospace products and parts industry (59%). It is also markedly higher than the all-business aggregate in the PST sector (20%). The next highest share is that of the computer and electronic products sector, at 7%.

Funding provided by other domestic companies, for most of the sectors and industries, were at or below the 4% aggregate average. The exception is PST, where it is 25% for the sector, but an even higher 48% in scientific R&D services. Funding provided by foreign companies was at about the 4% aggregate average for the computer and electronic products, transportation equipment, and PST sectors, but it was well below in the information section (1%) and well above in chemicals (9%).

Apart from direct funding for R&D in the form of contracts and grants to businesses, the U.S. government offers indirect R&D support via fiscal incentives such as tax credits. For recent statistics, see the sidebar Federal R&E Tax Credit and Appendix Table 4-14.

Finally, with regard to domestic business R&D performance and company size (as measured by the number of employees), Table 4-10 provides statistics for 2008–13. In 2013, large companies (i.e., those with 25,000 or more domestic employees) performed 37% of U.S. business R&D. Small companies (i.e., those with fewer than 500 domestic employees) accounted for 16%. The other 47% was spread among the size classifications between these extremes. As is apparent from the table, the distribution of all business R&D by company size has not greatly changed since 2008.

Federal R&E Tax Credit

The United States and other OECD countries offer fiscal incentives for business R&D at the national and subnational levels (Thomson 2012). For businesses, tax credits reduce after-tax costs of R&D activities. For governments, tax credits are forgone revenue, known as tax expenditures. Public incentives for R&D are generally justified by the inability of private performers to fully capture benefits from these activities, given the intangible nature of knowledge and information.

The U.S. research and experimentation (R&E) tax credit was originally established by the Economic Recovery Tax Act of 1981 on a temporary basis. The credit was extended on a temporary basis 17 times through 2014 and it was made permanent by the Protecting Americans From Tax Hikes Act of 2015 on December 18, 2015 (see Section 121 in H.R. 2029, Division Q, Title I, Subtitle A, Part 3).* The credit is designed to apply to incremental qualified research expenses by a business beyond a base amount. The bill making the credit permanent also included certain new provisions for small businesses. As of late December, details were still emerging about remaining and new features of the credit for different types of businesses. For an overview and methodologies to estimate the effectiveness of the R&E credit prior to recent changes see Guenther (2013) and Hall (1995).

Based on estimates from the Internal Revenue Service's (IRS's) Statistics of Income, R&E tax credit claims fell to $7.8 billion in 2009 from $8.3 billion in 2008 but rebounded in subsequent years, totaling $10.8 billion in 2012 (Appendix Table 4-14). Likewise, the number of corporate returns claiming the credit dropped in 2009 compared with 2008 but resumed an upward trend in the subsequent years. R&E credit claims relative to company-funded domestic R&D have fluctuated fairly narrowly between 3.0% and 4.4% since 2001 (3.6% in 2008, 3.5% in 2009, increasing gradually to 4.4% in 2012).

* See https://www.congress.gov/bill/114th-congress/house-bill/2029/text and Internal Revenue Code (IRC) Section 41, as amended. See also IRS Form 6765 at http://www.irs.gov/pub/irs-pdf/i6765.pdf and http://www.irs.gov/uac/SOI-Tax-Stats-Corporation-Research-Credit.

	Funds spent for business R&D performed in the United States, by size of

Table 4-10 **company: 2008–13**

Selected characteristic	Millions of dollars 2008	2010	2012	2013	Percentage of all business R&D 2008	2010	2012	2013
All business domestic R&D[a]	290,680	278,977	302,250	322,530	100.0	100.0	100.0	100.0
Size of company (number of domestic employees)								
5–499	58,138	52,202	49,962	53,002	20.0	18.7	16.5	16.4
5–24	14,280	12,573	9,841	10,296	4.9	4.5	3.3	3.2
25–49	9,626	8,625	7,195	7,941	3.3	3.1	2.4	2.5
50–99	9,351	8,855	9,182	8,910	3.2	3.2	3.0	2.8
100–249	14,662	11,866	12,480	13,666	5.0	4.3	4.1	4.2
250–499	10,219	10,283	11,264	12,189	3.5	3.7	3.7	3.8
500–999	11,886	10,117	11,484	12,002	4.1	3.6	3.8	3.7
1,000–4,999	46,336	48,228	50,691	55,517	15.9	17.3	16.8	17.2
5,000–9,999	24,764	27,463	30,483	31,514	8.5	9.8	10.1	9.8
10,000–24,999	48,737	41,835	49,493	51,218	16.8	15.0	16.4	15.9
25,000 or more	100,820	99,133	110,138	119,275	34.7	35.5	36.4	37.0

[a] For companies located in the United States that performed or funded R&D.

NOTES: Detail may not add to total because of rounding. This table excludes data for federally funded R&D. The Business R&D and Innovation Survey does not include companies with fewer than five employees.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (annual series).

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Cross-National Comparisons of Business R&D

The industries currently predominant in performing business R&D in the United States are generally also the main actors in the other largest R&D-performing countries. Table 4-11 provides cross-national comparisons for the United States, France, Germany, the United Kingdom, China, Japan, and South Korea (corresponding statistics for India and Russia are not presently available). These data come from the OECD's Analytical Business Enterprise R&D (ANBERD) database.[i] Note that the classification of industries in this table reflects the International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4 for all countries (including the United States), which differs somewhat from NAICS, which is used to report U.S. data earlier in this section of the chapter.[ii] Table 4-11 is also truncated, in that only those industries with comparatively higher levels of annual R&D performance are included—for a more complete listing of industries, see Appendix Table 4-15.

[i] For a description of the OECD's ANBERD methodology and data, see http://www.oecd.org/innovation/inno/anberdanalyticalbusinessenterpriseresearchanddevelopmentdatabase.htm.

[ii] ISIC Revision 4 was released by the United Nations Statistics Division in August 2008. For an overview of the classification structure, comparisons with earlier editions, and background, see http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27.

Table 4-11 **Business expenditures for R&D, by selected countries and top R&D-performing industries: 2012 or most recent year**

	ISIC Rev.4								
Industry	Section	Division	United States (2011)	France (2012)	Germany (2012)	United Kingdom (2012)	China (2012)	Japan (2012)	South Korea (2012)
			Millions of current PPP dollars						
Total business enterprise	A–U	1–99	294,093	35,237	68,469	24,610	223,169	116,321	50,245
Manufacturing	C	10–33	201,361	17,691	58,977	9,837	194,810	102,306	44,127
Chemicals and chemical products		20	9,375	1,060	4,450	378	17,559	7,138	2,655
Pharmaceuticals, medicinal chemical, and botanical products		21	45,949	946	5,209	725	8,062	12,484	1,214
Computer, electronic, and optical products		26	62,704	4,050	9,409	1,405	33,819	28,291	25,081
Motor vehicles, trailers, and semi-trailers		29	11,695	2,212	22,098	2,126	16,238	26,839	5,688
Other transport equipment		30	29,185	3,685	3,415	2,025	9,754	586	886
Air and spacecraft and related machinery		303	26,054	3,368	3,026	1,938	NA	309	185
Total services	G–U	45–99	88,945	16,532	8,975	14,300	14,156	12,403	4,391
Information and communication	J	58–63	55,124	3,845	4,042	3,483	NA	5,164	2,364
Publishing activities		58	28,435	930	NA	74	NA	6	1,518
Software publishing		582	27,965	920	NA	34	NA	NA	1,507

	ISIC Rev.4								
Industry	Section	Division	United States (2011)	France (2012)	Germany (2012)	United Kingdom (2012)	China (2012)	Japan (2012)	South Korea (2012)
Computer programming, consultancy, and related activities		62	13,259	1,877	3,072	2,250	NA	2,086	245
Professional, scientific, and technical activities	M	69–75	24,960	10,282	3,997	8,583	NA	6,280	1,037
Scientific R&D		72	15,301	4,334	2,155	6,744	NA	5,694	273
	Percentage of total business enterprise								
Total business enterprise	A–U	1–99	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Manufacturing	C	10–33	68.5	50.2	86.1	40.0	87.3	88.0	87.8
Chemicals and chemical products		20	3.2	3.0	6.5	1.5	7.9	6.1	5.3
Pharmaceuticals, medicinal chemical, and botanical products		21	15.6	2.7	7.6	2.9	3.6	10.7	2.4
Computer, electronic, and optical products		26	21.3	11.5	13.7	5.7	15.2	24.3	49.9
Motor vehicles, trailers, and semi-trailers		29	4.0	6.3	32.3	8.6	7.3	23.1	11.3
Other transport equipment		30	9.9	10.5	5.0	8.2	4.4	0.5	1.8
Air and spacecraft and related machinery		303	8.9	9.6	4.4	7.9	NA	0.3	0.4
Total services	G–U	45–99	30.2	46.9	13.1	58.1	6.3	10.7	8.7
Information and communication	J	58–63	18.7	10.9	5.9	14.2	NA	4.4	4.7
Publishing activities		58	9.7	2.6	NA	0.3	NA	0.0	3.0

	ISIC Rev.4								
Industry	Section	Division	United States (2011)	France (2012)	Germany (2012)	United Kingdom (2012)	China (2012)	Japan (2012)	South Korea (2012)
Software publishing		582	9.5	2.6	NA	0.1	NA	NA	3.0
Computer programming, consultancy, and related activities		62	4.5	5.3	4.5	9.1	NA	1.8	0.5
Professional, scientific, and technical activities	M	69–75	8.5	29.2	5.8	34.9	NA	5.4	2.1
Scientific R&D		72	5.2	12.3	3.1	27.4	NA	4.9	0.5

NA = not available.

ISIC Rev.4 = International Standard Industrial Classification of All Economic Activities, Revision 4; PPP = purchasing power parity.

NOTES: Detail may not add to total because of rounding. Industry classifications for all countries are based on main activity. The U.S. business R&D data are from the U.S. Business R&D and Innovation Survey 2011 (cross-walked to the ISIC Rev.4 classifications). In general, the table includes industries with annual R&D expenditures of $10 billion or more (i.e., each country's largest R&D performers). See appendix table 4-15 for a more comprehensive list of industries.

SOURCE: Organisation for Economic Co-operation and Development, Analytical Business Enterprise R&D, Statistical Analysis Database, R&D Expenditures in Industry, http://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4, accessed 9 April 2015.

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Based on ISIC, the manufacturing section (ISIC 10–33) accounted for about 69% of the $294.1 billion of overall business R&D performance in the United States in 2011. As apparent in Table 4-11, this stemmed in large part from the relatively high levels of R&D performed in the computer, electronic, and optical products division (ISIC 26—$62.7 billion, or 21% of all business-performed R&D in the United States in 2011); the pharmaceuticals, medicinal chemical, and botanical products division (ISIC 21—$45.9 billion, 16%); and the air and spacecraft and related machinery industry (ISIC 303—$26.1 billion, 9%). (The shares reported here are not materially different from those reported earlier in this section based on the NAICS categories.)

Outside of manufacturing, a comprehensive group encompassing all services divisions (ISIC 45–99) accounted for most of the rest ($88.9 billion, or 30%) of U.S. business R&D in 2011 (Table 4-11). The information and communication section (ISIC 58–63) itself accounted for 19%—including software publishing (ISIC 582, 10%). The PST activities section (ISIC 69–75) represented 9%—including scientific research and development (ISIC 72, 5%).

For Germany, Japan, South Korea, and China, the manufacturing sector accounts for a substantially higher share of overall business R&D: 86%–88%, depending on the country (Table 4-11). With Germany, the motor vehicles, trailers, and semi-trailers division (ISIC 29) accounted for 32% of the $68.5 billion of business R&D in 2012. The next-largest share was computer, electronic, and optical products (ISIC 26) at 14%. For Japan, with $116.3 billion of business R&D in 2012, the R&D preponderances were 24% in computer, electronic, and optical products (ISIC 26); 23% in motor vehicles, trailers, and semi-trailers (ISIC 29); and 11% in pharmaceuticals, medicinal chemical, and botanical products (ISIC 21). For South Korea, 50% of its $50.2 billion of business R&D in 2012 was in computer, electronic, and optical products (ISIC 26); the next highest share was 11% in motor vehicles, trailers, and semi-trailers (ISIC 29). China's business R&D, $223.2 billion in 2012, although conducted mainly in manufacturing, is more diverse: 15% in computer, electronic, and optical products (ISIC 26); 8% in chemicals and chemical products (ISIC 20); and 7% in motor vehicles, trailers, and semi-trailers (ISIC 29), with the rest widely spread.

France and the United Kingdom are exceptions to this manufacturing emphasis, given the quite large shares of R&D that occur in services industries (Table 4-11). For France, 50% of its $35.2 billion of business R&D in 2012 was in manufacturing, with peaks in computer, electronic, and optical products (12%) and in air and spacecraft and related machinery (10%). But 47% of France's business R&D total comes from services, with 29% in the PST activities section (ISIC 69–75) and 11% in the information and communication section (ISIC 58–63). Somewhat similarly, for the United Kingdom, with $24.6 billion of business R&D in 2012, 40% is manufacturing, with modest peaks in motor vehicles, trailers, and semi-trailers (9%) and air and spacecraft and related machinery (8%). But 58% is in services: 35% in PST activities (ISIC 69–75) and 14% in information and communication (ISIC 58–63).

R&D by Multinational Enterprises

The extent and geographic spread of R&D by multinational enterprises (MNEs) are useful markers of the increasing global character of supply chains for production and innovation in R&D-intensive sectors. These business activities reflect a mix of international economic trends, including the increased complexity of global supply chains, the deepening arrays of scientific/technological capabilities and resources around the globe, and the need to economically and strategically strengthen internal technological capabilities (Moncada-Paternò-Castello, Vivarelli, and Voigt 2011; OECD 2008).

This section is based on MNE operations data collected in annual foreign direct investment surveys conducted by BEA. These cover majority-owned affiliates (those owned more than 50% by their parent companies) of foreign MNEs located in the United States (Survey of Foreign Direct Investment in the United States) and U.S. MNEs and their majority-owned foreign affiliates (Survey of U.S. Direct Investment Abroad).[i]

R&D Performed in the United States by Affiliates of Foreign MNEs

Affiliates of foreign MNEs located in the United States (hereafter, U.S. affiliates) performed $48.0 billion of R&D in the United States in 2012 (Table 4-12). This was equivalent to 16% of the $302.3 billion of business R&D performed in the United States that year (comparing data in Table 4-1 and Table 4-12). Both the level of U.S. affiliate R&D and its share of the total of U.S. business R&D have generally increased since the later 1990s. In 1997, U.S. affiliate R&D was $17.2 billion, or equivalent to 11% of the U.S. business total; in 2007, it was $41.0 billion, or equivalent to 15% of the U.S. business R&D total (Appendix Table 4-2 and Appendix Table 4-16).

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[i] For further information on these BEA surveys, see http://www.bea.gov/international.

Table 4-12 R&D performed by majority-owned affiliates of foreign companies in the United States, by selected industry of affiliate and investor country: 2012

(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing		
Country	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Wholesale trade	Information	Professional, scientific, and technical services
All countries	47,994	33,953	18,281	2,711	4,339	637	4,787	7,448	1,347	4,174
Canada	631	365	1	D	62	0	203	66	77	97
Europe	36,821	29,349	16,573	2,415	3,347	547	3,814	3,044	789	3,062
France	6,501	5,632	D	D	1,584	D	D	160	558	95
Germany	5,839	4,478	1,629	D	147	26	1,046	377	D	D
Netherlands	1,882	1,289	215	D	D	0	D	422	D	33
Switzerland	9,387	7,408	D	52	D	D	D	D	5	1,427
United Kingdom	6,753	6,359	4,491	84	400	32	650	94	172	109
Other	6,459	4,184	390	647	201	D	D	D	D	D
Asia and Pacific	7,900	2,741	957	D	339	D	D	3,729	D	D
Japan	6,209	2,108	874	152	263	D	485	3,124	209	661
Other	1,691	633	82	D	77	0	D	606	D	D
Other	2,642	1,498	751	D	589	D	D	608	D	D

D = suppressed to avoid disclosure of confidential information.

NOTES: Data are preliminary and are for majority-owned (> 50%) affiliates of foreign companies by country of ultimate beneficial owner and industry of affiliate. Includes R&D conducted by foreign affiliates, whether for themselves or others under contract; excludes R&D conducted by others for affiliates.

SOURCE: U.S. Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/internationa /fdius2012_preliminary.htm, accessed 19 August 2015.

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About three-quarters of this U.S. affiliate R&D in 2012 was performed by firms owned by parent companies based in five countries: Switzerland (20%), the United Kingdom (14%), France (14%), Japan (13%), and Germany (12%) (Table 4-12). Although the relative rankings have shifted somewhat from year to year, these have been the predominant countries throughout the last 5 years.

U.S. affiliates classified in manufacturing accounted for 71% of the U.S. affiliate R&D total in 2012 (Table 4-12). This manufacturing share has generally been 70% or more since 2007 (Appendix Table 4-17). The chemicals subsector had 38%, with 35% pharmaceuticals. Other manufacturing subsectors with appreciable shares in 2012 included transportation equipment (10%), computer and electronic products (9%), and machinery (6%) (Appendix Table 4-17). For nonmanufacturing, the most notable sectors in 2012 were wholesale trade (16%) and PST services (9%).

U.S. MNE Parent Companies and Their Foreign Affiliates

R&D performed outside the United States by majority-owned foreign affiliates of U.S. MNEs totaled $45.0 billion in 2012 (Table 4-13). The parent companies of these U.S. MNEs performed $233.0 billion of R&D in the United States (Appendix Table 4-20), which was equivalent to about 77% of the total of business R&D conducted in the United States that year. In 1997, these foreign affiliates' R&D performance abroad was $14.6 billion; in 2007, it was $34.4 billion (Appendix Table 4-18).

Table 4-13 R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies, by selected industry of affiliate and host region/country/economy: 2012

(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing		
Region/country/economy	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Wholesale trade	Information	Professional, scientific, and technical services
All countries	44,983	30,497	9,153	2,214	7,074	681	7,700	2,510	3,214	8,065
Canada	2,864	1,702	267	25	593	D	584	D	D	616
Europe	26,742	19,448	6,245	1,636	3,752	328	5,044	1,717	1,304	3,852
Austria	257	205	23	119	8	D	1	D	0	D
Belgium	2,547	2,140	D	13	50	1	D	11	*	390
Denmark	237	123	9	D	74	*	0	D	D	2
Finland	191	163	11	D	D	3	2	2	1	25
France	2,031	1,749	357	161	494	8	284	140	77	56
Germany	8,027	6,628	431	415	1,878	186	3,165	524	71	713
Ireland	1,465	836	319	*	315	D	2	D	424	188
Italy	683	458	155	99	68	10	59	33	2	187
Luxembourg	302	D	D	*	*	0	0	*	D	D
Netherlands	1,489	1,207	729	26	55	23	D	16	65	195
Norway	299	89	6	D	D	0	0	D	D	D
Poland	207	124	11	2	D	1	52	2	2	78
Russia	130	104	D	1	D	0	D	9	D	D
Spain	272	213	D	7	D	9	D	10	0	37

		Manufacturing						Nonmanufacturing		
Region/country /economy	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Wholesale trade	Information	Professional, scientific, and technical services
Sweden	572	436	46	D	75	4	132	D	46	59
Switzerland	2,364	1,297	475	D	225	10	D	589	255	222
United Kingdom	5,206	3,169	1,350	229	326	28	938	203	225	1,393
Latin America and OWH	2,747	1,616	509	97	71	D	685	133	D	167
Argentina	161	83	45	*	D	0	D	2	*	D
Brazil	1,285	1,131	336	89	D	*	589	60	D	D
Mexico	405	250	70	5	D	D	70	D	*	31
Africa	129	52	17	4	*	0	27	3	0	D
South Africa	102	D	17	4	0	0	D	3	0	D
Middle East	2,033	899	27	140	604	0	0	D	D	D
Israel	2,012	895	26	140	604	0	0	D	D	874
Asia and Pacific	10,470	6,779	2,088	314	2,053	278	1,361	341	801	2,505
Australia	1,153	921	199	15	29	9	D	30	D	142
China	2,012	956	230	47	327	116	109	D	D	717
India	2,289	655	305	D	224	D	37	D	248	1,206
Japan	2,314	1,933	1,185	141	204	D	112	53	123	205
Malaysia	655	640	2	*	596	*	0	D	0	D
Singapore	509	391	55	19	274	D	D	15	37	62
South Korea	898	833	51	25	117	0	D	32	D	19
Taiwan	274	168	16	4	129	9	5	4	D	D

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

	OWH = other Western Hemisphere.
NOTES:	Data are for majority-owned (> 50%) affiliates of U.S. parent companies by host country and industry of affiliate. Includes R&D conducted by foreign affiliates, whether for themselves or others under contract; excludes R&D conducted by others for affiliates.
SOURCE:	U.S. Bureau of Economic Analysis, Direct Investment and Multinational Enterprises (annual series), http://www.bea.gov/iTable/index_MNC.cfm, accessed 18 August 2015.
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European countries hosted $26.7 billion (59%) of this foreign affiliate R&D in 2012 (Table 4-13). The largest R&D expenditures by U.S.-owned affiliates in this region were located in Germany ($8.0 billion, 18%) and the United Kingdom ($5.2 billion, 12%). Other notable locations included Belgium ($2.5 billion, 6%), Switzerland ($2.4 billion, 5%), and France ($2.0 billion, 5%). The European share overall was 66% in 2007 and 69% in 1997 (Appendix Table 4-18). Germany and the United Kingdom were the predominant host countries over this 15-year period, although the two countries had more evenly matched shares before 2008.

Canada hosted $2.9 billion (6%) of U.S. MNE foreign affiliate R&D in 2012, a sizable amount in comparison with other countries, but its share has been gradually declining since 1997 (Appendix Table 4-18).

Countries in the Asia and Pacific regions hosted $10.5 billion (23%) of foreign affiliate R&D in 2012 (Table 4-13). Majority-owned affiliates of U.S. MNEs located in Japan and India had the largest R&D expenditures in this region (each hosting about $2.3 billion, or 5%), followed closely by affiliates located in China ($2.0 billion, 4%). Similar to other cross-national comparative indicators for R&D, the Asia/Pacific region continues to gain an increasing share as a host for U.S. parent companies' foreign affiliate R&D. The region accounted for only 13% of the total in 1997. While Japan's share has remained sizable across the 1997–2012 period, although declining somewhat since the early 2000s, the growth areas for this foreign affiliate R&D have been India and China, each of which accounted for a negligible share in the late 1990s but grew to largely match that of Japan by 2012 (Appendix Table 4-18).

Latin America and other Western Hemisphere countries accounted for $1.6 billion (3%) in R&D expenditures by U.S.-owned affiliates in 2012, mostly in Brazil. U.S.-owned affiliates in the Middle East accounted for $2.0 billion (5%) in 2012, nearly all in Israel.

With respect to economic sectors, foreign affiliate R&D of U.S. MNEs was concentrated in four industries in 2012: chemicals (manufacturing, particularly pharmaceuticals, $9.2 billion, 20%), PST services (nonmanufacturing, $8.1 billion, 18%), transportation equipment (manufacturing, $7.7 billion, 17%), and computer and electronic products (manufacturing, $7.1 billion, 16%) (Table 4-13). Other notable industries include information (nonmanufacturing, $3.2 billion), wholesale trade (nonmanufacturing, $2.5 billion), and machinery (manufacturing, $2.2 billion). These industries have been similarly prominent over the last several years (Appendix Table 4-19).

Despite a decline in the shares held by traditional locations for this foreign affiliate R&D, Europe (as a whole) and Japan remain the top R&D hosts for U.S. MNEs in major industries, reflecting both strengths of the host countries in certain technologies and the large, longstanding investments by U.S. MNEs in these locations. In transportation equipment, Germany is by far the largest location of U.S.-owned foreign affiliate R&D: $3.2 billion of the $7.7 billion total R&D in 2012 performed by majority-owned foreign affiliates of U.S. MNEs is classified in this industry (Table 4-13). Similarly, for computers and electronic products manufacturing, Germany was the leading host location, with $1.9 billion in R&D expenditures out of the $7.1 billion total R&D performed by majority-owned foreign affiliates of U.S. MNEs classified in this industry. In chemicals manufacturing, the United Kingdom and Japan were the top locations of U.S.-owned R&D in 2012: $1.4 billion and $1.2 billion, respectively, of the $9.2 billion in total U.S.-owned affiliates' R&D outside of the United States in this industry.

Finally, for R&D performed by U.S. MNE foreign affiliates classified in PST services, the host country roles reflect both older trends and the rise of Asia as a host of U.S.-owned R&D (Table 4-13). The United Kingdom hosted the largest amount of R&D performed in this industry in 2012 ($1.4 billion of the $8.1 billion total of U.S.-owned R&D outside the United States in PST services), followed by India ($1.2 billion). China and Germany were essentially tied for third largest in PST services by U.S.-owned affiliates ($0.7 billion each).

Recent Trends in Federal Support for U.S. R&D

The U.S. government supports the nation's R&D system through various policy avenues. Its most direct role is as provider of a regular funding stream for the R&D activities conducted by both federal organizations (agency intramural laboratories/facilities and FFRDCs) and by external, nonfederal organizations such as businesses and academic institutions. Fifteen federal departments and a dozen other agencies engage in and/or provide funding for R&D in the United States (Table 4-14). Even so, in recent years, the vast majority of the yearly federal funding total is accounted for by the R&D activities of a small group of departments/agencies: the Department of Defense (DOD), the Department of Health and Human Services (HHS), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), NSF, the U.S. Department of Agriculture (USDA), and the Department of Commerce (DOC). The sections immediately following provide statistics on several topics that illuminate the key recent trend in this important federal role: the ups and downs of overall federal funding for R&D over the last 10 years in particular, how this federal financial support has been distributed across the various federal departments and agencies and by types of performers, looking at federal funding just for research (i.e., basic research and applied research) and seeing which fields of S&E predominate, and finally, how the priorities of the United States for federal R&D funding compare with those of the other large, global R&D-performing countries.

(Note: The corresponding data for federal funding of U.S. R&D cited in Table 4-1 earlier in this chapter are lower. The Table 4-1 numbers are based on performers' reports of their R&D expenditures from federal funds. This difference between performer and source of funding reports of the level of R&D expenditures has been present in the U.S. data for more than 15 years and reflects various technical issues. For a discussion, see sidebar, Tracking R&D Expenditures: Disparities in the Data Reported by Performers and Sources of Funding)

Tracking R&D Expenditures: Disparities in the Data Reported by Performers and Sources of Funding

In the United States—and in some other OECD countries—the data on government funding of R&D as reported by the government often differ from those reported by performers of R&D. Consistent with international guidelines, most countries report their national R&D expenditures based chiefly on data from R&D performers (OECD 2002). In the United States, over the last several decades, a sizable gap has opened between what the federal government and R&D performers separately report as the level of federally funded R&D (Figure 4-A; Appendix Table 4-21).

In the mid- to later 1980s, the total of federally funded R&D reported by all U.S. performers exceeded by \$3–\$4 billion (i.e., 6%–9% of the federally reported total) what the federal government said it funded (left panel of Figure 4-A). In 1989–91, however, the pattern reversed, with the performer-reported total of federal funding less than the federally reported total by \$1–\$2 billion annually. From the early 1990s through the mid-2000s, this federal report excess grew larger. In 2007, the federal report indicated \$127 billion of federal funding for R&D, compared with R&D performers' report of \$107 billion—a difference of almost \$21 billion, or 16% of the federally reported total. As implied by Figure 4-A's right panel (which focuses on only business R&D performers), much of the disparity arose from differences in the federal and performer reports regarding business R&D.

More recently, the all-performer gap has narrowed. In 2009, the federal report showed federal funding for all R&D performers exceeding the performer-reported total by \$14 billion (10% of the federal report) and in 2013, only \$4 billion (3% of the federal report). Nonetheless, the federal report excess for only the business R&D performers in these most recent years has remained as sizable (see right panel of Figure 4-A). The appearance is that the federal report now includes lower estimates of the level of federally funded R&D by performers (notably in higher education and the FFRDCs) other than the business sector, which then offset the federal report's higher estimates of funding for business R&D.

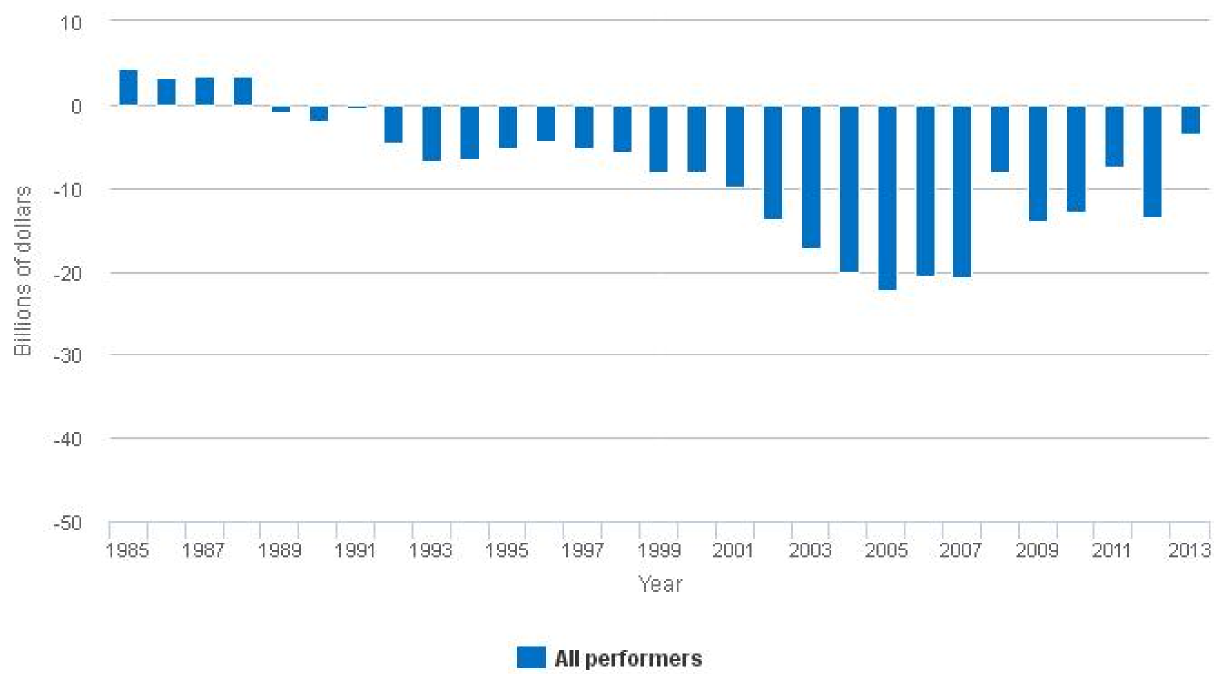
Federal R&D funding data are normally reported as obligations on a fiscal year basis; performers typically report R&D expenditures on a calendar year basis. Some of the observed discrepancies reflect this difference in reporting calendars. Nevertheless, adjusting the two data series to a common calendar does not significantly remove the observed gaps.

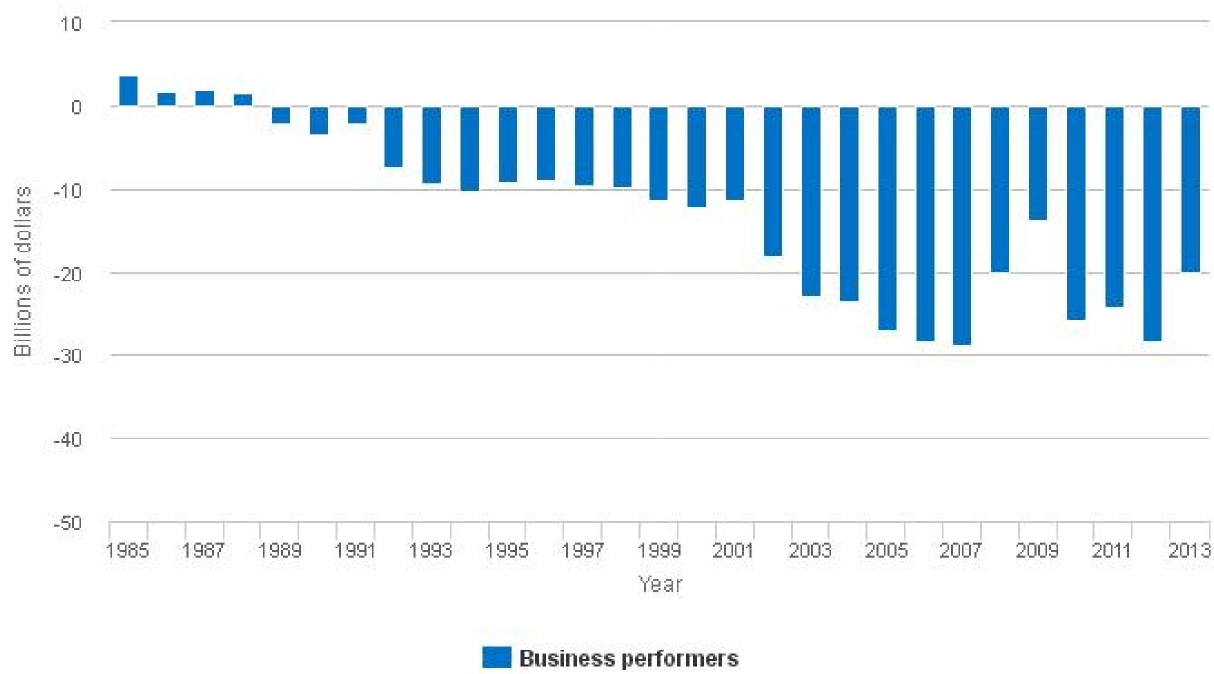
Several investigations into the possible causes for these data disparities have produced insights but no conclusive explanation. A General Accounting Office (GAO) investigation made the following assessment:

Because the gap is the result of comparing two dissimilar types of financial data [federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist. (GAO 2001:2)

Figure 4-A

Discrepancy in federal R&D support, as reported by performers and federal agencies: 1985–2013





NOTES: Discrepancy is defined as performer-reported R&D minus federally reported R&D funding. A negative discrepancy indicates that agency-reported R&D funding exceeds performer-reported R&D.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series), and Survey of Federal Funds for Research and Development, FYs 2013–15. See appendix table 4-21.

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Table 4-14 Federal obligations for R&D and R&D plant, by agency: FYs 2007–14

(Millions of dollars)

Agency	2007	2008	2009	2010	2011	2012	2013	2014[a]
All agencies	129,431.2	129,049.5	144,758.1	146,967.8	139,661.5	140,635.8	127,297.3	130,807.7
Department of Defense	72,290.5	71,996.6	75,973.7	73,623.9	75,327.6	73,973.6	63,654.7	63,711.3
Department of Health and Human Services	29,556.1	29,700.7	35,735.9	37,616.9	30,928.0	31,335.8	29,512.8	30,422.1
National Aeronautics and Space Administration	6,205.8	5,847.1	5,957.6	8,691.3	8,429.0	10,758.3	10,494.3	11,010.0
Department of Energy	8,629.8	8,990.3	11,562.2	11,644.9	10,680.4	10,635.2	10,397.1	11,114.7
National Science Foundation	4,406.9	4,506.4	6,924.8	6,073.4	5,536.6	5,705.4	5,328.5	5,551.3
Department of Agriculture	2,372.3	2,246.0	2,344.7	2,615.4	2,376.9	2,194.3	2,037.4	2,435.7
Department of Commerce	1,145.4	1,196.4	1,533.4	1,683.2	1,308.9	1,230.7	1,293.9	1,632.7
Department of Transportation	811.0	825.2	846.2	929.2	861.8	936.1	875.8	967.1
Department of Homeland Security	1,106.4	1,056.8	983.6	1,131.8	1,127.5	832.2	718.8	973.9
Department of the Interior	624.7	645.3	738.8	728.0	716.5	742.7	717.3	753.4
Department of Veterans Affairs	446.5	480.0	510.0	563.0	612.9	614.8	639.0	600.2
Environmental Protection Agency	576.0	532.0	552.8	572.3	581.7	581.1	529.7	538.0

Agency	2007	2008	2009	2010	2011	2012	2013	2014[a]
Department of Education	333.1	328.1	322.4	362.8	346.1	338.0	309.9	324.7
Smithsonian Institution	186.0	188.0	226.7	213.0	248.7	246.2	240.3	232.3
Agency for International Development	234.5	123.8	160.1	84.3	119.2	77.4	125.5	128.0
Department of Justice	184.4	114.5	103.4	125.4	102.3	85.0	118.7	104.2
All other agencies	321.8	272.3	281.8	309.0	357.4	349.0	303.6	308.1

[a] FY 2014 data are preliminary and may later be revised.

NOTES: This table lists all agencies with R&D and R&D plant obligations greater than $100 million in FY 2013. All other agencies include Department of Housing and Urban Development, Department of Labor, Department of State, Department of the Treasury, Appalachian Regional Commission, Consumer Product Safety Commission, Federal Communications Commission, Federal Trade Commission, Library of Congress, National Archives and Records Administration, Nuclear Regulatory Commission, and Social Security Administration.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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Total of Federal Funding for R&D and for Major Departments/Agencies

The federal government has long provided funding support annually for the R&D activities of its own departments and agencies, as well as all the other major U.S. R&D performers.[i] The level of overall federal support for R&D (including for both R&D conduct and R&D plant) has generally increased year to year since the early 1950s (Figure 4-10; Appendix Table 4-22). What was $2–$5 billion in the mid-1950s increased to well above $100 billion in FY 2003, to just under $130 billion in FYs 2007 and 2008. The level moved higher still in FYs 2009 and 2010, largely as a result of the $18.7 billion of incremental funding for R&D authorized by the ARRA. In fact, the 2009 and 2010 levels were the highest since the early 1950s (whether considered in current or constant dollar terms). Annual growth in federal funding averaged 6.2% in current dollars over FYs 2000–10, or 4.0% when adjusted for inflation.

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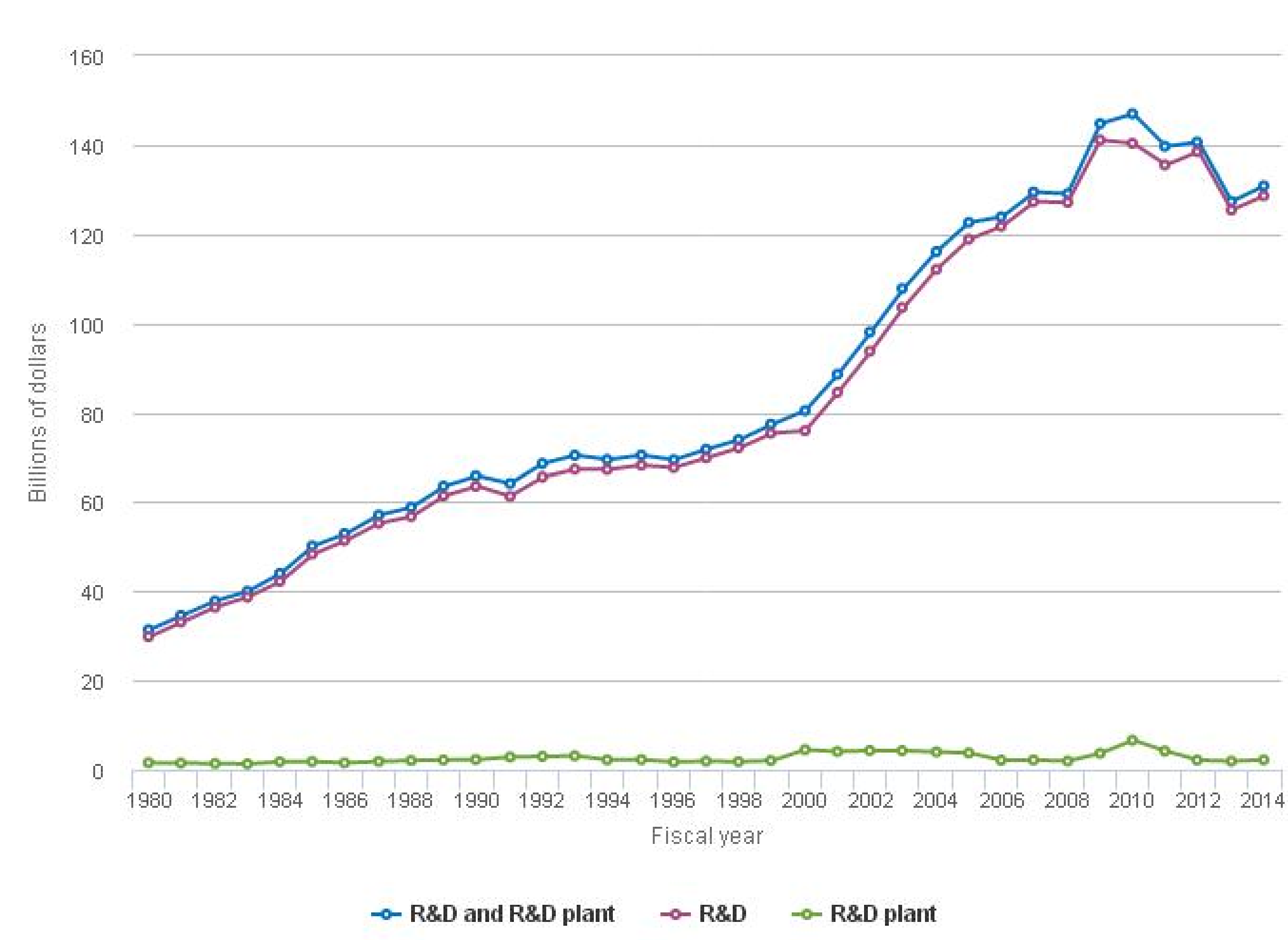
[i] The analysis in this section focuses primarily on developments in federal R&D priorities and funding support over the course of the last decade. Nevertheless, there is an important and interesting story to tell about how the comparatively minor federal role in the nation’s science and research system up until World War II was reconsidered, redirected, and greatly enlarged, starting shortly after the end of the war and moving through the subsequent decades to the present. For a review of the essential elements of this evolving postwar federal role, see Jankowski (2013).

Figure 4-10

Federal obligations for R&D and R&D plant: FYs 1980–2014



NOTE: Data for FYs 2009 and 2010 include obligations from the additional federal R&D funding appropriated by the American Recovery and Reinvestment Act of 2009.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15. See appendix table 4-22.

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However, a decidedly different trend has prevailed in the years since then, as federal R&D funding has been buffeted by the more challenging policy-making circumstances for the federal budget that has prevailed over the last several years. The $147.0 obligations in FY 2010 dropped by $6–$7 billion in FYs 2011 and 2012, and then more precipitously to $127.3 in FY 2013. The more favorable budget-making circumstances in FY 2014 yielded an increase to $130.8 billion that year. Nonetheless, the drop from the FY 2010 level to the FY 2014 level is a current dollar decline of 11% and is steeper still, at 17%, when factoring in inflation.

Some of this post–FY 2010 drop in federal R&D funding is the waning of the effects of the incremental funding provided by ARRA, which showed up as R&D obligations mainly in FYs 2009 and 2010. Nonetheless, the still-sluggish U.S. economy and continuing differences among the main parties involved in negotiating and enacting the annual federal budgets (the White House and Congress) have taken a toll—with federal funding for R&D affected as part of this larger picture.[ii]

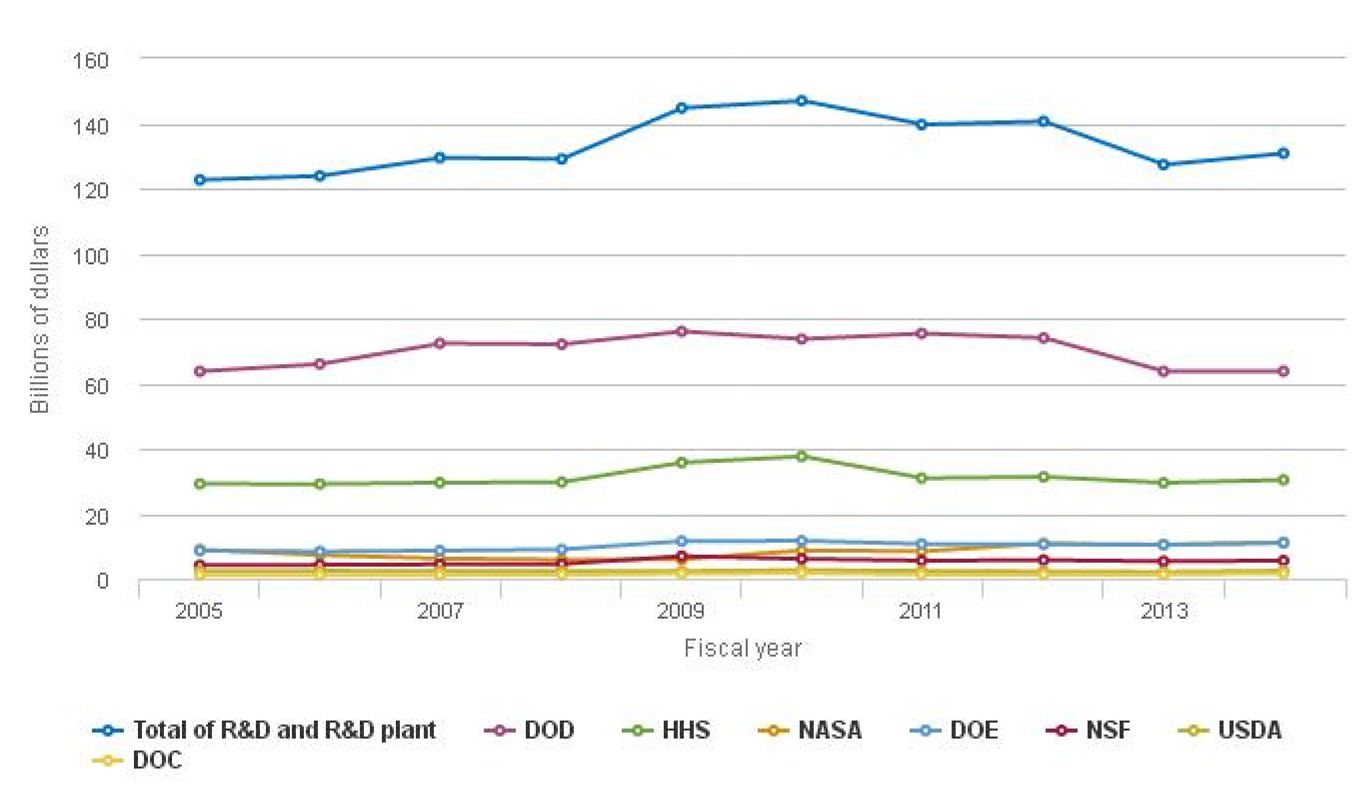
In FYs 2013 and 2014, seven departments/agencies each obligated more than $1 billion annually (current dollars): DOD, HHS, NASA, DOE, NSF, USDA, and DOC (Table 4-14). Together, these accounted for about 96% of the federal R&D and R&D plant total these years. Another five departments/agencies obligated funding in the $500 million to $900 million range that year: the Department of Transportation (DOT), the Department of Homeland Security (DHS), the Department of the Interior, the Department of Veterans Affairs (VA), and the Environmental Protection Agency (EPA).

Figure 4-11 charts the annual total federal funding for R&D and R&D plant together and that for each of the seven principal departments/agencies from FY 2005 to FY 2014. The figure shows the substantial drop in the federal funding total (current dollars) that has occurred since the peak in FY 2010. It also shows that the funding drop through FY 2014 has been borne most heavily by DOD ($9.9 billion of the $16.1 billion cumulative decline from FY 2010 to FY 2014) and HHS ($7.2 billion of the $16.1 decline). DOE and NSF sustained cumulative drops of $0.5 billion over this same period. NASA was the exception, at $2.3 billion higher in FY 2014 than in FY 2010. The other departments/agencies sustained substantially smaller losses or gains.

For a further account of this recent federal budget history, see Boroush (2014). Notable among the various interconnected developments over these years were the federalwide spending reductions imposed by the enacted FY 2011 federal budget: the Budget Control Act of 2011, intended to address the then-ongoing national debt ceiling crisis, which commanded a 10-year schedule of budget caps and spending cuts; the budget sequestration provision, which ultimately took hold in the FY 2013 federal budget; and the Bipartisan Budget Act of 2013, which provided some subsequent relief from the deepening sequestration requirements, but only for the FY 2014 and FY 2015 budgets.

Figure 4-11

Federal obligations for R&D and R&D plant, by selected agencies: FYs 2005–14



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

NOTES: The departments and agencies included in this figure all had annual R&D obligations of $1 billion or more and together account for the vast majority of the R&D and R&D plant total. Data for FYs 2009 and 2010 include obligations from the additional federal R&D funding appropriated by the American Recovery and Reinvestment Act of 2009.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development (annual series).

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Distribution of Federal Funding of R&D, by Performer and Type of Work

Table 4-15 and Table 4-16 provide breakdowns by departments/agencies of the $127.3 billion of federal dollars obligated for R&D and R&D plant in FY 2013 according to purpose (R&D conduct, R&D plant), performers funded (intramural, extramural), and type of work (basic research, applied research, development).

Table 4-15 **Federal obligations for R&D and R&D plant, by agency and performer: FY 2013**

(Millions of dollars)

				Total by performers			
Agency	Total	R&D	R&D plant	Intramural and FFRDCs	Percentage of total	Extramural performers	Percentage of total
All agencies	127,297.3	125,387.5	1,909.8	44,297.9	34.8	82,999.4	65.2
Department of Defense	63,654.7	63,557.7	97.0	21,544.6	33.8	42,110.1	66.2
Department of Health and Human Services	29,512.8	29,382.5	130.3	6,656.0	22.6	22,856.9	77.4
National Aeronautics and Space Administration	10,494.3	10,368.1	126.2	2,953.3	28.1	7,540.9	71.9
Department of Energy	10,397.1	9,841.0	556.1	7,749.0	74.5	2,648.0	25.5
National Science Foundation	5,328.5	4,955.9	372.6	251.4	4.7	5,077.2	95.3
Department of Agriculture	2,037.4	2,020.6	16.8	1,407.9	69.1	629.6	30.9
Department of Commerce	1,293.9	1,092.2	201.7	1,008.4	77.9	285.3	22.1
Department of Transportation	875.8	855.0	20.9	255.4	29.2	620.4	70.8
Department of Homeland Security	718.8	390.8	327.9	441.7	61.4	277.2	38.6
Department of the Interior	717.3	709.3	8.0	635.9	88.6	81.3	11.3
Department of Veterans Affairs	639.0	639.0	0.0	639.0	100.0	0.0	0.0
Environmental Protection Agency	529.7	522.8	7.0	253.8	47.9	276.0	52.1
Department of Education	309.9	309.9	0.0	14.1	4.5	295.8	95.5
Smithsonian Institution	240.3	195.0	45.3	240.3	100.0	0.0	0.0
Agency for International Development	125.5	125.5	0.0	3.8	3.0	121.8	97.1
Department of Justice	118.7	118.7	0.0	45.0	37.9	73.7	62.1
All other agencies	303.7	303.7	0.0	198.6	65.4	105.0	34.6

FFRDC = federally funded R&D center.

NOTES: This table lists all agencies with R&D obligations greater than $100 million in FY 2013. R&D is basic research, applied research, and development and does not include R&D plant. Intramural activities include actual intramural R&D performance and costs associated with planning and administering both intramural and extramural programs by federal personnel. Extramural performers include federally funded R&D performed in the United States and U.S. territories by businesses, universities and colleges, other nonprofit institutions, state and local governments, and foreign organizations. All other agencies include Department of Housing and Urban Development, Department of Labor, Department of State, Department of the Treasury, Appalachian Regional Commission, Consumer Product Safety Commission, Federal Communications Commission, Federal Trade Commission, Library of Congress, National Archives and Records Administration, Nuclear Regulatory Commission, and Social Security Administration.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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Table 4-16 Federal obligations for R&D, by agency and type of work: FY 2013

(Millions of current dollars)

					Percentage of total R&D		
Agency	Total R&D	Basic research	Applied research	Development	Basic research	Applied research	Development
All agencies	125,387.5	29,779.4	29,420.4	66,187.8	23.7	23.5	52.8
Department of Defense	63,557.7	1,862.8	4,092.5	57,602.4	2.9	6.4	90.6
Department of Health and Human Services	29,382.5	15,288.3	14,026.3	67.9	52.0	47.7	0.2
National Aeronautics and Space Administration	10,368.1	2,824.2	2,598.2	4,945.7	27.2	25.1	47.7
Department of Energy	9,841.0	3,851.1	3,482.3	2,507.6	39.1	35.4	25.5
National Science Foundation	4,955.9	4,361.5	594.4	0.0	88.0	12.0	0.0
Department of Agriculture	2,020.6	844.2	1,025.2	151.2	41.8	50.7	7.5
Department of Commerce	1,092.2	190.6	832.6	69.0	17.4	76.2	6.3
Department of Transportation	855.0	7.2	647.5	200.3	0.8	75.7	23.4
Department of Homeland Security	390.8	0.0	140.7	250.2	0.0	36.0	64.0
Department of the Interior	709.3	51.4	551.9	106.0	7.2	77.8	14.9
Department of Veterans Affairs	639.0	249.0	355.0	35.0	39.0	55.6	5.5

					Percentage of total R&D		
Agency	Total R&D	Basic research	Applied research	Development	Basic research	Applied research	Development
Environmental Protection Agency	522.8	0.0	446.2	76.6	0.0	85.4	14.6
Department of Education	309.9	24.4	177.8	107.7	7.9	57.4	34.8
Smithsonian Institution	195.0	195.0	0.0	0.0	100.0	0.0	0.0
Agency for International Development	125.5	9.0	116.5	0.0	7.1	92.9	0.0
Department of Justice	118.7	20.7	57.1	41.0	17.4	48.1	34.5
All other agencies	303.6	0.1	276.4	27.1	0.0	91.0	8.9

NOTES: This table lists all agencies with R&D obligations greater than $100 million in FY 2013. Detail may not add to total because of rounding. All other agencies include Department of Housing and Urban Development, Department of Labor, Department of State, Department of the Treasury, Appalachian Regional Commission, Consumer Product Safety Commission, Federal Communications Commission, Federal Trade Commission, Library of Congress, National Archives and Records Administration, Nuclear Regulatory Commission, and Social Security Administration.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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The vast majority ($125.4 billion) was for R&D conduct, whether performed by the intramural R&D facilities of the departments/agencies themselves or by one or more of various extramural performers receiving federal R&D funding (the FFRDCs, private businesses, universities and colleges, state and local governments, other nonprofit organizations, or foreign performers) (Table 4-15). Barely 2% of the annual total ($1.9 billion) funded R&D plant, with most of the obligations in this category coming from a few agencies.

For the $125.4 billion of obligations that year for R&D, 24% was for basic research, 24% for applied research, and 53% for development (Table 4-16). These proportions vary widely, however, when specific departments/agencies are considered.

Department of Defense

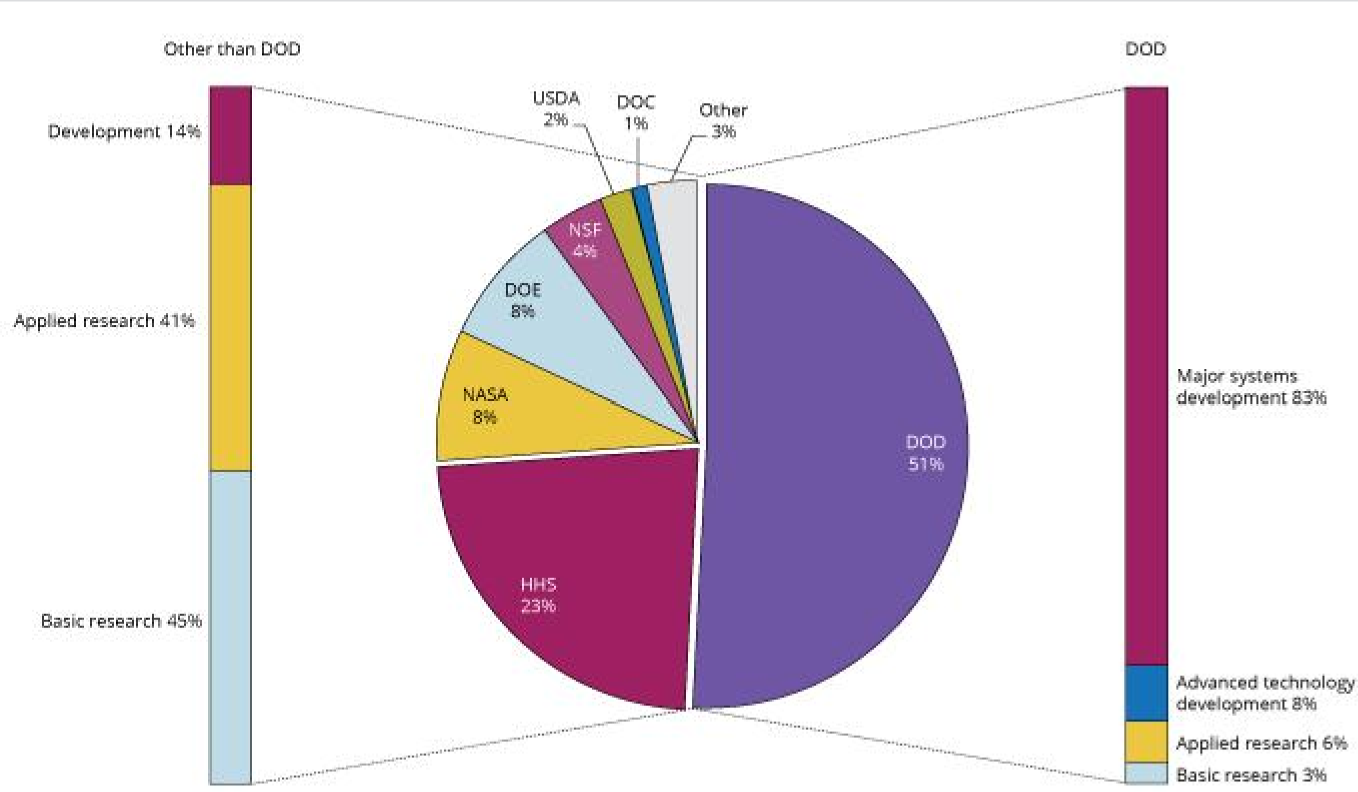
In FY 2013, DOD obligated a total of $63.7 billion for R&D and R&D plant (Table 4-15), which represented about 50% of all federal spending on R&D and R&D plant that year. Nearly the entire DOD total was R&D spending ($63.6 billion), with the remainder spent on R&D plant.

Of the total, 34% ($21.5 billion) was spending by the department’s intramural laboratories, related agency R&D program activities, and FFRDCs (Table 4-15). Extramural performers accounted for 66% ($42.1 billion) of the obligations, with the bulk going to business firms ($39.2 billion) (Appendix Table 4-23).

Considering just the R&D, relatively small amounts were spent on basic research ($1.9 billion, 3%) and applied research ($4.1 billion, 6%) in FY 2013 (Table 4-16). The vast majority of obligations, $57.6 billion (91%), went to development. Furthermore, the bulk of this DOD development ($52.7 billion) was allocated for major systems development, which includes the main activities in developing, testing, and evaluating combat systems (Figure 4-12). The remaining DOD development ($4.9 billion) was allocated for advanced technology development, which is more similar to other agencies' development obligations.

Figure 4-12

Federal obligations for R&D, by agency and type of work: FY 2013



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

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

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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Department of Health and Human Services

HHS is the main federal source of spending for health-related R&D. In FY 2013, the department obligated $29.5 billion for R&D and R&D plant, or 23% of the total of federal obligations that year. Nearly all of this was for R&D ($29.4 billion). Furthermore, the vast majority, $28.2 billion, supported the R&D activities of the National Institutes of Health (NIH).

For the department as a whole, R&D and R&D plant obligations for agency intramural activities and FFRDCs accounted for 23% ($6.7 billion) of the total. Extramural performers accounted for 77% ($22.9 billion). Universities and colleges ($16.6 billion) and other nonprofit organizations ($4.4 billion) conducted the most sizable of these extramural activities (Appendix Table 4-23).

Nearly all of HHS R&D funding was allocated to research: 52% for basic research and 48% for applied research. Only a tiny fraction, 0.2%, funded development.

National Aeronautics and Space Administration

NASA obligated $10.5 billion to R&D in FY 2013, which was 8% of the federal total. Nearly all of it ($10.4 billion) was for R&D. Of these obligations, 72% were for extramural R&D, which was conducted chiefly by business performers. Agency intramural R&D and that done by FFRDCs represented 28% of the total NASA obligations.

By type-of-R&D, 48% of the NASA R&D obligations funded development activities, 27% funded basic research, and 25% funded applied research.

Department of Energy

DOE obligated $10.4 billion for R&D and R&D plant in FY 2013 or, like NASA, about 8% of the total of federal obligations that year. Of this amount, $9.8 billion was for R&D, and $0.6 billion was for R&D plant.

The department's intramural laboratories and FFRDCs accounted for 75% of the total obligations, a substantially higher percentage than most other agencies. Many of DOE's research activities require specialized equipment and facilities available only at its intramural laboratories and FFRDCs, which are used by scientists and engineers from other agencies and sectors as well as by DOE researchers. The remaining 26% of obligations to extramural performers went chiefly to businesses and to universities and colleges.

Basic research accounted for 39% of the $9.8 billion obligated to R&D, applied research for 35%, and development for 26%.

DOE R&D activities are distributed among domestic energy systems, defense (much of it funded by the department's National Nuclear Security Administration), and general science (much of which is funded by the department's Office of Science).

National Science Foundation

In FY 2013, NSF obligated $5.3 billion for R&D and R&D plant (4% of the federal total): $5.0 billion for R&D and $0.4 billion for R&D plant. Extramural performers, chiefly universities and colleges, accounted for 95% of this total ($5.1 billion). Basic research was about 88% of the R&D component. NSF is the federal government's primary source of funding for academic basic S&E research and the second-largest federal source (after HHS) of R&D funds for universities and colleges.

Department of Agriculture

USDA obligated $2.0 billion for R&D and R&D plant in FY 2013, with the main focus on life sciences. The agency is also one of the largest research funders in the social sciences, particularly agricultural economics. Of USDA's total obligations for FY 2013, about 69% ($1.4 billion) funded R&D by agency intramural performers, chiefly the Agricultural Research Service. Basic research accounts for about 42%, applied research accounts for 51%, and development accounts for 8%.

Department of Commerce

DOC obligated $1.3 billion for R&D in FY 2013, most of which represented the R&D and R&D plant spending of the National Oceanic and Atmospheric Administration and the National Institute of Standards and Technology (NIST): $1.1 billion of the total was for R&D, and $0.2 billion was for R&D plant. Of this total, 78% was for agency intramural R&D; 22% went to extramural performers, primarily businesses and universities and colleges. For the R&D component, 17% was for basic research, 76% was for applied research, and 6% was for development.

Other Departments/Agencies

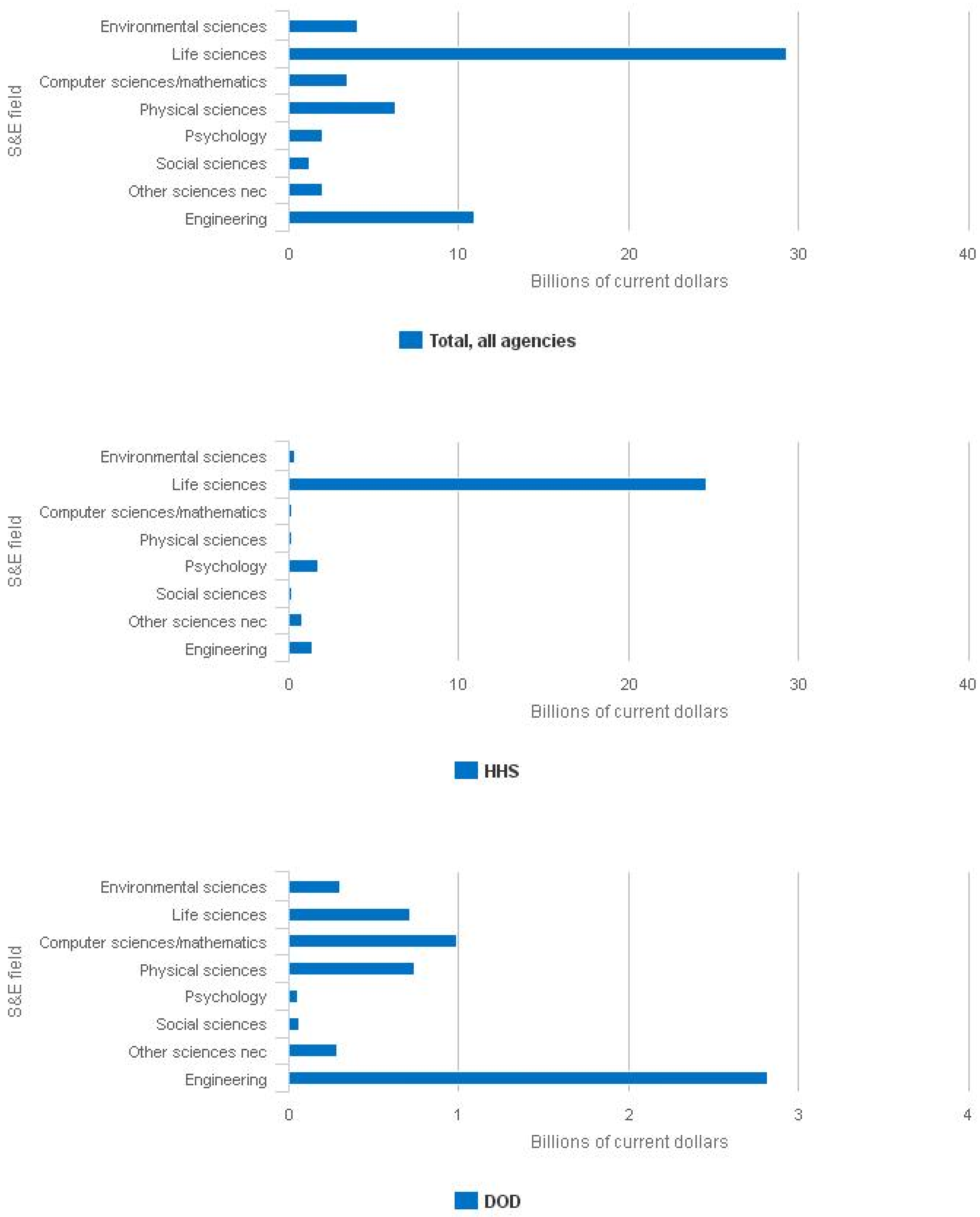
The seven departments/agencies discussed specifically accounted for slightly more than 96% of $127.3 billion of R&D and R&D plant obligations total in FY 2013. The other departments/agencies shown in Table 4-15 and Table 4-16 play significant roles in the overall U.S. R&D system, but individually, they account for comparatively small to very small levels of federal resources annually. (DHS deserves, perhaps, a particular callout in the FY 2013 data, because of its $0.3 billion obligated to R&D plant, which was sizable in comparison with that of other departments/agencies obligating funds for R&D plant that year.) As the tables show, these agencies continue to vary considerably with respect to the character of research and the roles of intramural, FFRDC, and extramural performers.

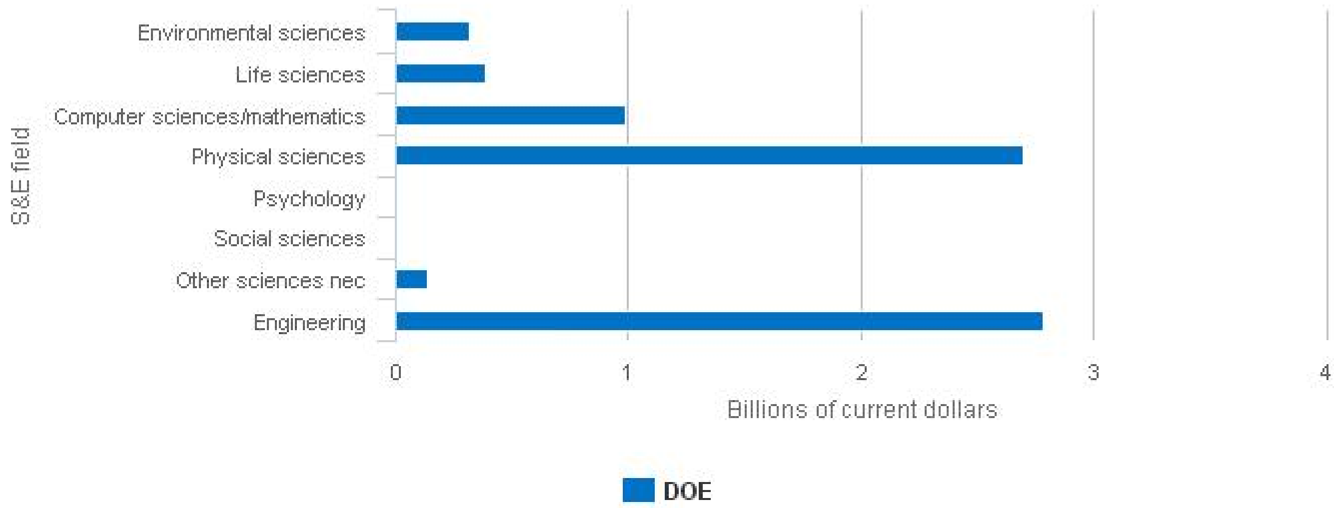
Distribution of Federal Spending for Research, by Fields of S&E

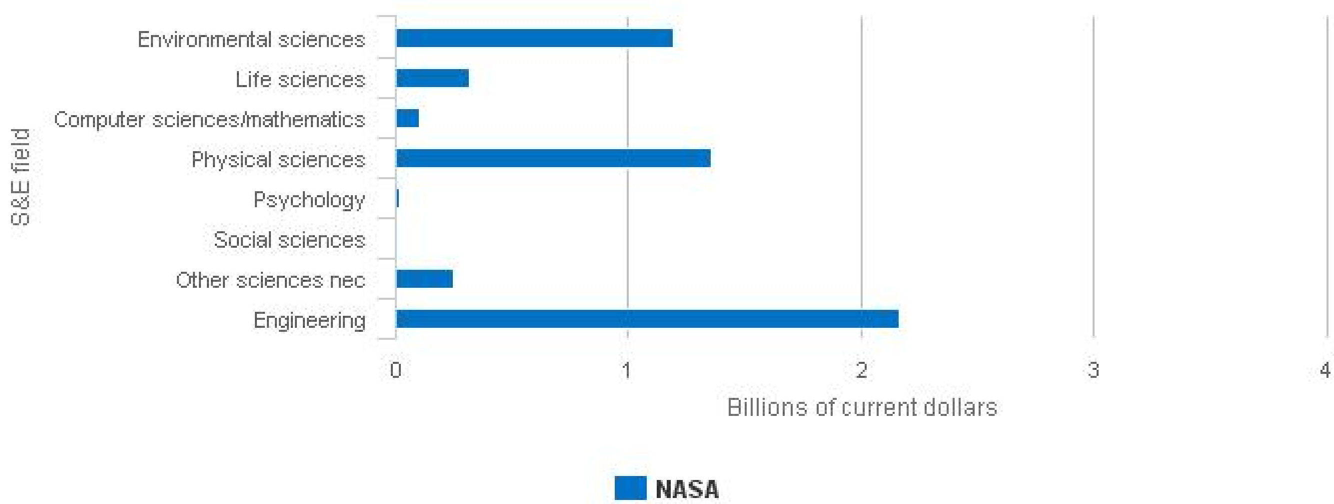
Development work cannot easily be classified by S&E field, but research—basic and applied—can. The research conducted and/or funded by the federal government spans a full range of S&E fields (environmental sciences, computer sciences and mathematics, physical sciences, psychology, social sciences, other sciences, and engineering). The incidence of these fields varies widely with respect to their main federal support agency and current funding levels (Figure 4-13; Appendix Table 4-24 and Appendix Table 4-25).

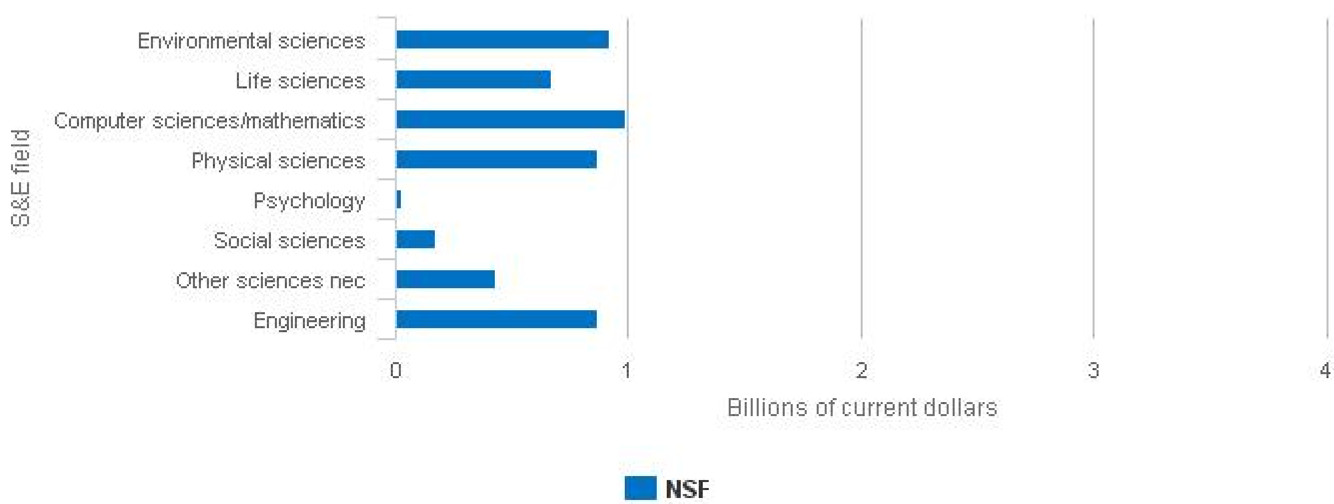
Figure 4-13

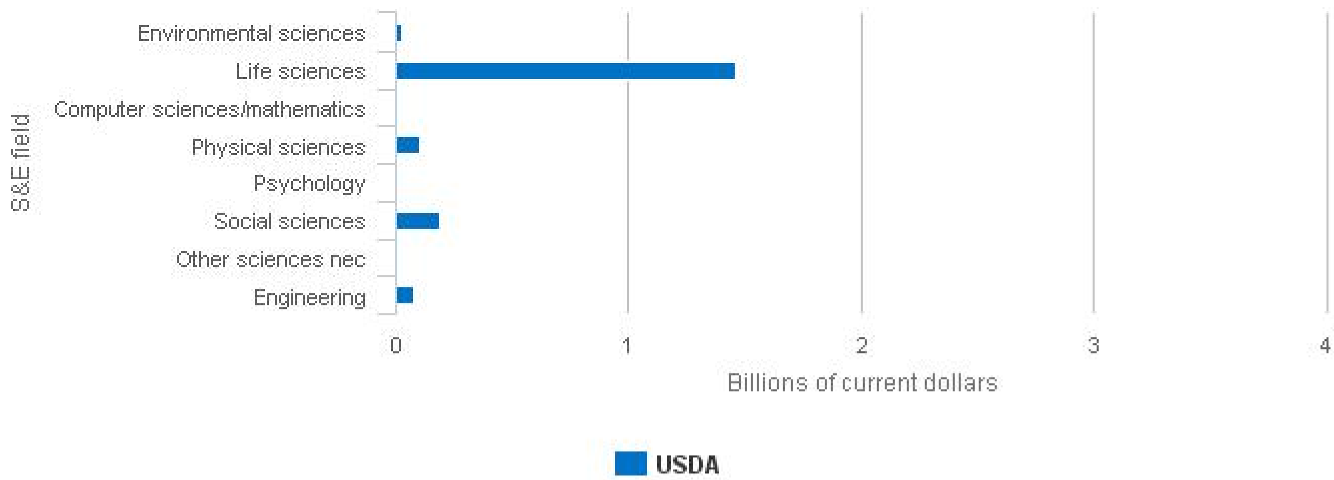
Federal obligations for research, by agency and major S&E field: FY 2013

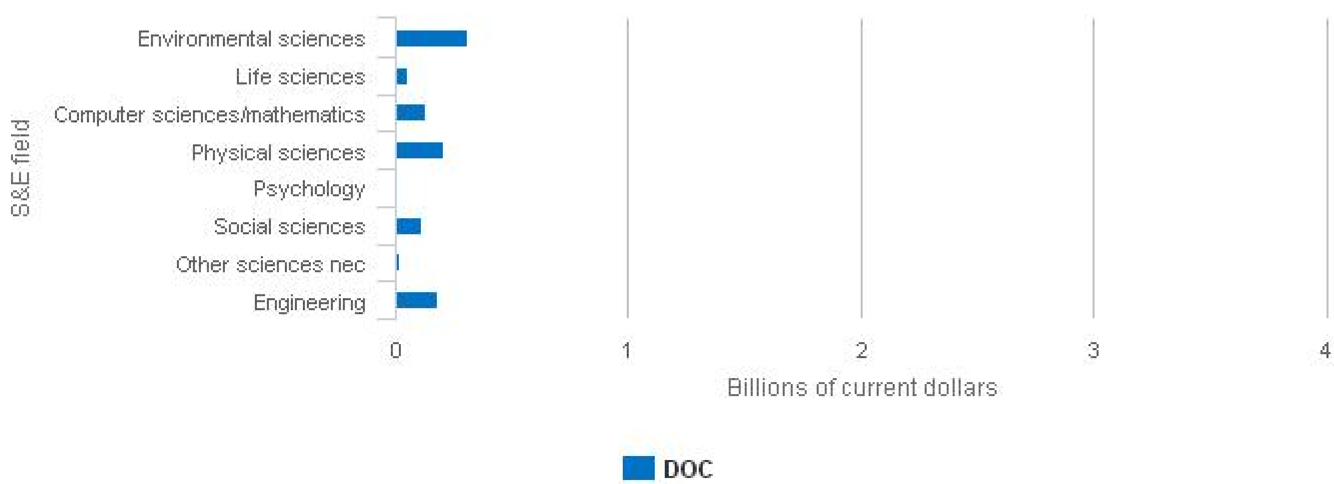


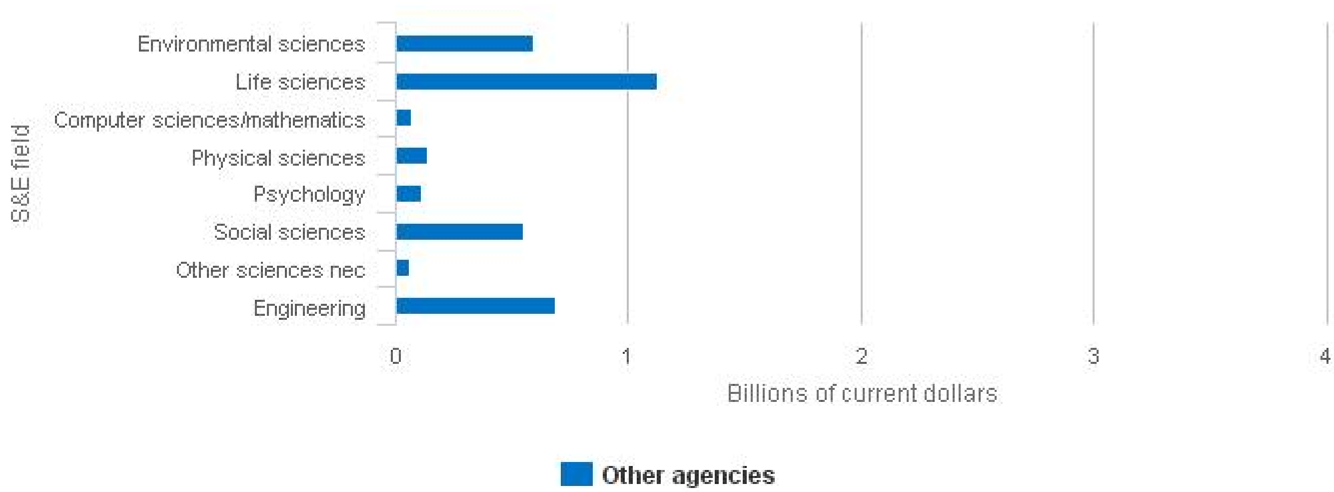

Environmental sciences
Life sciences
Computer sciences/mathematics
Physical sciences
Psychology
Social sciences
Other sciences nec
Engineering
S&E field
0
1
2
3
4
Billions of current dollars
DOE


Environmental sciences
Life sciences
Computer sciences/mathematics
Physical sciences
Psychology
Social sciences
Other sciences nec
Engineering
S&E field
0
1
2
3
4
Billions of current dollars
NASA


Environmental sciences
Life sciences
Computer sciences/mathematics
Physical sciences
Psychology
Social sciences
Other sciences nec
Engineering
S&E field
0
1
2
3
4
Billions of current dollars
NSF







DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; nec = not elsewhere classified; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTES: The scales differ for Total, all agencies and HHS compared with the scales for the other agencies listed. Research includes basic and applied research.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15. See appendix table 4-24.

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In FY 2013, funding for basic and applied research combined accounted for nearly half ($59.2 billion, 47%) of the $125.4 billion total of federal obligations for R&D (Table 4-16). Half of this amount, $29.3 billion, supported research in the life sciences (Appendix Table 4-24). The fields with the next-largest amounts were engineering ($10.9 billion, 18%) and the physical sciences ($6.3 billion, 11%), followed by the environmental sciences ($4.0 billion, 7%) and computer sciences and mathematics ($3.4 billion, 6%). The balance of federal obligations for research in FY 2013 supported psychology, the social sciences, and all other sciences ($5.2 billion overall, or 9% of the total for research).

With differing missions, the federal agencies vary significantly in the types of S&E fields emphasized. HHS accounted for the largest share (50%) of federal obligations for research in FY 2013 (Appendix Table 4-24). Most of this amount funded research in life sciences, primarily through NIH. The six next-largest federal agencies for research funding that year were DOE (12%), DOD (10%), NASA (9%), NSF (8%), USDA (3%), and DOC (2%).

DOE's $7.3 billion in research obligations provided funding for research in the physical sciences ($2.7 billion) and engineering ($2.8 billion), along with computer sciences and mathematics ($1.0 billion). DOD's $6.0 billion of research funding emphasized engineering ($2.8 billion) but also included computer sciences and mathematics ($1.0 billion), physical sciences ($0.7 billion), and life sciences ($0.7 billion). NASA's $5.4 billion for research emphasized engineering ($2.2 billion), followed by the physical sciences ($1.4 billion) and environmental sciences ($1.2 billion). NSF—not a mission agency in the traditional sense—is charged with "promoting the health of science." As such, it had a comparatively diverse $5.0 billion research portfolio that allocated about $0.7 billion to $1.0 billion in each of the following fields: environmental sciences, life sciences, computer sciences and mathematics, physical sciences, and engineering. Lesser amounts were allocated to psychology, social sciences, and other sciences. USDA's $1.9 billion was directed primarily at the life (agricultural) sciences ($1.5 billion). DOC's $1.0 billion was distributed mainly in the fields of environmental sciences, physical sciences, and engineering.

Viewed over the 2000–13 time span, federal obligations for research in all S&E fields increased on average by 3.4% annually (or 1.3% when adjusted for inflation). More recently, research funding levels have been declining, starting in FY 2011, by an average of 1.5% annually through FY 2013 (or down by 2.5% yearly, adjusted for inflation) (Appendix Table 4-25).

The trends within more narrowly defined fields are more nuanced, depending on whether the base year is in the 1990s, 2000, 2005, or a more recent year (Appendix Table 4-25). Looking at only the period of FY 2005–13, the life sciences' share declines from about 52% of the research total in FY 2005 to 50% in FY 2013. (Before FY 2005, the life sciences' share had mainly been rising from year to year.) Over the same period, engineering's share increased from about 16% in FY 2005 to 18% in FY 2013. The share for the other major fields remained mainly stable.

Cross-National Comparisons of Government R&D Priorities

Government R&D funding statistics compiled annually by the OECD provide insights into how national government priorities for R&D differ across countries. Known technically as government budget appropriations or outlays for R&D (GBAORD), this indicator provides data on how a country's overall government funding for R&D splits among a set of socioeconomic categories (e.g., defense, health, space, general research).[i] GBAORD statistics for the United States and most of the other top R&D-performing countries discussed earlier appear in Table 4-17 (corresponding GBAORD data for China and India are not currently available).

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[i] GBAORD classifies total government funding on R&D into the 14 socioeconomic categories specified by the EU's 2007 edition of the Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NABS). These categories are exploration and exploitation of the earth; environment; exploration and exploitation of space; transport, telecommunications, and other infrastructures; energy; industrial production and technology; health; agriculture; education; culture, recreation, religion, and mass media; political and social systems, structures, and processes; general advancement of knowledge: R&D financed from general university funds; general advancement of knowledge: R&D financed from sources other than general university funds; and defense. GBAORD statistics published by the OECD in the *Main Science and Technology Indicators* series report on clusters of these 14 NABS categories.

Table 4-17 Government R&D support by major socioeconomic objectives, by selected countries/regions and years: 2000–13

			Percentage of GBAORD		Percentage of nondefense					
Region /country	Year	GBAORD (current PPP US$millions)	Defense	Nondefense	Economic development programs	Health and environment	Education and society	Civil space	Non-oriented research	General university funds
United States	2000	83,612.5	51.6	48.4	13.4	49.9	1.8	20.9	13.8	na
	2010	148,962.0	57.3	42.7	12.5	56.1	1.6	12.9	16.9	na
	2013	132,477.0	52.7	47.3	10.4	54.7	2.9	16.7	15.4	na
EU	2000	77,028.5	12.9	87.1	23.3	11.8	3.5	6.0	17.9	34.9
	2010	117,886.5	6.4	93.6	22.2	14.1	6.5	5.3	18.3	33.2
	2013	117,621.6	4.4	95.6	20.7	14.2	5.5	5.1	18.5	35.1
France	2000	14,747.5	21.4	78.5	17.7	9.7	1.1	13.2	27.4	28.5
	2010	19,093.2	14.7	85.3	21.1	12.6	5.3	12.7	19.6	27.0
	2013	17,540.5	6.3	93.7	17.6	11.4	5.4	10.4	21.2	27.0
Germany	2000	16,817.0	7.8	92.2	21.6	9.4	3.9	5.1	17.5	42.4
	2010	28,896.9	5.0	95.0	24.4	9.2	4.4	5.0	17.0	40.6
	2013	31,961.8	3.7	96.3	22.9	9.8	4.2	4.8	17.7	41.5
United Kingdom	2000	10,520.2	35.7	64.4	14.2	27.7	6.3	3.4	18.3	29.7
	2010	13,529.6	18.2	81.8	8.5	32.3	5.0	2.1	22.0	30.1
	2013	13,744.3	15.9	84.1	15.8	32.0	4.4	3.9	15.8	28.1
Japan	2000	21,193.4	4.1	95.9	33.4	6.6	1.0	5.8	14.6	37.0
	2010	32,150.0	4.8	95.2	27.6	7.4	0.9	7.1	21.0	35.9
	2013	34,679.3	4.6	95.4	25.2	9.0	0.7	6.5	21.7	36.9
South Korea	2000	5,020.2	20.5	79.5	53.4	14.8	3.8	3.1	24.9	**

			Percentage of GBAORD		Percentage of nondefense					
Region /country	Year	GBAORD (current PPP US$millions)	Defense	Nondefense	Economic development programs	Health and environment	Education and society	Civil space	Non-oriented research	General university funds
	2010	14,225.6	15.8	84.2	49.5	13.8	2.7	2.7	31.3	**
	2011	15,265.4	16.3	83.7	49.9	14.1	2.7	2.4	30.9	**

** = included in other categories; na = not applicable.

EU = European Union; GBAORD = government budget appropriations or outlays for R&D; PPP = purchasing power parity.

NOTES: Foreign currencies are converted to dollars through PPPs. The GBAORD statistics reported for the United States are federal budget authority data. The most recent data available for South Korea are from 2011. GBAORD data are not yet available for China or India. The socioeconomic objective categories are aggregates of the 14 categories identified by Eurostat's 2007 Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets. The data are as reported by the Organisation for Economic Co-operation and Development (OECD).

SOURCE: OECD, *Main Science and Technology Indicators* (2014/2), http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB, accessed 3 March 2015.

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Defense is an objective for government funding of R&D for all the top R&D-performing countries, but the shares vary considerably (Table 4-17). Defense accounted for 53% of U.S. federal R&D support in 2013, but it was markedly lower elsewhere: a smaller but still sizable 16% in South Korea and 16% in the United Kingdom, and below 7% in France, Germany, and Japan.

Defense has received 50% or more of the federal R&D budget in the United States for many years. It was 63% in 1990 as the Cold War period drew to a close, but then dropped in subsequent years. It rose again in the first decade of the 2000s—in large part, reflecting post–9/11 security concerns—but it has been declining again over the last several years. For the other countries, the defense share of government R&D funding has generally declined or remained at a stable, low level.

The health and environment objective accounted for almost 55% of nondefense federal R&D budget support in the United States in FY 2013 and 32% in the United Kingdom. For both countries, the share has expanded markedly over the share prevailing several decades ago. The health and environment share is currently 14% in South Korea and 11% or less in France, Germany, and Japan.

The economic development objective encompasses agriculture, energy, fisheries and forestry, industry, transportation, telecommunications, and other infrastructure. In the United States, government R&D funding in this category was 13% of all nondefense federal support for R&D in 2000 but had dropped to 10% in 2013, substantially lower than most other major nations (Table 4-17).[ii] In the United Kingdom, it was 14% in 2000, declining from 2000 to 2010, but rising to 16% in 2013. France had 18% in 2000, rising to 21% by 2010, but declining back to 18% by 2013. Japan had 33% in 2000, but generally declined in the years after, to 25% in 2013. Germany had 22% in 2000, rising to 23% in 2013. South Korea, 50% in 2011, has consistently exhibited the largest share for this category in 2011 among the top R&D-performing countries.

The civil space objective accounted for about 17% of nondefense federal R&D funding in the United States in 2000 (Table 4-17). The share was 21% in 2000 and declined to 13% by 2010 but has experienced increases more recently. The share in France is about 10% for 2013, down from 13% in 2000. The space share has been well below 10% for the rest of the top R&D-performing countries.

Both the nonoriented research funding and general university fund (GUF) objectives reflect government support for R&D by academic, government, and other performers that is directed chiefly at the "general advancement of knowledge" in the natural sciences, engineering, social sciences, humanities, and related fields. For some of the countries, the sum of these two objectives currently represents by far the largest part of nondefense GBAORD: Germany (59%), Japan (59%), France (48%), the United Kingdom (44%), and South Korea (31%). The corresponding 2013 share for the United States (15%), although appearing substantially smaller, requires interpretive caution. Cross-national comparisons of these particular indicators can be difficult because some countries (notably the United States) do not use the GUF mechanism to fund R&D for general advancement of knowledge, do not separately account for GUF (e.g., South Korea), and/or more typically direct R&D funding to project-specific grants or contracts, which are then assigned to the more specific socioeconomic objectives (see sidebar, Government Funding Mechanisms for Academic Research).

Finally, the education and society objective represents a comparatively small component of nondefense government R&D funding for all of the top R&D-performing countries. However, it is notably higher in France (5%), Germany (4%), and the United Kingdom (4%) than in Japan (1%). The United States (3%) and South Korea (3%) are in between.

[ii] Some analysts argue that the relatively low nondefense GBAORD share for economic development in the United States reflects the expectation that businesses will finance industrial R&D activities with their own funds. Moreover, government R&D that may be useful to industry is often funded with other purposes in mind, such as defense and space, and then classified in these other socioeconomic objectives.

Government Funding Mechanisms for Academic Research

U.S. universities generally do not maintain data on departmental research (i.e., research that is not separately budgeted and accounted for). As such, U.S. R&D totals are understated relative to the R&D effort reported for other countries. The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants provided by all levels of government to the academic sector. These funds can support departmental R&D programs that are not separately budgeted. GUF is not equivalent to basic research. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. However, some state government funding probably does support departmental research, not separately accounted for, at U.S. public universities.

The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Moreover, government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds that can be assigned to specific socioeconomic categories).

In several large European countries (France, Germany, Italy, and the United Kingdom), GUF accounts for 50% or more of total government R&D funding to universities. In Canada, GUF accounts for about 38% of government academic R&D support. Thus, international data on academic R&D reflect not only the relative international funding priorities but also the funding mechanisms and philosophies regarded as the best methods for financing academic research.

Federal Programs to Promote the Transfer and Commercialization of Federal R&D

Starting in the late 1970s, concerns by domestic policymakers about the strength of U.S. industries and their ability to succeed in the increasingly competitive global economy took on greater intensity. The issues raised included whether the new knowledge and technologies arising from federally funded R&D were being fully and effectively exploited for the benefit of the national economy, whether undue barriers in the private marketplace worked to slow businesses in creating and commercializing innovations and new technologies, and whether better public-private partnerships for R&D and business innovation had the potential to significantly aid the nation's economy in responding to these emerging challenges (Tassey 2007).

Numerous national policies and related initiatives have been directed at these challenges over the last 30 years, including how to better transfer and economically exploit the results of federally funded R&D—and how to avoid unduly placing government in positions to substitute for private business decisions better left to the competitive marketplace (see sidebar, Major Federal Policies Promoting Technology Transfer and Commercialization of R&D). One major national policy thrust has been to enhance formal mechanisms for transferring knowledge arising from federally funded and performed R&D (Crow and Bozeman 1998; National Research Council [NRC] 2003). Other policies have been directed toward strengthening the prospects for the development and flow of early-stage technologies into the commercial marketplace, accelerating the commercial exploitation of academic R&D, and facilitating the conduct of R&D on ideas and technologies with commercial potential by entrepreneurial small and/or minority-owned businesses.

The sections immediately following focus on this theme of the transfer and commercial exploitation of federally funded R&D and review status indicators for several major federal policies and programs directed at these objectives. (Chapter 5 contains related information about S&E publications and the patents arising from academic research.)

Major Federal Policies Promoting Technology Transfer and Commercialization of R&D

Technology Innovation Act of 1980 (Stevenson-Wydler Act) (P.L. 96–480)—Established technology transfer as a federal government mission by directing federal laboratories to facilitate the transfer of federally owned and originated technology to nonfederal parties.

University and Small Business Patent Procedures Act of 1980 (Bayh-Dole Act) (P.L. 96–517)—Permitted small businesses, universities, and nonprofits to obtain titles to inventions developed with federal funds. Also allowed government-owned and government-operated laboratories to grant exclusive patent rights to commercial organizations.

Small Business Innovation Development Act of 1982 (P.L. 97–219)—Established the Small Business Innovation Research (SBIR) program, which required federal agencies to set aside funds for small businesses to engage in R&D connected to agency missions.

National Cooperative Research Act of 1984 (P.L. 98–462)—Encouraged U.S. firms to collaborate in generic precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures.

Patent and Trademark Clarification Act of 1984 (P.L. 98–620)—Provided further amendments to the Stevenson-Wydler Act and the Bayh-Dole Act regarding the use of patents and licenses to implement technology transfer.

Federal Technology Transfer Act of 1986 (P.L. 99–502)—Enabled federal laboratories to enter Cooperative R&D Agreements (CRADAs) with outside parties and to negotiate licenses for patented inventions made at the laboratory.

Executive Order 12591, Facilitating Access to Science and Technology (April 1987)—Issued by President Reagan, this executive order sought to ensure that the federal laboratories implemented technology transfer.

Omnibus Trade and Competitiveness Act of 1988 (P.L. 100–418)—Directed attention to public-private cooperation on R&D, technology transfer, and commercialization (in addition to measures on trade and intellectual property protection). Also established the Hollings Manufacturing Extension Partnership (MEP) program at NIST.

National Competitiveness Technology Transfer Act of 1989 (P.L. 101–189)—Amended the Federal Technology Transfer Act to expand the use of CRADAs to include government-owned, contractor-operated federal laboratories and to increase nondisclosure provisions.

Small Business Innovation Development Act of 1992 (P.L. 102–564)—Reauthorized the existing SBIR program, increasing both the percentage of an agency's budget to be devoted to SBIR and the maximum level of awards. Also established the Small Business Technology Transfer (STTR) program to enhance opportunities for collaborative R&D efforts between government-owned, contractor-operated federal laboratories and small businesses, universities, and nonprofit partners.

National Cooperative Research and Production Act of 1993 (P.L. 103–42)—Relaxed restrictions on cooperative production activities, enabling research joint venture participants to work together on jointly acquired technologies.

National Technology Transfer and Advancement Act of 1995 (P.L. 104–113)—Amended the Stevenson-Wydler Act to make CRADAs more attractive to federal laboratories, scientists, and private industry.

Technology Transfer Commercialization Act of 2000 (P.L. 106–404)—Broadened CRADA licensing authority to make such agreements more attractive to private industry and to increase the transfer of federal technology. Established technology transfer performance reporting requirements for agencies with federal laboratories.

America COMPETES Act of 2007 (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Sciences [COMPETES] Act) (P.L. 110–69)—Authorized increased investment in R&D; strengthened educational opportunities in science, technology, engineering, and mathematics from elementary through graduate school; and further promoted the nation's innovation infrastructure. Among various provisions, the act created the Advanced Research Projects Agency–Energy (ARPA-E) to promote and fund R&D on advanced energy technologies; it also called for a President's Council on Innovation and Competitiveness.

America COMPETES Reauthorization Act of 2010 (P.L. 111–358)—Updated the America COMPETES Act of 2007 and authorized additional funding to science, technology, and education programs over the succeeding 3 years. Numerous provisions were intended to broadly strengthen the foundation of the U.S. economy, create new jobs, and increase U.S. competitiveness abroad.

Presidential Memorandum—Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses (October 2011)—Issued by President Obama, this memorandum directed a variety of actions by federal departments and agencies to establish goals and measure performance, streamline administrative processes, and facilitate local and regional partnerships to accelerate technology transfer and support private-sector commercialization.

Federal Technology Transfer

Technology transfer is "the process by which technology or knowledge developed in one place or for one purpose is applied and used in another place for the same or different purpose" (Federal Laboratory Consortium for Technology Transfer [FLC] 2011:3). As applied in the federal setting, technology transfer can occur through varied channels: *commercial transfer* (the movement of knowledge or technology developed by a federal laboratory to private organizations or the commercial marketplace) *scientific dissemination* (publications, conference papers, and working papers distributed through scientific/technical channels; or other forms of data dissemination) the *export of resources* (federal laboratory personnel made available to outside organizations with R&D needs, through collaborative agreements or other service mechanisms) the *import of resources* (outside technology or expertise brought in by a federal laboratory to enhance existing internal capabilities) and *dual use* (development of technologies, products, or families of products with both commercial and federal [mainly military] applications).

The Stevenson-Wydler Act of 1980 (P.L. 96–480) directed federal agencies with laboratory operations to become active in the technology transfer process. It also required these agencies to establish technology transfer offices (termed Offices of Research and Technology Applications) to assist in identifying transfer opportunities and establishing appropriate arrangements for transfer relationships with nonfederal parties. Follow-on legislation in the 1980s through 2000 amending the Stevenson-Wydler Act has worked to extend and refine the authorities available to the agencies and their federal laboratories to identify and manage intellectual assets created by their R&D and to participate in collaborative R&D relationships with nonfederal parties, including private businesses, universities, and nonprofit organizations (FLC 2011).

The metrics on federal technology transfer continue to primarily track the number of activities—that is, invention disclosures, patent applications and awards, licenses to outside parties of patents and other intellectual property, and agreements to conduct collaborative research with outside parties (Institute for Defense Analyses Science and Technology Policy Institute 2011). Nonetheless, systematic documentation of the downstream outcomes and impacts of transfer remains a challenge.[i] Also missing for most agencies and their laboratories are comprehensive data on technology transfer through the *scientific dissemination* mode (i.e., technical articles published in professional journals, conference papers, and other kinds of scientific communications), which remains widely regarded by laboratory scientists, engineers, and managers (federal and private sector) as a key means of transfer.

Six agencies continue to account for most of the annual total of federal technology transfer activities: DOD, HHS, DOE, NASA, USDA, and DOC. Technology transfer statistics for these agencies for FY 2012 (the latest data year available) with comparisons with FYs 2006 and 2009 appear in Table 4-18. (Similar statistics for a larger set of agencies, going back to FY 2001, appear in Appendix Table 4-26.) Consistent with the agencies' statutory annual reports, these statistics span mainly the activity areas of invention disclosures and patenting, intellectual property licensing, and collaborative relationships for R&D.

[i] Data on technology transfer metrics such as these are now increasingly available. Nonetheless, the federal technology transfer community has long recognized that counts of patent applications and awards, intellectual property licenses, CRADAs, and the like do not usually of themselves provide a reasonable gauge of the downstream outcomes and impacts that eventually result from transfers––many of which involve considerable time and numerous subsequent developments to reach full fruition. Literature on federal technology transfer success stories is growing, facilitated in part by the annual agency technology transfer performance reporting mandated by the Technology Transfer Commercialization Act of 2000 and through regularly updated reports by technology transfer professional organizations such as the FLC. Even so, the documentation of these downstream outcomes and impacts remains well short of being complete.

Table 4-18 **Federal laboratory technology transfer activity indicators, total and for selected agencies: FYs 2006, 2009, and 2012**

(Number)

Technology transfer activity	All federal laboratories	DOD	HHS	DOE	NASA	USDA	DOC
	FY 2012						
Invention disclosures and patenting							
Inventions disclosed	5,149	1,037	252	1,661	1,582	160	52
Patent applications	2,346	888	222	780	139	122	21
Patents issued	1,808	667	372	483	136	70	12
Licensing							
All licenses, total active in the FY	13,405	520	1,465	5,328	4,870	384	41
Invention licenses	4,029	432	1,090	1,428	434	341	41
Other intellectual property licenses	9,376	88	375	3,900	4,436	43	0
Collaborative relationships for R&D							
CRADAs, total active in the FY	8,812	2,400	377	742	0	257	2,934
Traditional CRADAs	4,288	1,328	245	742	0	180	156
Other collaborative R&D relationships	21,677	0	0	0	4,245	14,351	2,782
	FY 2009						
Invention disclosures and patenting							
Inventions disclosed	4,452	831	389	1,439	1,412	143	41
Patent applications	1,957	690	156	775	141	123	20
Patents issued	1,319	404	397	363	93	24	7
Licensing							
All licenses, total active in the FY	12,596	432	1,584	5,742	4,181	330	40
Invention licenses	3,851	386	1,304	1,452	146	302	40

Technology transfer activity	All federal laboratories	DOD	HHS	DOE	NASA	USDA	DOC
Other intellectual property licenses	8,745	46	280	4,290	4,035	28	0
Collaborative relationships for R&D							
CRADAs, total active in the FY	7,756	2,870	457	744	1	259	2,397
Traditional CRADAs	4,296	2,247	284	744	1	207	101
Other collaborative R&D relationships	17,649	1	0	0	4,507	10,306	2,828
	FY 2006						
Invention disclosures and patenting							
Inventions disclosed	5,193	1,056	442	1,694	1,749	105	14
Patent applications	1,912	691	166	726	142	83	5
Patents issued	1,284	472	164	438	85	39	7
Licensing							
All licenses, total active in the FY	10,186	444	1,535	5,916	2,856	332	111
Invention licenses	4,163	438	1,213	1,420	308	332	111
Other intellectual property licenses	6,023	6	322	4,496	2,548	0	0
Collaborative relationships for R&D							
CRADAs, total active in the FY	7,268	2,999	164	631	1	195	3,008
Traditional CRADAs	3,666	2,424	92	631	1	163	149
Other collaborative R&D relationships	9,738	0	0	0	4,275	3,477	2,114

NOTES: CRADA = Cooperative R&D Agreement; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = U.S. Department of Agriculture.

Other federal agencies not listed but included in the All federal laboratories totals are Department of Homeland Security, Department of the Interior, Department of Transportation, Department of Veterans Affairs, and Environmental Protection Agency. Invention licenses refer to inventions that are patented or could be patented. Other intellectual property refers to intellectual property protected through mechanisms other than a patent (e.g., copyright). Total CRADAs refers to all agreements executed under CRADA authority (15 USC 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. Federal agencies have varying authorities for other kinds of collaborative R&D relationships.

SOURCE: National Institute of Standards and Technology, U.S. Department of Commerce, *Federal Laboratory Technology Transfer, Fiscal Year 2012 Summary Report to the President and the Congress*, December 2014, http://nist.gov/tpo/publications/upload/Federal-Laboratory-TT-Report-FY2012.pdf. See appendix table 4-26.

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As the distribution of the statistics across the activity types in Table 4-18 shows, most agencies engage in all of the transfer activity types to some degree, but the emphases differ. Some agencies (e.g., HHS, DOE, NASA) are more intensive in patenting and licensing activities; some (e.g., DOD, USDA, DOC) place greater emphasis on transfer through collaborative R&D relationships. Some agencies have unique transfer authorities that can confer practical advantages. NASA, for example, can establish collaborative R&D relationships through special authorities it has under the National Aeronautics and Space Act of 1958; USDA has a number of special authorities for establishing R&D collaborations other than Cooperative R&D Agreements (CRADAs); DOE has contractor-operated national laboratories, with nonfederal staff, that are not constrained by the normal federal limitation on copyright by federal employees and can use copyright to protect and transfer computer software. In general, the mix of technology transfer activities pursued by each agency reflects a broad range of considerations such as agency mission priorities, the technologies principally targeted for development, the intellectual property protection tools and policies available, and the types of external parties through which transfer and collaboration are chiefly pursued.

Small Business Innovation-Related Programs

The Small Business Innovation Research (SBIR) program and Small Business Technology Transfer (STTR) program are longstanding federal programs that provide competitively awarded funding to small businesses for purposes including stimulating technological innovation, addressing federal R&D needs, increasing private-sector commercialization of innovations flowing from federal R&D, and fostering technology transfer through cooperative R&D between small businesses and research institutions. The U.S. Small Business Administration provides overall coordination for both programs, with implementation by the federal agencies that participate (SBA 2015).

The SBIR program was established by the Small Business Innovation Development Act of 1982 (P.L. 97–219) for the purpose of stimulating technological innovation by increasing the participation of small companies in federal R&D projects, increasing private-sector commercialization of innovation derived from federal R&D, and fostering participation by minority and disadvantaged persons in technological innovation. The program has subsequently received several extensions from Congress and is now authorized through 2017. Eleven federal agencies currently participate in the SBIR program: USDA, DOC, DOD, the Department of Education, DOE, HHS, DHS, DOT, EPA, NASA, and NSF.

The STTR program was established by the Small Business Technology Transfer Act of 1992 (P.L. 102–564, Title II) for the purpose of facilitating cooperative R&D by small businesses, universities, and nonprofit research organizations and encouraging the transfer of technology developed through such research by entrepreneurial small businesses. Congress has likewise provided a number of extensions since then, with the program continuing through 2017. Five federal agencies currently participate in the STTR program: DOD, DOE, HHS, NASA, and NSF.

For SBIR, federal agencies with extramural R&D budgets exceeding $100 million annually must currently (FY 2015) set aside at least 2.9% for awards to U.S.-based small businesses (defined as those with fewer than 500 employees, including any affiliates). (The set-aside minimum was 2.5% for FYs 1997–2011, rising incrementally to 2.9% in FY 2015, 3.0% in FY 2016, and 3.2% in FY 2017.) Three phases of activities are recognized. In Phase I, a small company can apply for a Phase I funding award (normally not exceeding $150,000) for up to 6 months to assess the scientific and technical feasibility of an idea with commercial potential. Based on the scientific/technical achievements in Phase I and continued expectation of commercial potential, the company can apply for Phase II funding (normally not exceeding $1 million) for 2 years of further development. Where the Phase I and II results warrant, the company pursues a course toward Phase III commercialization. The SBIR program itself does not provide funding for Phase III, but depending on the agency, Phase III may involve non-SBIR-funded R&D or production contracts for products, processes, or services intended for use by the federal government. Several agencies offer bridge funding to Phase III and other commercialization support for startups (NRC 2008:208–16).

The initial round of SBIR awards was for FY 1983. It yielded 789 Phase I awards, across the participating agencies, for a total of $38.1 million of funding (Table 4-19; Appendix Table 4-27 and Appendix Table 4-28). But the program expanded considerably in subsequent years. To date, the peak in awards was FY 2003, when the annual total of awards was 6,844 (5,100 Phase I awards and 1,744 Phase II awards), with total funding of $1.743 billion ($467 million for Phase I awards and $1.275 billion for Phase II awards). In FY 2013, the award total was 4,452 (2,999 Phase I awards and 1,453 Phase II awards), with total funding of $1.772 billion ($486 million for Phase I awards and $1.286 billion for Phase II awards). In FY 2013, the majority of the funding reflected awards by DOD (44%) and HHS (33%) (Appendix Table 4-28). DOE (8%), NSF (6%), and NASA (5%) accounted for smaller shares. The other six participating agencies were 1% or less of the total.

Table 4-19 **SBIR and STTR awards, number and funding, by type of award: Selected years, FYs 1983–2013**

	Number of awards			Funding ($millions)		
Fiscal year	Total	Phase I	Phase II	Total	Phase I	Phase II
SBIR						
1983	789	789	0	38.1	38.1	0.0
1985	1,838	1,483	355	195.3	74.5	120.8
1990	3,220	2,374	846	453.3	120.9	332.4
1995	4,367	3,092	1,275	962.2	236.5	725.8
2000	5,286	3,941	1,345	1,058.9	293.7	765.1
2005	6,085	4,216	1,869	1,862.5	452.5	1,410.0
2010	6,194	4,255	1,939	2,197.9	546.8	1,651.1
2011	5,399	3,629	1,770	2,030.5	507.7	1,522.8
2012	5,005	3,417	1,588	1,984.5	561.7	1,422.8
2013	4,452	2,999	1,453	1,771.8	485.5	1,286.3
STTR						
1983	na	na	na	na	na	na
1985	na	na	na	na	na	na
1990	na	na	na	na	na	na
1995	1	1	0	0.1	0.1	0.0
2000	410	315	95	64.0	23.7	40.3
2005	801	579	222	226.4	66.1	160.3
2010	905	625	280	298.6	77.5	221.1
2011	708	468	240	259.4	67.7	191.7
2012	636	467	169	218.0	73.1	144.9
2013	640	455	185	206.2	74.1	132.1

NOTES: na = not applicable.
SBIR = Small Business Innovation Research program; STTR = Small Business Technology Transfer program.
The first SBIR program awards were made in FY 1983. The first STTR program award was made in FY 1995.

SOURCE:	U.S. Small Business Administration, SBIR/STTR official website, http://www.sbir.gov/awards/annual-reports, accessed 26 February 2015. See appendix table 4-27, appendix table 4-28, and appendix table 4-29. *Science and Engineering Indicators 2016*

For the STTR program, federal agencies with extramural R&D budgets that exceed $1 billion annually must currently (FYs 2014 and 2015) reserve not less than 0.4% for STTR awards to small businesses. (The set-aside minimum was 0.3% for FYs 2004–11, rising incrementally to 0.4% in FYs 2014–15, and to 0.45% in FY 2016 and thereafter.) STTR operates within the same three-phase framework as SBIR. Phase I provides awards for company efforts to establish the technical merit, feasibility, and commercial potential of proposed projects; the funding in this phase normally does not exceed $100,000 over 1 year. Phase II is for continued R&D efforts, but award depends on success in Phase I and continued expectation of commercial potential. Phase II funding normally does not exceed $750,000 over 2 years. Phase III is for the small business to pursue commercialization objectives, based on the Phase I and II results. The STTR program does not provide funding for Phase III activities. Furthermore, to pursue Phase III, companies must secure non-STTR R&D funding and/or production contracts for products, processes, or services for use by the federal government.

The STTR program started with a single Phase I award for $100,000 in FY 1995 (Table 4-19; Appendix Table 4-27 and Appendix Table 4-29). This program has also expanded considerably in subsequent years. The peak years to date for number of awards were FY 2004 with a total of 903 awards (719 Phase I awards and 184 Phase II awards) and FY 2010 with 905 awards (625 Phase I awards and 280 Phase II awards). The total of funding in FY 2004 was $206 million ($82 million for Phase I awards and $123 million for Phase II awards) and $299 million in FY 2010 ($78 million for Phase I and $221 million for Phase II). In FY 2013, 640 awards were made (455 for Phase I and 185 for Phase II), with funding totaling $206 million ($74 million for Phase I and $132 million for Phase II). Fewer federal agencies participate in STTR, but those dominant in SBIR are also dominant in STTR. STTR awards from DOD accounted for 47% of the $206 million award total in FY 2013 (Appendix Table 4-29). HHS accounted for 32% of the STTR awards, and the remaining awards were from DOE (10%), NASA (7%), and NSF (4%).

Other Programs

The federal policies, authorities, and incentives established by the Stevenson-Wydler Act (and the subsequent amending legislation) and the SBIR and STTR programs are far from the whole of federal efforts to promote the transfer and commercialization of federal R&D. Numerous programs for these purposes exist in the federal agencies. Given the specifics of agency missions, they have a narrower scope and smaller pools of resources. Several examples are described subsequently.

The **Hollings Manufacturing Extension Partnership (MEP)** is a nationwide network of manufacturing extension centers located in all 50 U.S. states and Puerto Rico. MEP was created by the Omnibus Trade and Competitiveness Act of 1988 (P.L. 100–418) and is headed by DOC's NIST (NIST 2015). The MEP centers (which are nonprofit) exist as a partnership among the federal government, state and local governments, and the private sector. MEP provides technical expertise and other services to small and medium-sized U.S. manufacturers to improve their ability to develop new customers, expand into new markets, and create new products. The centers work directly with manufacturers to engage specific issues, including technology acceleration, process improvements, innovation strategies, workforce training, supply-chain development, and exporting. They also serve to connect manufacturers with universities and research laboratories, trade associations, and other relevant public and private resources. The MEP annual report for FY 2013 describes the national network of MEP centers as operating with a total budget of about $300 million annually—$123 million from the federal government (with more than three-quarters going to the centers), with the balance from state and local governments and the private sector (NIST 2014). The MEP report indicates that technical expertise and other services were provided during FY 2013 to 31,131 U.S.

manufacturing companies and attributes impacts of $8.4 billion in increased or retained sales, 62,703 increased or retained jobs, and $1.2 billion in cost savings for these businesses. (These services and impacts metrics are comparable with the reports of recent previous years.)

DOE's **Advanced Research Projects Agency–Energy (ARPA-E)** provides funding, technical assistance, and market development to advance high-potential, high-impact energy technologies that are too early stage for private-sector investment (DOE 2015). The main interest is energy technology projects with the potential to radically improve U.S. economic security, national security, and environmental quality––in particular, short-term research that can have transformational impacts, not basic or incremental research. ARPA-E was authorized by the America COMPETES Act of 2007 (P.L. 110–69), and it received $400 million of initial funding through the ARRA (P.L. 111–5). Federal funding (appropriations) for ARPA-E was $180 million in FY 2011, $275 million in FY 2012, and $250 million in FY 2013 (appropriated at $265 million that fiscal year, but received funding was reduced because of the budget sequestration applied across the board to FY 2013 appropriations). ARPA-E's annual report for FY 2013 (the most recent available) indicated 71 new project awards in FY 2013—with a total of 362 funded projects and $900 million of funding since the program's inception (DOE 2014). The program currently identifies 18 focused and 2 open project areas, with topics including advanced batteries, energy storage technologies, improved building energy efficiencies, biofuels, and solar energy.

NSF's **Industry/University Cooperative Research Centers (I/UCRC)** Program supports industry/university partnerships for the conduct of industrially relevant fundamental research, collaborative education, and the transfer of university-developed ideas, research results, and technology to industry (NSF 2015). NSF supports I/UCRC through partnership mechanisms where, according to NSF, the federal funding is typically multiplied 10 to 15 times by supplementary funding from businesses and other nonfederal sources. The I/UCRC Program reports that there are currently 60 such centers across the United States, with more than 1,000 nonacademic members: 85% are industrial firms, with the remainder consisting of state governments, national laboratories, and other federal agencies. NSF funding to I/UCRC was about $15 million in FY 2011. Research is prioritized and executed in cooperation with each center's membership organizations.

Conclusion

Worldwide R&D performance (measured as expenditures) totaled an estimated $1.671 trillion (current PPP dollars) in 2013 (latest global total available). The comparable figure for 2003 was $836 billion, which reflected a still brisk 7.2% average annual rate of growth over this 10-year period.

U.S. R&D increased to $456.1 billion in 2013 (Table 4-1), which represented 27% of the global total that year. As such, the United States remains the world's largest R&D performer. Nonetheless, investments in R&D by other countries—particularly those in Asia—continue to increase, closing the gap with the United States. China ($336.5 billion of R&D in 2013) has now moved well ahead of Japan ($160.3 billion) as the second-largest R&D-performing nation. Countries/economies of the East/Southeast and South Asian regions accounted for 27% of the global total in 2003 but rose to a striking 40% in 2013. EU countries accounted for 25% of the global total in 2003 but dropped to 20% in 2013.

In 2008, just ahead of the onset of the main economic effects of the national/international financial crisis and the Great Recession, U.S. R&D totaled $407.0 billion. The increase to $456.1 billion in 2013 is sizable. Nonetheless, inflation-adjusted growth in this R&D total over the 2008–13 period averaged only 0.8% annually, behind the 1.2% annual average for U.S. gross domestic product. By comparison, the growth of U.S. R&D averaged 3.9% annually over the 2003–08 period and similarly for 1993–2003, both well ahead of the corresponding GDP growth rates of 2.2% and 3.4%. From looking at these numbers, the longstanding vigor in the expansion of U.S. R&D has yet to return in the post-2008 era.

Glossary

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

Development: 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.

European Union (EU): As of September 2015, the EU consists of 28 member nations: Austria, Belgium, Bulgaria, Croatia, 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. Unless otherwise noted, data on the EU include all 28 member countries.

Federally funded research and development center (FFRDC): R&D-performing organizations that are exclusively or substantially financed by the federal government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered by an industrial firm, a university, or a nonprofit institution.

Gross domestic product (GDP): The market value of goods and services produced within a country. It is one of the main measures in the national income and product accounts.

G20: Group of Twenty brings together finance ministers and central bank governors from Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, the Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the EU.

Innovation: The introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or in the open marketplace (OECD /Eurostat 2005).

Multinational enterprise (MNE): A parent company and its foreign affiliates. An affiliate is a company or business enterprise (incorporated or unincorporated) located in one country but owned or controlled (10% or more of voting securities or the equivalent) by a parent company in another country. A majority-owned affiliate is a company owned or controlled by more than 50% of the voting securities (or equivalent) by its parent company.

National income and product accounts (NIPA): The economic accounts of a country that display the value and composition of national output and the distribution of incomes generated in this production.

Organisation for Economic Co-operation and Development (OECD): An international organization of 34 countries, headquartered in Paris, France. The member countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Among its many activities, the OECD compiles social, economic, and science and technology statistics for all member and selected nonmember countries.

R&D: Research and development, also called research and experimental development; comprises creative work undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and its use to devise new applications (OECD 2002).

R&D intensity: A measure of R&D expenditures relative to size, production, financial, or other characteristics for a given R&D-performing unit (e.g., country, sector, company). Examples include R&D/GDP ratio and R&D value-added ratio.

Technology transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place for some other purpose. In the federal setting, technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal R&D funding are used to fulfill public and private needs.

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