Chapter 4
U.S. and International Research and Development: Funds and Technology Linkages

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Highlights

National R&D Trends

♦ **Research and development expenditures continued to grow in the United States, reaching an estimated $276 billion in 2002.** But the rapid rate of growth of the late 1990s slowed considerably in 2001 and 2002.

♦ **Industry performed an estimated $194 billion of R&D in 2002, or 70 percent of the national total.** Industry was also the largest source of R&D funding, paying for 65 percent of all R&D. Nearly all (98 percent) of these funds flowed to industry; the remainder financed R&D at universities, colleges, and nonprofit organizations.

♦ **In the industrial sector in 2001, computer and electronic products manufacturing performed 24 percent ($47 billion) of all industrial R&D and 17 percent of the nation's total R&D.** The next largest industrial sector, transportation equipment, performed $26 billion in R&D in 2001. Nonmanufacturing industries associated with software and computer-related services performed between $24 and $25 billion of R&D in 2001.

♦ **Universities and colleges performed an estimated $36 billion of R&D in 2002, or 13 percent of the national total.** However, universities and colleges performed the majority (54 percent) of all basic research.

♦ **In 2000 California had the highest level of R&D expenditures among all states, $55 billion.** However, the ratio of R&D to gross state product was highest in Michigan at 5.8 percent compared with 4.1 percent in California.

Federal R&D Performance and Support

♦ **Federal R&D support, in absolute terms, expanded from $66 billion to an estimated $78 billion between 2000 and 2002.** This growth increased the Federal R&D support share of total U.S. R&D from 25 to 28 percent. In contrast, Federal laboratories and federally funded research and development centers performed only 12 percent of U.S. R&D in 2002.

♦ **In fiscal year 2003 the Department of Defense (DOD) is expected to obligate the most funds among Federal agencies for R&D support—$45 billion, or 46 percent of all Federal R&D obligations.** The Department of Health and Human Services (HHS) is expected to obligate the second largest amount in R&D support ($28 billion), followed by the National Aeronautics and Space Administration ($9 billion), the Department of Energy (DOE) ($8 billion), and the National Science Foundation ($3 billion).

♦ **The budget allocation for counterterrorism-related R&D increased dramatically between FY 2001 and FY 2003 from $0.6 to $2.9 billion.** Most of this budget now falls under the aegis of the National Institutes of Health and the newly formed Department of Homeland Security.

♦ **In 1999 (the latest year for which these data are available), 10,000 companies claimed $5.3 billion in R&D tax credits, about the same level as in 1998.** In 1999, 267 companies claimed $540 million for basic research, about 10 percent of the total research and experimentation credit.

Technology Linkages: Contract R&D, and Federal Technology Transfer

♦ **In 2001, more than 1,300 manufacturing companies (or 8 percent of all manufacturing R&D-performing companies) reported contract R&D expenditures of $4 billion in the United States.** Contract R&D expenditures as a proportion of in-house company-funded R&D is particularly notable in pharmaceuticals and R&D services.

♦ **Federal technology transfer activities continued to rise.** In FY 2001, 10 Federal agencies reported more than 3,900 invention disclosures and filed nearly 2,200 patent applications. Patent applications increased to a peak of 2,172 in FY 2001, up 4.3 percent from FY 2000. Patents issued to these Federal agencies reached 1,608 in FY 2001, up 15.6 percent from FY 2000.

♦ **The same 10 Federal agencies executed 926 new cooperative R&D agreements (CRADAs) with industrial and university partners in FY 2001, up 5.9 percent from FY 2000, bringing the number of active CRADA agreements to 3,603.** DOD, DOE, and HHS accounted for more than 80 percent of active CRADAs in FY 2001.

♦ **The Small Business Innovation Research Program (SBIR), designed to stimulate technical innovation by small firms and their participation in Federal R&D funding, awarded $1.29 billion in R&D funding to 4,748 projects in FY 2001.** DOD led the 10 participating agencies in obligated SBIR funding at $576 million (45 percent of all SBIR funding), followed by HHS at $412 million (32 percent).

Technology Linkages: R&D Collaboration

♦ **From 1985 to 2001 a total of 861 technology alliances were registered in filings required by the National Cooperative Research and Production Act.** About half of the technology alliances during the period 1985–2001 involved activities classified in three industrial areas: electronic and electrical equipment, communication services, and transportation equipment. Fifteen percent (125 of 861) of these alliances involved a U.S. university, whereas about 12 percent (99 of 861) included a Federal laboratory.

♦ **A separate database covering international alliances shows that in 2001 there were 602 new international technology alliances in six major sectors, notably information technology and biotechnology/pharmaceuticals, up from 483 in 2000, a 25 percent increase.** This is the first increase since a 19.5 percent increase in 1995 to its all-time high of 674 technology alliances. From 1991 to 2001, there were 5,892 new technology alliances. About 80 percent (4,646 of 5,892) of the 1991–2001 technology alliances worldwide involved at least one U.S.-owned company.

International R&D Trends and Comparisons

♦ **The United States accounts for approximately 44 percent of total R&D expenditures in all Organisation for Economic Co-operation and Development (OECD) countries combined.** R&D investments in the United States are 2.7 times greater than R&D investments made by Japan, the second largest performer. In 2000 the United States spent more on R&D activities than all other "group of seven" (G-7) countries (Canada, France, Germany, Italy, Japan, and the United Kingdom) combined.

♦ **A noteworthy trend among G-7 and other OECD countries has been the relative decline in government R&D funding over the past 2 decades.** In 2000, less than 30 percent of all OECD R&D funds were derived from government sources, down considerably from the 44 percent share reported in 1981. In aggregate terms, this change reflects a decline in industrial reliance on government funds for R&D performance.

♦ **As a result of a worldwide slowing in R&D spending during the early 1990s, the latest ratio of R&D spending to gross domestic product (R&D/GDP) for most G-7 countries is no higher now than it was a decade ago.** The United States, devoting 2.7 percent of its GDP to R&D, ranked fifth among OECD countries during the 1996–2001 period. Sweden led OECD countries at 3.8 percent of its GDP devoted to R&D, followed by Finland (3.4 percent), Japan (3.0 percent), and Iceland (2.9 percent).

♦ **As an indication of an overall pattern of increased university-firm interactions, the proportion of academic R&D funding from industry sources (for G-7 countries combined) climbed from 2.6 percent of the academic R&D total in 1981 to 5.2 percent in 1990 and to 6.0 percent in 1999.**

♦ **Among nondefense objectives, government R&D spending shares changed during the 1981–99 period: government R&D shares increased most for health and the environment and for various nondirected R&D (including many basic research) activities.** Conversely, the relative share of government R&D support provided for economic development programs (which include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy) declined considerably.

R&D Investments by Multinational Corporations

♦ **Foreign-owned firms conducting R&D in the United States accounted for $26.1 billion (13 percent) of the $199.5 billion in total industrial R&D expenditures in the United States in 2000.** This share fluctuated between 11 and 13 percent during the period 1994–2000.

♦ **In 2000 about two-thirds of foreign-owned R&D in the United States was performed in three industries: chemicals (27 percent), computer and electronic products (24 percent), and transportation equipment (12 percent).** Seven countries invested $1 billion or more in R&D in the United States in 2000: Canada, France, Germany, Japan, the Netherlands, Switzerland, and the United Kingdom, accounting for about 90 percent of all R&D expenditures by foreign-owned firms in the United States.

♦ **Parent companies of U.S. multinational corporations accounted for two-thirds of the R&D spending by all industrial R&D performers in the United States in 2000.** These parent companies had R&D expenditures of $131.6 billion in the United States in 2000, whereas their majority-owned foreign affiliates had R&D expenditures of $19.8 billion, for a total of $151.3 billion in global R&D expenditures.

♦ **Two-thirds of the R&D performed overseas in 2000 by U.S.-owned subsidiaries ($13.2 of $19.8 billion) took place in six countries: Canada, France, Germany, Japan, Sweden, and the United Kingdom.** Three-fourths of this overseas R&D activity was performed in three manufacturing sectors: transportation equipment ($5.7 billion, or 29 percent), computer and electronic products ($4.9 billion, or 25 percent) and chemicals ($4.3 billion, or 22 percent). These are the same three industries that accounted for most foreign-owned R&D in the United States, implying a high degree of R&D internationalization in these industries.

♦ **Certain emerging markets played an increasing role in U.S.-owned overseas R&D.** In 2000, U.S. subsidiaries had R&D expenditures of $500 million or more in China, Ireland, Israel, and Singapore, increasing significantly their rank as hosts of R&D activities compared with that in 1994. U.S. computer and electronic products subsidiaries in Ireland, Israel, Singapore, South Korea, and Taiwan spent a total of $1.2 billion in R&D activities in 2000, or 25 percent of $4.9 billion in U.S.-owned overseas R&D in this industry.

Introduction

Chapter Overview

Research and development is widely recognized as being key to economic growth and social welfare, often resulting in benefits unimagined at the time it is initiated. Although R&D expenditures never have exceeded 3 percent of the U.S. gross domestic product (GDP) and the returns on investment in R&D have been difficult to measure, academic and government communities continue to study R&D expenditures as an indicator of technological change in and the innovative capacity of the nation.

The results of R&D decisionmaking—including the resources that various organizations devote to R&D and to what ends they devote them—affect both the economy and national well-being. For this reason, the United States and many other nations collect extensive R&D expenditure data, which are disseminated worldwide for study by analysts in a variety of fields.

In addition to indicating the direction and rate of technological change, R&D expenditure data also measure the level of economic purchasing power devoted to R&D projects compared with other economic activities. Industrial (private sector) funding of R&D, for example, may be considered an indicator of how important R&D is to companies because companies could easily devote those same funds to other business activities such as advertising. Similarly, government support for R&D reflects governmental and societal commitment to scientific and technological advancement, an objective that must compete for dollars against other functions supported by discretionary government spending. The same basic idea is true for the other sectors that fund R&D: universities, colleges, and other nonprofit organizations.

Although total R&D expenditures reveal the perceived economic importance of R&D relative to all other economic activities, the composition of R&D expenditures is a policy variable of equal importance (Tassey 1999). Over the R&D life cycle, different classes of R&D funders and performers rise in importance, then give way to others. The success or failure of technology-intensive industries relative to foreign competitors often hinges on the availability and effectiveness of these differing participants. R&D flows between the sectors represented by these participants indicate a nation's capacity to leverage its science and technology (S&T) resources effectively.

In addition to R&D expenditures performed within a particular sector, this chapter presents data on outsourced and collaborative R&D activities across R&D-performing sectors and on Federal technology transfer. Technology sources outside a company or industry, including university research, have played a key role in innovation and competitiveness from the beginnings of corporate R&D in the United States (Mowery 1983; and Rosenberg and Nelson 1994). In recent decades, however, the increased relevance of scientific research to industrial technology, coupled with the demands from a global competitive environment, has increased the importance of collaborative activities for innovation and long-term competitiveness (Vonortas 1997).

Chapter Organization

This chapter is organized into five major sections that examine trends in R&D expenditures and collaborative technology activities. The first and second sections describe R&D performed in the United States. The first contains information on economic measures of R&D in the United States and trends in total R&D performance and funding; areas addressed include industrial R&D, R&D performance by state, and R&D performance and funding by character of work. The second focuses on the role of the Federal Government in the R&D enterprise, giving particular attention to direct Federal R&D support by national objective, Federal agency, and field of science as well as indirect fiscal measures to stimulate R&D growth.

The third section summarizes available information on external technology sourcing and collaborative R&D activities across R&D-performing sectors including industrial contract R&D expenditures, Federal technology transfer, and domestic and international technology alliances.

The fourth section compares R&D trends across nations. It contains sections on total and nondefense R&D spending; ratios of R&D to GDP in various nations; international R&D funding by performer and source (including information on industrial subsectors and academic science and engineering fields); the allocation of R&D efforts among basic research, applied research, and development components; and international comparisons of government R&D priorities and tax policies.

The fifth section discusses available R&D data for foreign-owned companies in the United States, parent companies of U.S. multinational corporations (MNCs), and U.S.-owned R&D overseas in terms of investing or host countries, their industrial focus, and implications for the ownership structure of U.S. R&D activity.

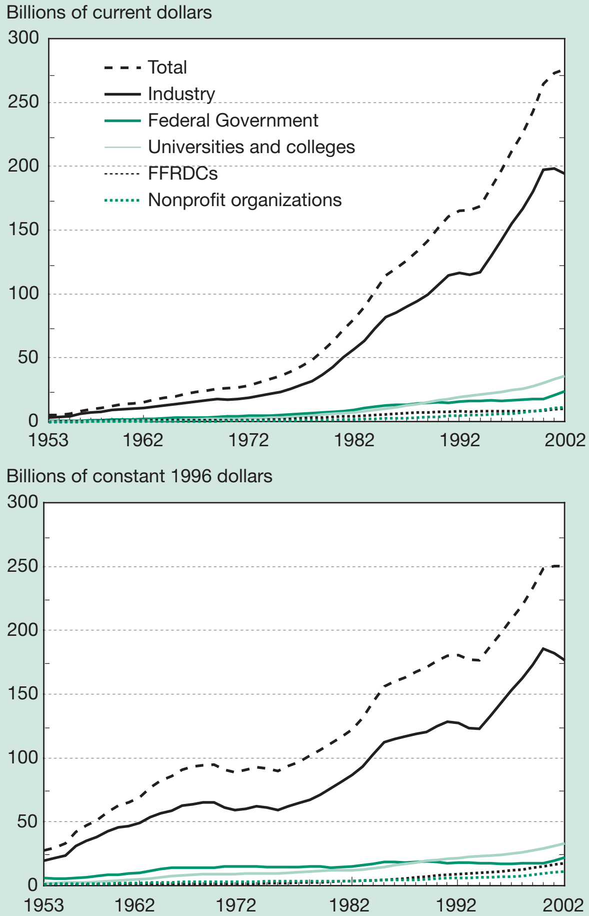
National R&D Trends

In the mid- to late 1990s, R&D performance in the United States surged.[1] In real terms (constant or inflation-adjusted dollars), total R&D performance grew 40.5 percent between 1994 and 2000 at an average annual real growth rate of 5.8 percent over the period (figure 4-1). National Science Foundation (NSF) data indicate that this growth rate was not sustained in the following 2 years, slowing to an estimated 1 percent between 2000 and 2001 and just keeping pace with inflation between 2001 and 2002. Total 2002 R&D performance in the United States is estimated to be $276.2 billion, up from an estimated $273.6 billion in 2001 and $264.7 billion in 2000.[2] (See sidebar, "Definitions of R&D.")

[1]Expenditures for research and development performance are used as a proxy for actual R&D performance. In this chapter, the phrases *R&D performance* and *expenditures for R&D performance* are interchangeable.

[2]At the time this report was written, estimated data for 2002 were the latest figures available for R&D expenditures.

Figure 4-1
National R&D performance, by performing sector: 1953–2002



FFRDC federally funded research and development center

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

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In comparison, GDP, the main measure of the nation's total economic activity, grew in real terms by 3.8 percent per year between 1994 and 2000. R&D performance as a proportion of GDP rose from 2.40 percent in 1994 to 2.69 percent in 2000 as growth in R&D outpaced the growth of the overall economy. The slowdown in R&D investment in 2001 and 2002 coincided with an overall economic slowdown in the United States, resulting in R&D to GDP ratios of 2.71 percent in 2001 and 2.64 percent in 2002.[3]

Organizations that perform R&D often receive outside funding; conversely, organizations that fund R&D often do not perform all the R&D themselves. Therefore, it is useful to analyze R&D expenditure data in terms of who performed the R&D and who funded it.

Definitions of R&D

The National Science Foundation (NSF) uses the following definitions in its research and development surveys. They have been in place for several decades and generally are consistent with international definitions.

R&D. According to international guidelines for conducting R&D surveys, R&D, also called research and experimental development, comprises creative work "undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD 2002f, p. 30).

Basic research. The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be performed in fields of present or potential commercial interest.

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

Development. Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

R&D plant. R&D plant includes the acquisition of, construction of, major repairs to, or alterations in structures, works, equipment, facilities, or land for use in R&D activities.

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

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

Outlays. Federal outlays represent the dollar amounts for checks issued and cash payments made during a given period, regardless of when funds were appropriated or obligated.

[3]The estimated U.S. gross domestic product (GDP) for 2000, 2001, and 2002 in constant 1996 dollars is $9,191 billion, $9,215 billion, and $9,440 billion, respectively. See appendix table 4-1 for a full time series.

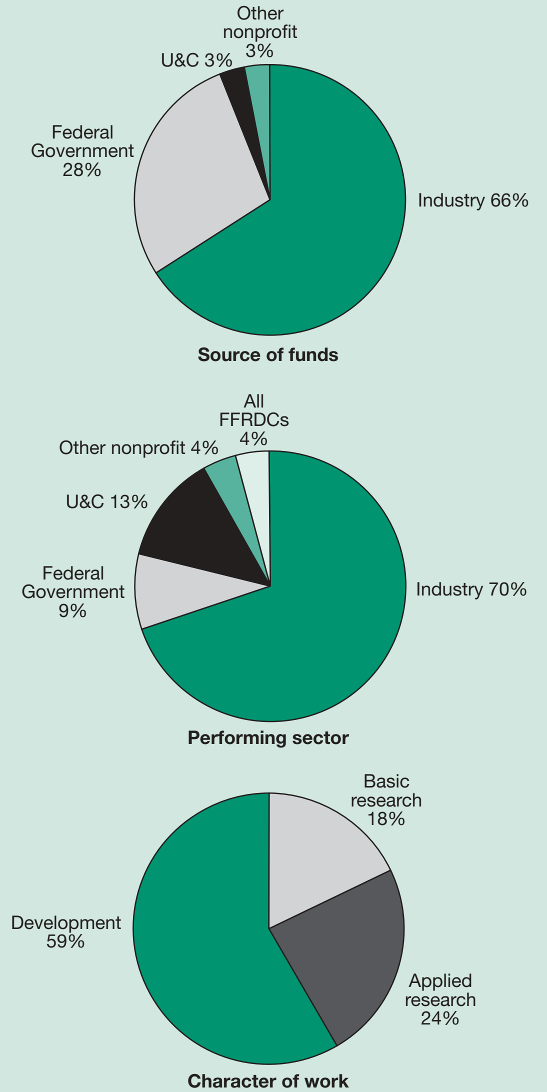
Industry performs most of the nation's R&D and accounted for 70.4 percent of total R&D performance in 2002.[4] Universities and colleges, excluding academically administered federally funded research and development centers (FFRDCs), accounted for 13.0 percent of national R&D performance in 2002, followed by the Federal Government (8.6 percent) and nonprofit institutions (4.2 percent).[5] All FFRDCs combined performed 3.7 percent of U.S. total R&D in 2002 (figures 4-1 and 4-2; table 4-1).

Private industry is also the largest source of R&D funding in the United States and provided 65.5 percent ($180.8 billion) of total R&D funding in 2002. Most of these funds (98.1 percent) flowed to industrial performers of R&D. The Federal Government provided the second largest share of R&D funding, 28.3 percent ($78.2 billion), with only 43.6 percent of these funds financing Federal labs and FFRDCs. The other sectors of the economy (i.e., state governments, universities and colleges, and nonprofit institutions) contributed the remaining 6.2 percent ($17.2 billion) (table 4-1).

Trends in R&D Performance

U.S. R&D has experienced largely uninterrupted growth over the past 50 years (figure 4-1). U.S. R&D performance grew each year between 1953 and 2002, even in the early 1990s when both Federal and industrial R&D funding slowed significantly[6] (figure 4-3). In the mid-1990s substantial increases in industrial R&D, most notably in the computer and other information technology (IT) sectors and in small R&D-performing firms, ended a brief slowdown in national R&D growth.[7] Between 1994 and 2000, an 8.9 percent real annual growth rate in industrial support for R&D overshadowed a slight decline (–0.3 percent per year) in Federal R&D support, resulting in overall real annual growth of 5.8 percent in U.S. R&D.

Figure 4-2
Shares of national R&D expenditures, by source of funds, performing sector, and character of work: 2002



FFRDC federally funded research and development center

NOTES: Figures are rounded to nearest whole number. National R&D expenditures were an estimated $276 billion in 2002.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources*, annual series. See appendix tables 4-3, 4-5, 4-7, 4-11, and 4-15.

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More recently, the growth of R&D investment in the United States has slowed. Preliminary data indicate that although total R&D expenditures continued to rise through 2002, industrial R&D, which fueled the growth over the prior period, failed to keep pace with inflation and experienced its first decline in real terms after 1994. This has occurred only six times in the past 49 years. The business activities of many R&D-performing firms were curtailed following the stock market decline and subsequent economic slowdown of 2001 and 2002. The same sectors that saw impressive

[4] Unless otherwise noted, whenever a sector is mentioned in this chapter, federally funded research and development centers (FFRDCs) are excluded. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the Federal Government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered either by an industrial firm, a university, or a nonprofit institution. In some of the statistics provided in this chapter, FFRDCs are included as part of the sector that administers them. In particular, statistics on the industrial sector often include industry-administered FFRDCs because some of the statistics from the National Science Foundation (NSF) Survey of Industrial Research and Development before 2001 cannot be separated from the FFRDC component.

[5] Recent methodological improvements have resulted in revisions from the amounts previously reported for total academic R&D expenditures. For more information, see M. Machen and B. Shackelford, *Academic R&D Spending Maintains Growth From All Major Sources in FY 2001,* NSF InfoBrief (forthcoming).

[6] These findings are based on performer-reported R&D levels. In recent years, increasing differences have been detected in data on federally financed R&D as reported by Federal funding agencies and by performers of the work (most notably, industrial firms and universities). This divergence in R&D totals is discussed subsequently in this chapter. (See sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures.")

[7] For most manufacturing industries, the U.S. Small Business Administration defines *small firm* as one with 500 or fewer employees. The share of company-financed R&D performed by these firms grew from 10 percent in 1990 to a peak of 20 percent in 1999.

Table 4-1
U.S. R&D expenditures, by character of work, performing sector, and source of funds: 2002

Performing sector	Source of funds: Total	Industry	Federal Government	U&C	Other nonprofit institutions	Percent distribution of total expenditures
	Millions of dollars					
R&D	276,185	180,769	78,185	7,455	7,304	100.0
Industry	194,430	177,345	17,085	—	—	70.4
Industry-administered FFRDCs	2,235	—	2,235	—	—	0.8
Federal Government	23,788	—	23,788	—	—	8.6
U&C	36,019	2,341	21,066	7,455	2,685	13.0
U&C-administered FFRDCs	6,060	—	6,060	—	—	2.2
Other nonprofit institutions	11,620	1,083	5,918	—	4,619	4.2
Nonprofit-administered FFRDCs	2,034	—	2,034	—	—	0.7
Percent distribution by source	100.0	65.5	28.3	2.7	2.6	—
Basic research	49,566	9,186	29,218	6,767	4,395	100.0
Industry	7,751	6,989	762	—	—	15.6
Industry-administered FFRDCs	611	—	611	—	—	1.2
Federal Government	4,617	—	4,617	—	—	9.3
U&C	26,677	1,596	16,484	6,767	1,830	53.8
U&C-administered FFRDCs	2,962	—	2,962	—	—	6.0
Other nonprofit institutions	6,020	601	2,854	—	2,565	12.1
Nonprofit-administered FFRDCs	928	—	928	—	—	1.9
Percent distribution by source	100.0	18.5	58.9	13.7	8.9	—
Applied research	64,803	39,833	20,507	2,591	1,872	100.0
Industry	42,590	38,947	3,643	—	—	65.7
Industry-administered FFRDCs	304	—	304	—	—	0.5
Federal Government	8,083	—	8,083	—	—	12.5
U&C	8,008	611	4,105	2,591	701	12.4
U&C-administered FFRDCs	1,645	—	1,645	—	—	2.5
Other nonprofit institutions	3,902	275	2,456	—	1171	6.0
Nonprofit-administered FFRDCs	271	—	271	—	—	0.4
Percent distribution by source	100.0	61.5	31.6	4.0	2.9	—
Development	161,817	131,750	28,460	569	1038	100.0
Industry	144,089	131,409	12,680	—	—	89.0
Industry-administered FFRDCs	1,320	—	1,320	—	—	0.8
Federal Government	11,088	—	11,088	—	—	6.9
U&C	1,334	134	477	569	154	0.8
U&C-administered FFRDCs	1,452	—	1,452	—	—	0.9
Other nonprofit institutions	1,699	207	608	—	884	1.0
Nonprofit-administered FFRDCs	835	—	835	—	—	0.5
Percent distribution by source	100.0	81.4	17.6	0.4	0.6	—

FFRDC federally funded research and development center
U&C universities and colleges

NOTES: State and local government support to industry is included in industry support for industry performance. State and local government support to U&C ($2,472 million in total R&D) is included in U&C support for U&C performance.

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

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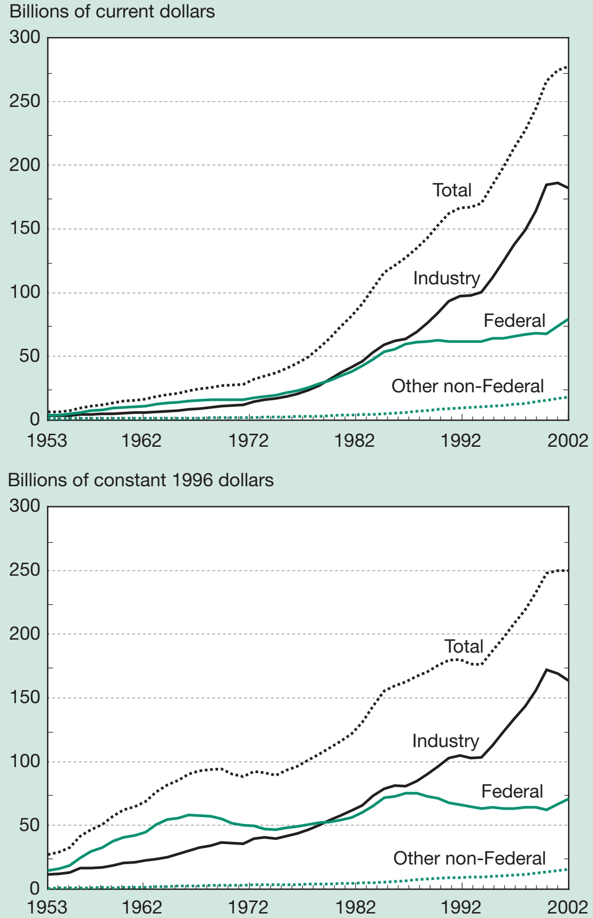
Figure 4-3
National R&D funding, by source of funds: 1953–2002



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

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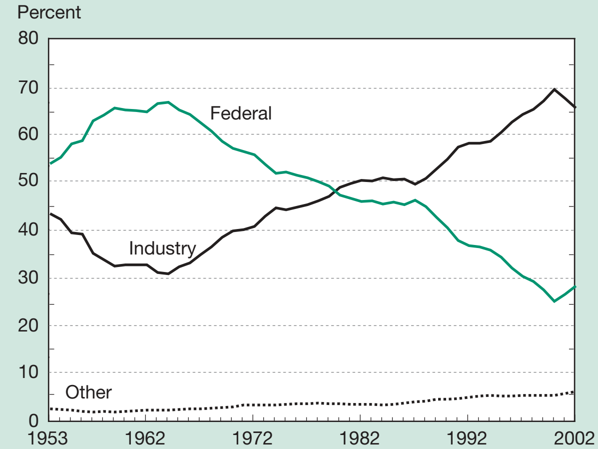
increases in the late 1990s experienced declines in sales, share prices, and R&D investment at the beginning of the 21st century.

Trends in Federal R&D Funding

Increases in Federal R&D investment, particularly in the areas of defense, health, and counterterrorism, helped to offset the slowdown in industrial R&D in 2001 and 2002. These increases also reversed a decades-long trend in the shrinking share of Federal R&D funding as a percentage of the nation's total R&D (figure 4-4).

The Federal Government was once the main source of the nation's R&D funds, funding as much as 66.7 percent of all U.S. R&D in 1964. The Federal share first fell below 50 percent in 1979, and after 1987 it fell steadily, dropping from 46.3 percent in that year to 25.1 percent in 2000 (the lowest it has ever been since the start of the time series in 1953). This sharp decline in the Federal Government share, however, should not be misinterpreted as a drastic decline in the actual amount of R&D funded (figure 4-3). Adjusting for inflation, Federal support decreased 18 percent from 1987 to 2000, although in nominal terms, Federal support grew from $58.5 billion to $66.4 billion during that period. Growth in industrial funding generally outpaced growth in Federal support, leading to the decline in Federal support as a proportion of the total. The slowdown of industry's investment in R&D, as well as increases in Federal R&D funding in recent years, reversed this trend. Thus in 2002, the Federal share of R&D funding is estimated to have grown to 28.3 percent.

Figure 4-4
National R&D expenditures, by source of funds: 1953–2002



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

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Trends in Non-Federal R&D Funding

R&D financing from non-Federal sources grew by 7.6 percent per year after inflation between 1980 and 1985, concurrent with gains in Federal R&D spending. This growth rate slowed to 3.3 percent between 1985 and 1994 but rose to 8.6 percent during the 1994–2000 period. More recently, between 2000 and 2002, non-Federal sources of R&D funding declined by 1.8 percent per year in real terms.

As previously discussed, most non-Federal R&D support is provided by industry. Of the 2002 non-Federal support total ($198 billion), 91.4 percent ($181 billion) was company funded. Industry's share of national R&D funding first surpassed the Federal Government's in 1980, and it has remained higher ever since. From 1980 to 1985, industrial support for R&D, in real dollars, grew at an average annual rate of 7.7 percent. This growth was maintained through both the mild 1980 recession and the more severe 1982 recession (figure 4-3). Key factors behind increases in industrial R&D included a growing concern with international competition, especially in high-technology industries; the increasing technological sophistication of products, processes, and services; and general growth in such defense-related industries as electronics, aircraft, and missiles. Between 1985 and 1994, growth in R&D funding from industry was slower, averaging only 3.1 percent per year in real terms, but from 1994 to 2000 industrial R&D support grew in real terms by 8.9 percent per year. This rapid growth rate came to a halt following the downturn in both the market valuation and economic demand for technology in the first years of the 21st century. Between 2000 and 2002 industrial R&D support declined by 2.5 percent per year in real terms.

Although industrial firms provide only a small portion of the R&D funding at U.S. universities and colleges (6.5 percent in 2002), their funding of academic research has grown faster than any other sector over the past 2 decades. Between 1980 and 2000, industry's funding of academic R&D grew at an average annual rate of 7.7 percent after adjusting for inflation, outpacing total academic R&D, which grew at an average annual rate of 4.8 percent over the same period. Growth in industry's funding of academic R&D has since slowed to an average annual rate of 1.9 percent between 2000 and 2002, indicating that this source of funding is not immune to economic forces, although apparently more so than industry's R&D funding of industry itself.

R&D funding from other non-Federal sectors, namely, academic and other nonprofit institutions and state and local governments, has been more consistent over time, growing at an average annual rate of 6.3 percent between 1980 and 2002 after adjusting for inflation. Most of these funds went to research performed within the academic sector.

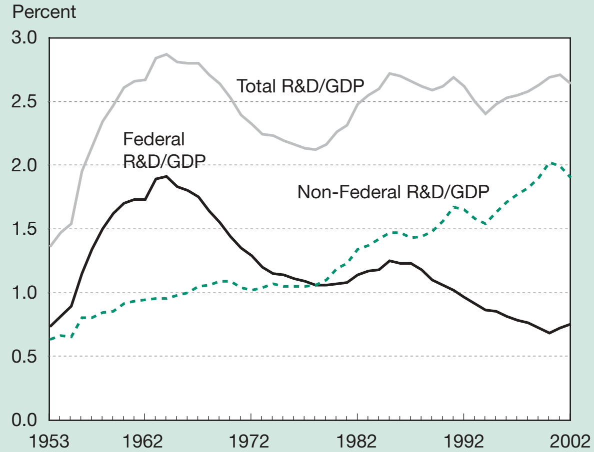
U.S. R&D/GDP Ratio

Economists often use the ratio of R&D expenditures to GDP to examine R&D in the context of a nation's overall economy. This ratio reflects the intensity of R&D activity in relation to other economic activity and is often interpreted as a relative measure of a nation's commitment to R&D.

Since 1953, the first year for which national R&D data are available, U.S. R&D expenditures as a percentage of GDP have ranged from a minimum of 1.36 percent (in 1953) to a maximum of 2.87 percent (in 1964) (figure 4-5). From 1994 to 2001, R&D outpaced growth of the general economy and the R&D/GDP ratio rose close to its historic high. It is estimated that the amount of R&D performed in the United States equaled 2.71 percent of the United States GDP in 2001 and 2.64 percent in 2002.[8]

Most of the growth over time in the R&D/GDP ratio can be attributed to steady increases in non-Federal R&D spending.[9] Nonfederally financed R&D, the majority of which is company financed, increased from 0.63 percent of GDP in 1953 to an estimated 1.90 percent of GDP in 2002 (down from a high of 2.02 percent of GDP in 2000). The increase

Figure 4-5
R&D share of GDP: 1953–2002



GDP gross domestic product

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

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in nonfederally financed R&D as a percentage of GDP illustrated in figure 4-5 corresponds to an upward trend in R&D and technology intensive activities in the U.S. economy.

Historically, most of the peaks and valleys in the R&D/GDP ratio can be attributed to changing priorities in Federal R&D spending. The initial drop in the R&D/GDP ratio from its peak in 1964 largely reflects Federal cutbacks in defense and space R&D programs. Gains in energy R&D activities between 1975 and 1979 resulted in a relative stabilization of the ratio. Beginning in the late 1980s, cuts in defense-related R&D kept Federal R&D spending from keeping pace with GDP growth, whereas growth in non-Federal sources of R&D spending generally kept pace with or exceeded GDP growth. (See the discussion of defense-related R&D in the next section.)

Sectoral Composition of R&D Performance

Since the early 1980s, R&D performance in some sectors has grown much faster than in others. The industrial sector in particular has grown increasingly dominant (figure 4-1). In 1980, industry performed 68.4 percent of the nation's R&D, the academic sector performed 10.2 percent, laboratories within Federal agencies (Federal intramural R&D) performed 12.4 percent, and the nonprofit sector performed 2.6 percent. All FFRDCs combined performed 6.5 percent of the nation's R&D. Industry's defense-related R&D efforts accelerated in the early 1980s, and its share of R&D performance rose to 71.8 percent in 1985.

From 1985 to 1994, R&D performance grew by only 1.4 percent per year in real terms for all sectors combined. This growth was not evenly balanced across performing sectors, however. R&D performance at universities and colleges grew by 5.4 percent per year in real terms, compared with

[8]Growth in the R&D/GDP ratio does not necessarily imply increased R&D expenditures. For example, the rise in R&D/GDP from 1978 to 1985 was due as much to a slowdown in GDP growth as it was to increased spending on R&D activities.

[9]Non-Federal sources of R&D tracked by NSF include industrial firms, universities and colleges, nonprofit institutions, and state and local governments.

only 1.0 percent for industry, –0.5 percent for Federal intramural performance, 5.0 percent for nonprofit organizations, and 0.4 percent for all FFRDCs combined.

The 1994–2000 period was one of dramatic changes for these growth rates. Total R&D performance in real terms averaged 5.8 percent growth per year, which was substantially higher than in the earlier sluggish period. Yet, R&D performance at universities and colleges grew at a slower rate of 4.1 percent per year in real terms.[10] Industrial R&D expanded at a remarkable rate of 7.1 percent in real terms (despite a decline in company-reported Federal financing of R&D). Federal intramural performance decreased by 0.3 percent per year in real terms. Nonprofit organizations, according to current estimates, increased their R&D performance by 7.1 percent per year in real terms over the same 6-year period. Finally, R&D performance at all FFRDCs combined declined by 0.1 percent per year in real terms in this period.

Industry is expected to have performed 70.4 percent of the nation's total R&D in 2002 (table 4-1). The estimated $194.4 billion in industrial R&D performance represents a 2.5 percent average annual decrease in real terms from the 2000 level. Of the industrial R&D performed in 2002, 91.2 percent was funded by industry; the remaining 8.8 percent was federally funded. The federally funded share of industry's R&D performance total has fallen considerably from 31.9 percent in 1987.

Universities and colleges are estimated to have performed 13.0 percent ($36.0 billion) of national R&D in 2002, an average annual increase of 6.6 percent in real terms over their share in 2000. The Federal Government performed 8.6 percent ($23.8 billion) of U.S. R&D in 2002, an average annual increase in real terms of 13.3 percent over the 2000–2002 period. All FFRDCs combined performed an estimated $10.3 billion of R&D in 2002, or 3.7 percent of the U.S. total. The nonprofit sector performed an estimated $11.6 billion in 2002, or 4.2 percent of the U.S. total.

Trends in R&D by Character of Work

Because research and development encompasses a broad range of activities, it is helpful to disaggregate R&D expenditures into the traditional categories of basic research, applied research, and development. Despite the difficulties in classifying specific R&D projects, these categories are useful for characterizing the expected time horizons, outputs, and types of investments associated with R&D expenditures.

In 2002 the United States performed an estimated $49.6 billion of basic research, $64.8 billion of applied research, and $161.8 billion of development (table 4-1). As a share of all 2002 R&D expenditures, basic research represented 17.9 percent, applied research represented 23.5 percent, and development represented 58.6 percent.

Basic Research

In 2002, universities and colleges performed 53.8 percent of basic research, more than any other sector. The intellectual freedom and diversity of these institutions make them ideally suited to carry out basic research. Industry performed an estimated 15.6 percent of U.S. basic research in 2002. Rather than serve an immediate market need, the basic research performed by a firm with industry funds serves to strengthen the innovative capacity of the firm by developing human capital and increasing the capability of the firm to absorb external scientific and technological knowledge.

The Federal Government, estimated to have provided 58.9 percent of basic research funding in 2002, historically has provided the majority of funding for basic research (figure 4-6). Moreover, the Federal Government funded 61.8 percent of the basic research performed by universities and colleges in 2002. Industry devoted only an estimated 5 percent of its total R&D support to basic research in 2002, representing 18.5 percent of the national total. The reason for industry's relatively small contribution to basic research is that basic research generally involves the most uncertainty in terms of both the technical success and the commercial value of any results in the three broad categories of R&D. The industries that invest the most in basic research are those whose new products and services are most directly linked to advances in science and engineering, such as the pharmaceuticals industry and the scientific R&D services industry.

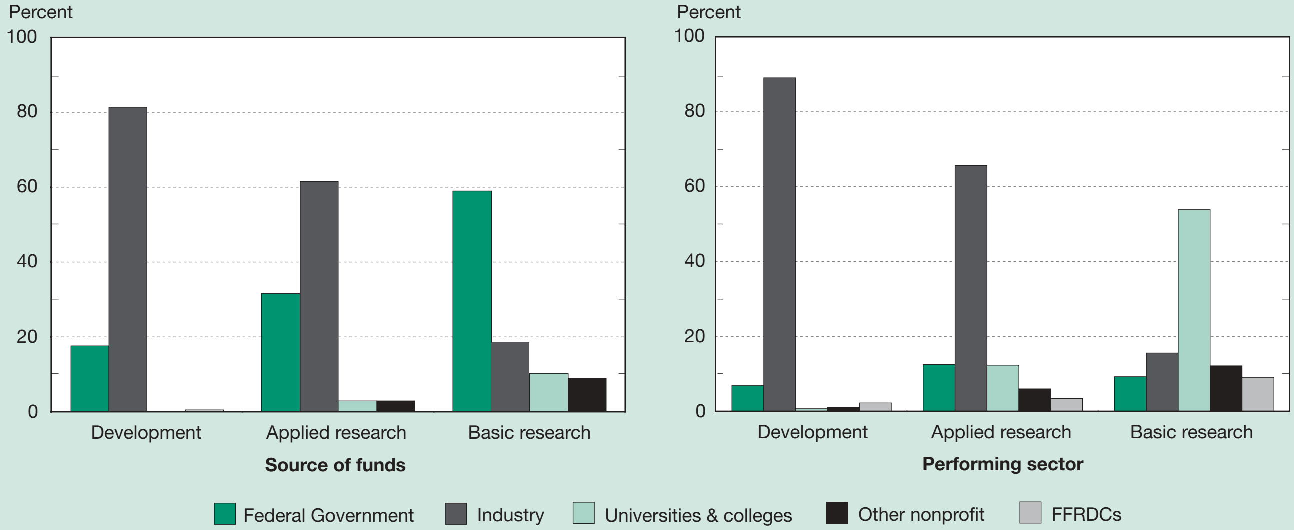
Applied Research

Nonacademic institutions perform the majority of U.S. applied research, which totaled $64.8 billion in 2002. Industrial performers accounted for 65.7 percent of all applied research, with the remainder largely performed by Federal laboratories (12.5 percent) and universities and colleges (12.4 percent). Industrial support accounts for 61.5 percent ($39.8 billion) of the 2002 total for applied research and Federal support for 31.6 percent ($20.5 billion). The Federal Government's investment in research has historically emphasized basic research over applied research, reflecting the belief that the private sector is less likely to invest in basic research. In 2002, Federal funding for applied research was 70 percent of that for basic research.

Within industry, applied research acts to refine and adapt existing scientific knowledge and technology into knowledge and techniques useful for creating or improving products, processes, or services. The level of applied research in an industry reflects both the market demand for substantially (as opposed to cosmetically) new and improved goods and services as well as the level of effort required to transition from basic research to technically and economically feasible concepts. Examples of industries that perform a relatively

[10]Recent methodological improvements in the estimation of total academic R&D have resulted in a break in the time series. Data for years before 1998 are slightly overstated compared with the data for later years. Had the same methodology been used for all years in the series, the average annual growth rate would have been closer to 4.3 percent per year in real terms from 1994 to 2000. See Machen and Shackelford (forthcoming) for details on the changes to methodology.

Figure 4-6
National R&D expenditure, by source of funds, performing sector, and character of work: 2002



FFRDC federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix tables 4-7 through 4-18.

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large amount of applied research are the semiconductor industry and the biotechnology industry.

Development

Development expenditures totaled an estimated $161.8 billion in 2002, representing the majority of U.S. R&D expenditures. The development of new and improved goods, services, and processes is dominated by industry, which performed 89.0 percent of all U.S. development in 2002. Federal laboratories and FFRDCs performed an estimated 9.1 percent of U.S. development; the remainder was performed by universities and colleges and nonprofit institutions.

Industry and the Federal Government together funded 99.0 percent of all development in 2002, with industry providing 81.4 percent and the Federal Government providing 17.6 percent. The Federal Government generally invests in the development of such products as tactical nuclear weapons and space exploration vehicles, for which it is the only consumer. The Federal investment in development is dominated by the Department of Defense (DOD), which invests 85 percent of its R&D funds in development (figure 4-7). For more information about Federal R&D funding by agency and character of work, see "R&D by Federal Agency."

Investments in development differ from investments in basic and applied research in that they are relatively short-term in nature and tend to depreciate in value relatively rapidly.[11] To track its longer-term investments in S&T, the Federal Government excludes much of its spending on development in favor of focusing on basic and applied research and other investments in R&D plant and S&E education. For more information, see "Federal S&T Budget" in "Federal R&D Funding by National Objective."

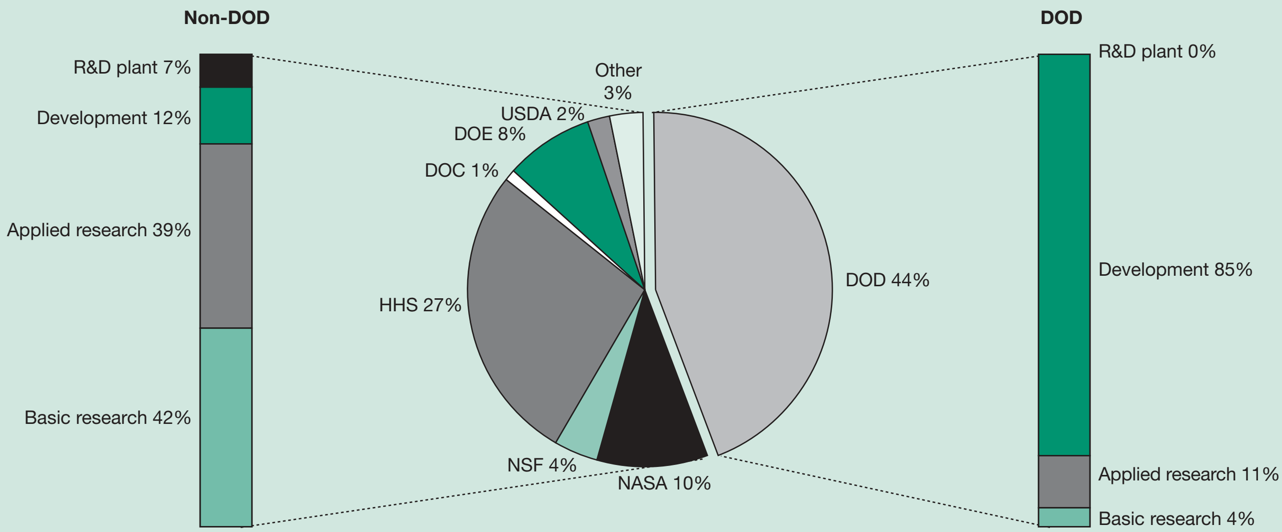
Industrial R&D by Industry, Firm Size, and R&D Intensity

The level of industrial R&D is one indicator of industry's commitment at any point in time to the production of new and improved products, services, and processes. R&D expenditures, like those for advertising, are discretionary and are set by firms at levels intended to maximize future profits. R&D expenditures therefore indicate both the importance that R&D is accorded with respect to other discretionary spending as well as firms' perceptions of the demand for new and improved technology. Of particular importance is industrial R&D that is financed by the private sector as opposed to the Federal Government. The broad themes explored in this section include the strong rise in industry-funded R&D, the rise of service-sector R&D after the early 1980s, a restructuring of U.S. industrial R&D that is partially related to changes in service-sector R&D trends, and R&D intensities as a tool for industry analysis.

As previously described, R&D performed by private industry reached $194.4 billion in 2002. This total represents a 2.5 percent average annual decline in real terms from the 2000 level of $197.6 billion. Most of this decline was in industry-financed R&D. Companies funded 91.2 percent ($177.3 billion) of their 2002 R&D performance, with the Federal Government funding nearly all the rest ($17.1 billion, or 8.8 percent of the total). For more than a decade the

[11]A newly developed product faces eventual obsolescence, whereas discoveries made through basic or applied research tend to be cumulative in nature and provide value for many years.

Figure 4-7
Projected Federal obligations for R&D and R&D plant, by agency and character of work: FY 2003



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

NOTE: Percents may not sum to 100 because of rounding.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 4-32.

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largest component of R&D in the United States has been performed by private industry through private industry's own funds. (Some of this funding is supported through venture capital investments. For a discussion of the relationship between venture capital and R&D expenditures, see chapter 6.) This component of U.S. R&D grew from 43 percent of total R&D in 1953 to 64 percent in 2002.

R&D in Nonmanufacturing Industries

Until the 1980s, little attention was paid to R&D performed by nonmanufacturing companies largely because R&D activity in the service sector was negligible compared with the R&D operations of manufacturing companies. Before 1983, nonmanufacturing industries accounted for less than 5 percent of total industrial R&D performance (including industry-administered FFRDCs), but by 2001 (the most current year for detailed data on industrial R&D), they accounted for 39.2 percent.[12] In 2001, firms classified in nonmanufacturing industries performed $77.8 billion of R&D ($72.4 billion in funds provided by companies and other non-Federal sources and $5.4 billion in Federal support) (table 4-2). Of this amount, 79 percent ($56.9 billion) can be attributed to trade, software and computer-related services, and scientific R&D services.[13] An examination of these three groups of industries helps explain the dramatic growth in nonmanufacturing R&D over the past 2 decades.

R&D performance attributed to the trade industry reached $24.4 billion in 2001. Although some of this R&D was performed by companies whose primary business was wholesale or retail trade, there is little doubt that this sum includes more than just the activities of dot.com retailers. A known consequence of assigning firms to one industry based on payroll data—the classification method used for the NSF Industry R&D Survey—is that a company can be classified in an industry that is not directly related to its reported R&D activities.[14] Although imperfect, this classification scheme reasonably categorizes all but the most diversified companies into industries closely aligned with their primary business activities. The classification of firms into the trade industry is one exception to this assertion because the sale and marketing of goods and services, a trade activity, is often a significant activity in both manufacturing and nonmanufacturing firms. A large pharmaceutical firm or diversified conglomerate would be classified in the trade

[12]Beginning with the 2001 survey cycle, industry-administered FFRDCs were removed from the industrial R&D statistics. This resulted in a relative increase in the share of R&D performed by nonmanufacturing industries. In 2000, when these FFRDCs were included in the industrial R&D totals, R&D performed by nonmanufacturing industries accounted for 37.8 percent of total industrial R&D.

[13]The trade and scientific R&D services industries are distinct entries in the NSF industrial R&D tables. Software and computer-related services, however, is the sum of three related entries: software, other information, and computer systems design and related services.

[14]Details on how companies are assigned industry codes in the NSF Survey of Industrial Research and Development can be found on the NSF website (http://www.nsf.gov/sbe/srs/nsf02312/sectb.htm#frame). National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http:// www.nsf.gov/sbe/srs/indus/start.htm.

Table 4-2
Industrial R&D performance, by industry and source of funding: 2001

Industry	NAICS code	Total	Federal Government	Company funded	Percent distribution of company-funded
		Millions of dollars			
All industries	21–23, 31–33, 42, 44–81	198,505	16,899	181,606	100.0
Manufacturing	31–33	120,705	11,484	109,221	60.1
Food	311	1,819	0	1,818	1.0
Beverage and tobacco products	312	152	0	152	0.1
Textiles, apparel, and leather	313–16	D	D	255	0.1
Wood products	321	182	0	181	0.1
Paper, printing, and support activities	322, 323	D	D	2,664	1.5
Petroleum and coal products	324	D	D	1,057	0.6
Chemicals	325	17,892	180	17,713	9.8
Basic chemicals	3251	1,876	42	1,835	1.0
Resin, synthetic rubber, fibers, and filament	3252	D	D	2,745	1.5
Pharmaceuticals and medicines	3254	10,137	0	10,137	5.6
Other	325 (minus 3251–52, 3254)	D	D	2,996	1.6
Plastics and rubber products	326	D	D	2,245	1.2
Nonmetallic mineral products	327	990	11	978	0.5
Primary metals	331	485	6	479	0.3
Fabricated metal products	332	1,599	54	1,545	0.9
Machinery	333	6,404	67	6,337	3.5
Computer and electronic products	334	47,079	5,848	41,232	22.7
Computers and peripheral equipment	3341	D	D	3,165	1.7
Communications equipment	3342	15,507	298	15,209	8.4
Semiconductor and other electronic components	3344	14,358	148	14,210	7.8
Navigational, measuring, electromedical, and control instruments	3345	12,947	5,382	7,565	4.2
Other	334 (minus 3341–42, 3344–45)	D	D	1,083	0.6
Electrical equipment, appliances, and components	335	4,980	301	4,680	2.6
Transportation equipment	336	25,965	4,961	21,004	11.6
Motor vehicles, trailers, and parts	3361–63	D	D	16,089	8.9
Aerospace products and parts	3364	7,868	3,785	4,083	2.2
Other	336 (minus 3361–64)	D	D	832	0.5
Furniture and related products	337	301	0	301	0.2
Miscellaneous manufacturing	339	6,606	25	6,581	3.6
Medical equipment and supplies	3391	D	D	5,903	3.3
Other	339 (minus 3391)	D	D	678	0.4
Nonmanufacturing	21–23, 42, 44–81	77,799	5,415	72,384	39.9
Mining, extraction, and support activities	21	D	D	846	0.5
Utilities	22	133	19	114	0.1
Construction	23	320	1	320	0.2
Trade	42, 44, 45	24,372	88	24,284	13.4
Transportation and warehousing	48, 49	1,848	72	1,776	1.0
Information	51	D	D	17,259	9.5
Publishing	511	13,760	44	13,716	7.6
Newspaper, periodical, book, and database	5111	649	0	649	0.4
Software	5112	13,111	44	13,067	7.2
Broadcasting and telecommunications	513	D	D	1,270	0.7
Other	51 (minus 511, 513)	D	D	2,273	1.3
Finance, insurance, and real estate	52, 53	D	D	2,424	1.3
Professional, scientific, and technical services	54	27,704	5,065	22,640	12.5
Architectural, engineering, and related services	5413	3,386	1,021	2,365	1.3
Computer systems design and related services	5415	9,154	498	8,656	4.8
Scientific R&D services	5417	14,244	3,352	10,893	6.0
Other	54 (minus 5413, 5415, 5417)	920	194	726	0.4
Management of companies and enterprises	55	381	0	381	0.2
Health care services	621–23	1,149	29	1,120	0.6
Other	56, 61, 624, 71, 72, 81	1,259	38	1,221	0.7

D data withheld to avoid disclosing operations of individual companies
NAICS North American Industry Classification System

NOTE: Manufacturing companies with fewer than 50 employees and nonmanufacturing companies with fewer than 15 employees were sampled separately without regard to industry classification to minimize year-to-year variation in survey estimates. However, estimates for companies in these groups are included with their respective NAICS classification for this table.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Research and Development in Industry: 2001*, forthcoming. See appendix tables 4-19, 4-20, and 4-21.

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industry if the payroll associated with its sales and marketing efforts outweighed that of any other industrial activity in the company. One indication of these classification artifacts is that in 2001, 86 percent of the R&D attributed to the trade industry was performed by companies with total R&D programs in excess of $100 million, whereas companies in the same size category accounted for only 42 percent of the R&D in all other nonmanufacturing industries combined. Another indication is that more than $1 billion of biotechnology R&D was reported by companies classified in the trade industry in 2001.

Nonmanufacturing industries associated with software and computer-related services such as data processing and systems design performed approximately $24.0 billion of company-funded R&D in 2001.[15] As computing and IT became more powerful, flexible, and ubiquitous over the past 2 decades, the demand for services associated with these technologies boomed. The R&D of companies providing these services also grew dramatically during this period. In 1987, when an upper-bound estimate of software and other computer-related services R&D first became available, companies classified in the industry group "computer programming, data processing, other computer-related, engineering, architectural, and surveying services" performed $2.4 billion of company-funded R&D, or 3.8 percent of all company-funded industrial R&D. In 2001 the company-funded R&D of a comparable group of industries (excluding engineering and architectural services) was greater by a factor of 10 and accounted for 13.2 percent of all company-funded industrial R&D[16] (table 4-3). This trend in the growth of software and computer-related services R&D shows no sign of slowing. Despite essentially no growth in total company-funded, industry-performed R&D between 2000 and 2001, the company-funded R&D for this group of industries grew by 10 percent.

The R&D performed by companies in the scientific R&D services industry more than doubled in the 4 years between 1997 and 2001 from $7.0 to $14.2 billion.[17] The portion of this industry's R&D that was company-funded increased at an even faster pace, from $4.7 billion in 1997 to $10.9 billion in 2001. The scientific R&D services industry comprises companies that specialize in conducting R&D for other organizations, such as many biotechnology companies. (See sidebar, "Biotechnology R&D in Industry.") Although these companies and their R&D activities are classified as nonmanufacturing because they provide business services, many of the industries they serve are manufacturing industries. This implies that the R&D activities of a research firm that services a manufacturer would have been classified as R&D in manufacturing if the same research firm were a subsidiary of the manufacturer. Consequently, a growth in measured R&D in services may, in part, "reflect a more general pattern of industry's increasing reliance on outsourcing and contract R&D" (Jankowski 2001). (For more information, see "Contract R&D.")

Although a great deal of R&D in the United States is related in some way to health care services, companies specifically categorized in the health care services sector accounted for only 0.4 percent of all industrial R&D and for only 1.0 percent of all R&D by nonmanufacturing companies. As in many industries, innovation often results from R&D performed in other industries, in this case the pharmaceutical, scientific instrument, and software industries in particular. These results illustrate that R&D data disaggregated according to industrial categories (including the distinction between manufacturing and nonmanufacturing industries) may not always reflect the relative proportions of R&D devoted

Table 4-3
Estimated share of computer-related services in company-funded R&D and domestic net sales: 1987–2001
(Percent)

Year	Company-funded R&D	Domestic net sales
1987	3.8	1.4
1988	3.6	1.5
1989	3.4	1.4
1990	3.7	1.5
1991	3.6	1.6
1992	4.0	1.6
1993	8.2	1.5
1994	6.6	2.2
1995	8.8	3.3
1996	8.8	2.6
1997	9.1	2.5
1998	9.5	2.2
1999	10.7	2.6
2000	12.1	2.9
2001	13.2	3.5

NOTES: Data before 1998 are for companies classified in Standard Industrial Classification (SIC) industries 737 (computer and data processing services) and 871 (engineering, architectural, and surveying services). For 1998 and later years, data are for companies classified in North American Industry Classification System (NAICS) industries 5112 (software), 51 minus (511, 513) (other information), and 5415 (computer systems design and related services). Using SIC classification, the information technology services share of company-funded R&D is 10.4 percent for 1998, indicating that SIC-based data are overestimates of actual information technology services R&D and net sales.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, special tabulations (Arlington, VA, 2003).

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[15]Although disclosure of Federal R&D funding prohibited the precise tabulation of total R&D performance for this industry, total R&D was between $24.5 billion and $24.6 billion.

[16]The introduction of a more refined industry classification scheme in 1999 allowed more detailed reporting in nonmanufacturing industries. For the cited 2001 statistic, the R&D of companies in software, other information, and computer systems design and related services industries were combined. These three industries provided the closest approximation to the broader category cited for earlier years without exceeding the coverage of the broader category.

[17]The 1997 data for this industry are bridged from a different industry classification scheme.

Biotechnology R&D in Industry

Of particular interest to researchers, investors, and policymakers are the R&D activities of companies in emerging, fast-growing sectors of science and technology such as biotechnology. Unfortunately, the rapidly evolving and often multidisciplinary nature of these sectors makes them very difficult to track as unique industry categories. In 2001, for the first time, NSF collected data on industrial R&D for biotechnology and other select technology areas on its NSF Survey of Industrial Research and Development (only companies with estimated total R&D of at least $5 million in 2000 were asked to report R&D by technology area in 2001). Although many companies were unable or unwilling to report their R&D activities by technology area, the data reported reveal much about the structure of biotechnology R&D in the United States. As table 4-4 illustrates, the scientific R&D services industry accounted for slightly more than half of the reported $7.4 billion of biotechnology R&D. Many biotechnology firms that perform contract R&D for pharmaceutical companies are classified as part of this industry. Biotechnology R&D accounts for at least a fourth of all R&D in this industry and accounted for at least 3.7 percent of total U.S. industrial R&D in 2001. The $1.1 billion of biotechnology R&D reported in the trade industry is predictable from the activities of pharmaceutical firms, which devote considerable resources to marketing and selling their products. The data suggest that smaller firms, on average, are more likely to perform biotechnology R&D than other industrial R&D; companies with fewer than 5,000 employees performed three-fourths of the reported biotechnology R&D, whereas companies in this size bracket performed only 38 percent of total industrial R&D in 2001.

Table 4-4
Total R&D and lower bound biotechnology R&D by industry and company size: 2001

Industry and company size	R&D: Total	R&D: Biotechnology	Biotechnology/ total R&D
	Millions of dollars		Percent
All industries	198,505	7,350	3.7
Manufacturing	120,705	2,193	1.8
Pharmaceuticals and medicines	10,137	1,882	18.6
Nonmanufacturing	77,799	5,157	6.6
Trade	24,372	1,104	4.5
Scientific R&D services	14,244	3,846	27.0
Company size (number of employees), total	198,505	7,350	3.7
5–24	4,828	0	0.0
25–49	3,750	118	3.1
50–99	8,202	398	4.9
100–249	12,916	869	6.7
250–499	8,702	533	6.1
500–999	10,564	1,300	12.3
1,000–4,999	26,748	2,155	8.1
5,000–9,999	17,487	D	D
10,000–24,999	27,065	149	0.6
25,000 or more	78,244	D	D

D data withheld to avoid disclosing operations of individual companies

NOTES: Details may not add to totals because of rounding. Data for biotechnology R&D are underestimated because no attempt was made to correct for item nonresponse. Counts of respondents suggest that actual figures could be much larger. Also, these totals exclude biotechnology R&D of firms whose total R&D was less than $5 million in 2000. These firms were not asked to report their biotechnology R&D separately on 2001 survey form. This is probably the main reason firms with 5–24 employees have no reported biotechnology R&D.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2001.

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Table 4-5
Funds for industry R&D performance and number of R&D-performing companies in manufacturing and nonmanufacturing industries, by size of company: 2001

Company size	Funds			Companies		
	Total	Manufacturing	Non-manufacturing	Total	Manufacturing	Non-manufacturing
	Millions of dollars			Number		
Total (number of employees)	198,505	120,705	77,799	33,263	16,817	16,446
5–25	4,828	973	3,855	14,681	5,802	8,879
25–49	3,750	1,123	2,627	5,036	2,013	3,023
50–99	8,202	3,924	4,278	5,030	3,209	1,820
100–249	12,916	4,817	8,099	4,261	2,817	1,444
250–499	8,702	3,345	5,357	1,504	1,040	464
500–999	10,564	5,290	5,273	1,194	851	343
1,000–4,999	26,748	15,828	10,919	1,039	755	284
5,000–9,999	17,487	10,918	6,569	244	164	80
10,000–24,999	27,065	15,647	11,418	156	97	60
25,000 or more	78,244	58,840	19,404	118	68	50

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Research and Development in Industry: 2001* (Arlington, VA, forthcoming).

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to particular types of scientific or engineering objectives or to particular fields of science or engineering.

R&D in Manufacturing Industries

Within the manufacturing industries, three groups dominate: computer and electronic products, transportation equipment, and chemicals (table 4-2). In 2001, computer and electronic products accounted for the largest amount of R&D performed among all industries at $47.1 billion, or 23.7 percent of all industrial R&D and 39.0 percent of all manufacturing R&D. For this subsector, industrial firms provided $41.2 billion in R&D support and the Federal Government funded the remainder.

In 2001, transportation equipment accounted for the second most R&D performed in the manufacturing sector at $26.0 billion, or 13.1 percent of all industrial R&D. Of these expenditures, 19.1 percent was federally funded, primarily for R&D on aerospace products (planes, missiles, and space vehicles). In addition to aerospace products, this subsector includes a variety of other forms of transportation equipment, such as motor vehicles, ships, military armored vehicles, locomotives, and smaller vehicles such as motorcycles, bicycles, and snowmobiles.

In 2001, chemicals ranked third in R&D performed in the manufacturing subsector at $17.9 billion, approximately 1 percent of which was federally funded. In terms of R&D performance, the largest industry within the chemicals subsector is pharmaceuticals and medicines. In 2001, R&D performed by these companies accounted for 61 percent of non-Federal R&D funding in the chemicals subsector ($12.9 billion).

Industrial R&D and Firm Size

Manufacturing R&D performers are typically quite different from nonmanufacturing R&D performers. Manufacturing R&D performers tend to be larger firms that perform more R&D on average than nonmanufacturing firms (table 4-5). Approximately 33,000 firms in the United States performed R&D in 2001; of these, 51 percent were in the manufacturing sector. Manufacturers account for an even greater share (61 percent) of total industrial R&D performance. As a share of the nation's GDP, on the other hand, manufacturing contributes less than 20 percent. Manufacturers dominate in terms of R&D performance largely because of the activities of the largest manufacturing firms. In 2001 the largest manufacturing firms (those with 25,000 or more employees) accounted for 49 percent of the R&D in the manufacturing sector, whereas nonmanufacturing firms in the same size category accounted for only 25 percent of total nonmanufacturing R&D.[18]

Among small R&D-performing firms (those with less than 500 employees), those in the nonmanufacturing sector conduct significantly more R&D than those in the manufacturing sector, both in aggregate and on a per-firm basis. These small firms accounted for 12 percent of manufacturing R&D, 31 percent of nonmanufacturing R&D, and 19 percent of all industrial R&D in 2001.

Although R&D tends to be performed by large firms in the manufacturing sector and smaller firms in the nonmanufacturing sector, considerable variation can be found within each sector, depending on the type of industry. R&D tends to be conducted primarily by large firms in several industrial

[18]R&D performance is even more skewed towards companies with large R&D programs (total R&D of $100 million or more). The 243 firms in this category accounted for 73 percent of manufacturing R&D, 56 percent of nonmanufacturing R&D, and 67 percent of all industrial R&D in 2001.

subsectors: aircraft and missiles; electrical equipment; professional and scientific instruments; transportation equipment (not including aircraft and missiles); and transportation and utilities, which are in the nonmanufacturing sector. In these same sectors, however, much of the economic activity occurs in large firms to begin with, so the observation that most of the R&D in these sectors is also conducted by large firms is not surprising.

R&D Intensity

In addition to absolute levels of and changes in R&D expenditures, another key indicator of industrial commitment to S&T is R&D intensity, a measure of R&D relative to production in a company, industry, or sector. For most firms, R&D is similar to sales, marketing, and general management expenses because it is a discretionary expense. R&D does not directly generate revenue in the same way that production expenses do, so it can be trimmed when profits fall. Evidence suggests, however, that R&D enjoys some degree of immunity from belt-tightening endeavors, even when the economy is faltering, because of its crucial role in laying the foundation for future growth and prosperity.

Many ways exist to measure R&D intensity; the one used most frequently is the ratio of company-funded R&D to net sales.[19] This statistic provides a way to gauge the relative importance of R&D across industries and among firms in the same industry. The industrial subsectors with the highest R&D intensities in 2001 were scientific R&D services (36.5 percent), software (19.3 percent), communications equipment (16.6 percent), and computer systems design and related services (16.5 percent). The R&D intensities of the professional, scientific, and technical services industries are particularly high because, as previously explained, much of the R&D reported by these companies also appears in their reported sales figures. Industries with the lowest R&D intensities (0.5 percent or less) were food, broadcasting and telecommunications, and utilities (table 4-6). A decrease in the net sales of R&D-performing companies between 2000 and 2001 resulted in the ratio of R&D to sales for all industries increasing to 3.8 percent in 2001, up from 3.4 percent in 2000.

Sales are more skewed towards larger companies than R&D performance (table 4-6). Smaller companies have much larger R&D-to-sales ratios than larger companies, reflecting that most startups and companies with less established revenue streams tend to be smaller. Large, well-established companies often have reserves of cash and other liquid assets that allow them to maintain their R&D activities amid short-term economic downturns. Less mature companies,

[19]A similar measure of R&D intensity is the ratio of R&D to *value added* (sales minus the cost of materials). Value added is often used in studies of productivity because it allows analysts to focus on the economic output attributable to the specific industrial sector in question by subtracting materials produced in other sectors. For a discussion of the connection between R&D intensity and technological progress, see, for example, R. Nelson, Modeling the connections in the cross section between technical progress and R&D intensity, *RAND Journal of Economics* 19(3) (Autumn 1988): 478–485.

Table 4-6
Company and other (non-Federal) R&D fund share of net sales in R&D-performing companies, by industry and company size: 2000, 2001
(Percent)

Industry and company size	2000	2001
All industries	3.4	3.8
Manufacturing	3.3	3.6
Communications equipment	10.1	16.6
Semiconductor and other electronic components	7.4	10.5
Medical equipment and supplies	12.9	9.0
Pharmaceuticals and medicines	9.6	7.8
Computers and peripheral equipment	6.4	7.6
Navigational, measuring, electro-medical, and control instruments	8.0	7.3
Resin, synthetic rubber, fibers, and filament	5.6	4.5
Machinery	3.8	4.2
Motor vehicles, trailers, and parts	3.2	3.5
Other chemicals	3.8	3.2
Aerospace products and parts	2.8	3.0
Electrical equipment, appliances, and components	2.2	2.9
Plastics and rubber products	1.4	2.9
Nonmetallic mineral products	1.8	2.3
Basic chemicals	2.3	2.2
Paper, printing, and support activities	1.6	2.1
Fabricated metal products	1.5	1.6
Furniture and related products	0.8	0.9
Primary metals	0.5	0.7
Food	0.4	0.5
Nonmanufacturing	3.8	4.0
Scientific R&D services	34.4	36.5
Software	20.4	19.3
Computer systems design and related services	15.8	16.5
Management of companies and enterprises	4.4	7.8
Trade	5.4	6.2
Architectural, engineering, and related services	7.3	5.2
Health care services	3.2	4.1
Newspaper, periodical, book, and database	2.0	2.7
Transportation and warehousing	0.3	2.4
Construction	1.8	1.4
Mining, extraction, and support activities	1.2	1.3
Finance, insurance, and real estate	1.2	0.7
Broadcasting and telecommunications	0.4	0.5
Utilities	0.1	0.0
Company size (number of employees)		
5–24	17.2	12.9
25–49	13.4	10.6
50–99	11.2	10.4
100–249	8.0	10.8
250–499	6.1	8.0
500–999	4.7	5.7
1,000–4,999	3.5	4.2
5,000–9,999	2.2	2.5
10,000–24,999	3.1	3.5
25,000 or more	2.9	3.0

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Research and Development in Industry: 2001* (Arlington, VA, forthcoming).

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however, tend to be more reliant on outside investment and thus their expenditures on R&D are more likely to be cut in the event of a contraction in the economy or capital markets. This is one explanation for the divergence in the R&D intensities of very small companies (less than 100 employees) and all other companies between 2000 and 2001.

R&D Expenses of Public U.S. Corporations

Most firms that make significant investments in R&D track their R&D expenses separately in their accounting records. (See sidebar, "R&D: Asset or Expense?") The annual reports of public U.S. corporations often include data on these R&D expenses.[20] In 2001 the 20 U.S. corporations with the largest reported R&D expenditures spent $67.9 billion on R&D. Ford Motor Company reported the most R&D ($7.4 billion), followed by General Motors Corporation ($6.2 billion) (table 4-7). IT companies and pharmaceutical companies dominate the remainder of the list.

Corporate data tabulated by the U.S. Department of Commerce (DOC) reveal that the R&D spending of U.S.-headquartered corporations grew from $93.6 billion in 1994 to $164.5 billion in 2000, implying average annual real growth of 7.9 percent over the period (U.S. DOC/TA 2002). The largest and fastest growing R&D sectors during this period were the information and electronics manufacture and services sector, which spent $35.3 billion on R&D in 1994 and $77.7 billion in 2000, and the medical substances and devices sector, which spent $16.7 billion in 1994 and $32.5 billion in 2000 (appendix table 4-22). Preliminary analysis of more recent company records indicates that the growth of U.S. corporate R&D slowed in 2001. (See sidebar, "Corporate R&D Strategies in an Uncertain Economy," for information on how some U.S.-based corporations intended to adjust their R&D policies in 2003.)

R&D Performance by State

The latest data available on the state distribution of R&D performance are for 2000. Although R&D expenditures are concentrated in relatively few states, patterns of R&D activities vary considerably among the top R&D-performing locations. In 2000, total U.S. R&D expenditures were $265 billion, of which $247 billion could be attributed to expenditures within individual states, with the remainder falling under an undistributed "other/unknown" category[21] (appendix tables 4-23 and 4-24). These totals include R&D performed by industry, universities, Federal agencies, and nonprofit organizations. (For a broader range of indicators of state-level S&E activities, see chapter 8.)

[20]This source of R&D data differs from the NSF Survey of Industrial Research and Development, so direct comparisons of these sources are not possible. See C. Shepherd and S. Payson, *U.S. R&D Corporate R&D* (Washington, DC: National Science Foundation, 2001) for an explanation of the differences between the two.

[21]Approximately two-thirds of the R&D that could not be associated with a particular state was R&D performed by the nonprofit sector.

R&D: Asset or Expense?

Recently economists at the U.S. Bureau of Economic Analysis (BEA) explored the effect on gross domestic product (GDP) of treating R&D as an investment in the National Income and Product Accounts (Fraumeni and Okubo 2002). Given reasonable assumptions regarding the rates of return on R&D and R&D depreciation, the economists reached the following conclusions:

- R&D accounted for approximately 13 percent of GDP growth between 1961 and 2000. Capitalizing R&D increased the rate of growth of GDP by 0.1 percentage point.
- Capitalizing R&D raised the national savings rate (the portion of the national product not devoted to consumption) by 2 percentage points, from 19 to 21 percent.
- Returns to R&D capital represented 19 percent of property-type income. Property-type income largely consists of corporate profits, proprietors' income, net interest, capital consumption allowances, and rental income of persons.

Current financial accounting standards dictate that firms expense R&D expenditures as they occur. But even though accountants do not show the value of R&D on the balance sheet as they do for plant and equipment, analysts have recognized that in theory R&D should be treated as an investment rather than as an expense when valuing a firm (Brealey and Myers 1996; and Lev 2001) or measuring national economic activity (Nakamura 2001). The reasoning for this is that even though the primary output of R&D—knowledge—is intangible, it has a very real impact on future production (new goods and services) and productivity. Thus failing to account for R&D as an "intangible asset" leads to the underestimation of national assets and consequently national production capabilities.

Distribution of R&D Expenditures Among States

In 2000 the 20 highest ranking states in R&D expenditures accounted for 87 percent of U.S. R&D expenditures, whereas the 20 lowest ranking states accounted for only 4 percent. The six states with the highest levels of R&D expenditures (in decreasing order of magnitude) were California, Michigan, New York, New Jersey, Massachusetts, and Illinois, and they accounted for half of the entire national effort. The top 10 states, which included Texas, Washington, Pennsylvania, and Maryland (ranked 7th, 8th, 9th, and 10th,

Table 4-7
Top 20 R&D-spending corporations: 2001

Corporation	R&D rank			R&D (millions of dollars)			Percent change from 1999 to 2001	Description	NAICS code
	2001	2000	1999	2001	2000	1999			
Ford Motor Company	1	1	1	7,400	6,800	7,100	4.2	Motor vehicle manufacturing	3361
General Motors	2	2	2	6,200	6,600	6,800	–8.8	Motor vehicle manufacturing	3361
Pfizer Inc.	3	4	8	4,847	4,435	2,776	74.6	Pharmaceutical and medicine manufacturing	3254
International Business Machines	4	5	4	4,620	4,336	4,464	3.5	Computer systems design and related services	5415
Microsoft	5	8	7	4,379	3,775	2,970	47.4	Software publishers	5112
Motorola	6	3	5	4,318	4,437	3,438	25.6	Communications equipment manufacturing	3342
Cisco Systems	7	11	20	3,922	2,704	1,594	146.0	Computer and peripheral equipment manufacturing	3341
Intel	8	7	6	3,796	3,897	3,111	22.0	Semiconductor and other electronic component manufacturing	3344
Johnson & Johnson	9	9	9	3,591	2,926	2,600	38.1	Pharmaceutical and medicine manufacturing	3254
Lucent Technologies	10	6	3	3,520	4,018	4,510	–22.0	Computer systems design and related services	5415
Hewlett-Packard	11	12	10	2,635	2,646	2,440	8.0	Computer and peripheral equipment manufacturing	3341
Merck & Company	12	13	11	2,456	2,344	2,068	18.8	Pharmaceutical and medicine manufacturing	3254
Bristol Myers Squibb	13	15	12	2,259	1,939	1,843	22.6	Pharmaceutical and medicine manufacturing	3254
Lilly (Eli) and Company	14	14	13	2,235	2,019	1,784	25.3	Pharmaceutical and medicine manufacturing	3254
Pharmacia	15	10	25	2,195	2,753	1,290	70.2	Pharmaceutical and medicine manufacturing	3254
Sun Microsystems	16	22	26	2,016	1,630	1,263	59.7	Computer and peripheral equipment manufacturing	3341
General Electric	17	17	17	1,980	1,867	1,667	18.8	Engine, turbine, and power transmission equipment manufacturing	3336[a]
Boeing	18	24	22	1,936	1,441	1,341	44.4	Aerospace product and parts manufacturing	3364
Wyeth	19	21	14	1,870	1,688	1,740	7.5	Pharmaceutical and medicine manufacturing	3254
Procter & Gamble	20	16	15	1,769	1,899	1,726	2.5	Soap, cleaning compound, and toilet preparation manufacturing	3256

NAICS North American Industry Classificaiton System

[a]General Electric is classified in Compustat as a conglomerate (NAICS code 9999). For the purpose of this analysis, the industry classification of General Electric's largest manufacturing business segment in 2001 in terms of sales was used.

SOURCE: Standard & Poor's COMPUSTAT database (Englewood, CO, 2003).

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respectively), accounted for two-thirds of U.S. R&D expenditures in 2000 (table 4-8). California alone accounted for more than one-fifth of the $247 billion U.S. R&D total, exceeding the next highest state by nearly a factor of three.[22]

[22]Reliability of the estimates of industrial R&D varies by state because the sample for the NSF Survey of Industrial Research and Development was not based on geography. Rankings do not take into account the margin of error of estimates from sample surveys. National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

Ratio of R&D to Gross State Product

States vary significantly in the size of their economies because of differences in population, land area, infrastructure, natural resources, and history. Consequently, state variations in R&D expenditure levels may simply reflect differences in economic size or the nature of their R&D efforts. One way to control for the size of each state's economy is to measure each state's R&D level as a percentage of its gross

Corporate R&D Strategies in an Uncertain Economy

For the past 19 years the Industrial Research Institute (IRI), a nonprofit association of more than 200 leading R&D-performing industrial companies, has surveyed its U.S.-based members on their intentions for the coming year with respect to R&D expenditures, effort allocation, personnel, and other items. Because IRI member companies carry out as much as three-fourths of the industrial R&D in the United States, the results from these surveys help identify broad trends in corporate R&D strategies. The most recent survey, administered in late 2002, suggests that many companies are shifting the focus of their R&D spending from directed basic research and support of existing business to new business projects (IRI 2003). This reported shift in R&D priorities also is reflected in how responding companies intend to spend their R&D budgets. In 2003, IRI survey respondents reported the following strategic shifts:

- Decreased outsourcing of R&D to other companies
- Increased outsourcing for university R&D and Federal laboratories
- Increased participation in alliances and joint R&D ventures
- Increased acquisition of technology capabilities through mergers and acquisitions

Overall, these strategic moves are consistent with responses suggesting tighter R&D budgets and lower targets for R&D/sales ratios. In the midst of an uncertain economy and technology market, companies are moving to leverage the value of their R&D spending through alliances and collaborations as opposed to contracting out their R&D to other companies. (For more information, see "Technology Linkages: Contract R&D, Federal Technology Transfer, and R&D Collaboration.")

state product (GSP).[23] Like the ratio of industrial R&D to net sales, the proportion of a state's GSP devoted to R&D is an indicator of R&D intensity. A list of states and corresponding R&D intensities can be found in appendix table 4-25.

Sector Distribution of R&D Performance by State

Although leading states in total R&D tend to be well represented in each of the major R&D-performing sectors, the proportion of R&D performed in each of these sectors varies across states. States that are national leaders in total R&D performance are usually leaders in R&D performance by industrial sector, which is not surprising because industry-performed R&D accounts for 77 percent of the distributed U.S. total. Although university-performed R&D accounts for only 12 percent of the U.S. total, it also is highly correlated with the total R&D performance in a state.

Less overlap is reported between the top 10 states for total R&D and the top 10 states for federally performed R&D.[24] Only 4 states are in both top 10 lists: Maryland, California, Texas, and New Jersey. Maryland ranked first in Federal R&D performance, followed by the District of Columbia, California, and Virginia. The inclusion of Maryland, Virginia, and the District of Columbia in the top four ranking reflects the concentration of Federal facilities and administrative offices within the national capital area. Alabama, Florida, and New Mexico rank among the highest in Federal R&D because of their relatively high shares of Federal space- and defense-related R&D.

Industrial R&D in Top States

The types of companies that carry out R&D vary considerably among the 10 leading states in industry-performed R&D (table 4-9). This reflects regional specialization or clusters of industrial activity. For example, in Michigan the transportation equipment industry accounted for 73 percent of industrial R&D in 2000, whereas it accounted for only 15 percent of the nation's total industrial R&D. Washington, having a high concentration of software R&D, has less of its industrial R&D concentrated in manufacturing industries than the nation as a whole. The computer and electronic products industry accounts for 24 percent of the nation's total industrial R&D but accounts for a larger share of the industrial R&D in California (36 percent), Massachusetts (44 percent), and Texas (42 percent). These three states have clearly defined regional centers of high-technology research and manufacturing: Silicon Valley in California, Route 128 in Massachusetts, and the Silicon Hills of Austin in Texas. In addition, New Jersey and Pennsylvania, both home to robust pharmaceutical and chemical manufacturing industries, show much higher concentrations of R&D in these industries than the nation as a whole. Of course other factors besides the location of industrial production also play a role in the location of industrial R&D activities. For example, industries tend to perform research near universities that conduct the same type of research, enabling them to benefit

[23]Gross state product (GSP) is often considered the state counterpart of the nation's GDP. GSP is estimated by summing the *value added* of each industry in a state. Value added for an industry is equivalent to its gross output (sales or receipts and other operating income, commodity taxes, and inventory change) minus its intermediate inputs (consumption of goods and services purchased from other U.S. industries or imported). U.S. Bureau of Economic Analysis, *Gross State Product: New Estimates for 2000 and Revised Estimates for 1998–1999* (Washington, DC, 2002). (See http://www.bea.gov/bea/newsrel/gspnewsrelease.htm.)

[24]Federally performed R&D includes costs associated with the administration of intramural and extramural programs by Federal personnel as well as actual intramural performance.

Table 4-8
Top 10 states in R&D performance, R&D by sector, and R&D as percentage of gross state product: 2000

			States with highest R&D performance, by sector			R&D intensity (highest R&D/GSP ratio)		
Rank	State	Total R&D[a] (millions of current dollars)	Industry[b]	U&C[c]	Federal Government[d]	State	R&D/GSP (percent)	GSP (billions of current dollars)
1	California	55,093	California	California	Maryland	Michigan	5.81	325.4
2	Michigan	18,892	Michigan	New York	District of Columbia	New Mexico	5.68	54.4
3	New York	13,556	New Jersey	Texas	California	Washington	4.78	219.9
4	New Jersey	13,133	Illinois	Pennsylvania	Virginia	Maryland	4.64	186.1
5	Massachusetts	13,004	New York	Maryland	Alabama	Massachusetts	4.56	284.9
6	Illinois	12,767	Massachusetts	Massachusetts	Ohio	Delaware	4.22	36.3
7	Texas	11,552	Washington	Illinois	Florida	Rhode Island	4.12	36.5
8	Washington	10,516	Texas	North Carolina	Texas	California	4.10	1,344.6
9	Pennsylvania	9,842	Pennsylvania	Michigan	New Jersey	Idaho	3.87	37.0
10	Maryland	8,634	Ohio	Georgia	New Mexico	District of Columbia	3.87	59.4

FFRDC federally funded research and development center
GSP gross state product
U&C universities and colleges

[a]Includes in-state total R&D performance of industry, universities, Federal agencies, FFRDCs, and federally financed nonprofit R&D.
[b]Includes R&D activities of industry-administered FFRDCs located within these states.
[c]Excludes R&D activities of university-administered FFRDCs located within these states.
[d]Includes costs associated with administration of intramural and extramural programs by Federal personnel and actual intramural performance.

NOTES: Reliability of estimates of industry R&D varies by state because sample allocation was not based on geography. Rankings do not take into account margin of error of estimates from sample surveys.

SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series); U.S. Bureau of Economic Analysis, U.S. Department of Commerce, 2002, http://www.bea.gov/bea/newsrel/gspnewsrelease.htm.

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Table 4-9
Top 10 states in industry R&D performance and share of R&D by selected industries: 2000

		Share of total industry-performed R&D				
		Manufacturing industries				
State	Industry-performed R&D[a]	Total	Computer and electronic products	Transportation equipment	Chemicals	Professional, scientific, and technical services
	Millions of current dollars	Percent				
Total	199,539	62.2	22.6	15.1	10.5	11.3
California	45,769	54.1	36.0	7.0	2.9	18.0
Michigan	17,640	88.9	2.0	73.4	6.5	4.7
New Jersey	12,062	61.9	27.6	1.0	25.1	5.6
Illinois	10,661	59.8	26.6	2.5	17.0	2.7
New York	10,539	65.6	16.4	14.7	18.7	3.7
Massachusetts	9,863	59.7	43.5	D	7.7	21.0
Washington	9,265	32.9	5.7	D	D	11.4
Texas	8,961	58.3	42.2	1.5	5.3	7.0
Pennsylvania	7,873	68.5	14.6	4.5	32.9	7.2
Ohio	5,962	65.6	3.0	7.9	D	20.1
All other states	60,946	64.7	17.1	14.5	12.0	10.9

D data withheld to avoid disclosing operations of individual companies

[a]Includes company and federally financed R&D activities and R&D activities of industry-administered federally funded research and development centers (FFRDCs) located within these states.

NOTES: Reliability of the estimates of industry R&D varies by state because sample allocation was not based on geography. Rankings do not take into account margin of error of estimates from sample surveys. Details may not add to totals because not all industries are shown.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2000.

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from local academic resources. (For more information, see "Technology Linkages: Contract R&D, Federal Technology Transfer, and R&D Collaboration.")

Federal R&D Performance and Funding

When Nelson (1959) and Arrow (1962) first laid out their seminal economic arguments that the private sector generally invests less than the socially optimal amount in R&D, the Federal Government funded almost twice as much R&D as did the private sector. Since then these relative positions have reversed, but the argument in support of public funding for R&D is still valid more than 40 years later. Briefly, the argument is that the returns on investment in R&D cannot be fully appropriated by an investor because of the very nature of the primary output of R&D: knowledge. This being the case, firms will only invest in those R&D projects from which, through secrecy, patents, or some other means, they are able to recoup their investment plus an acceptable profit. The government endeavors to correct this market failure through a number of policy measures, the most direct of which is the funding and performance of R&D that would not or could not be financed or performed in the private sector. Thus, despite its declining share in total R&D funding, the Federal Government still supports the majority of basic research in the United States. This section examines the Federal Government's role in performing, funding, and stimulating R&D in the private sector through tax policy.

Federal R&D Performance

Federal laboratories and FFRDCs performed $34.1 billion of total U.S. R&D in 2002, an average annual increase in real terms of 10.4 percent from the 2000 level of $27.1 billion. Among individual agencies, DOD continued to perform the most intramural R&D and is expected to account for more than half of all Federal obligations for intramural R&D in the future. In fiscal year 2003, DOD is expected to perform more than twice the R&D of the second largest R&D-performing agency, the Department of Health and Human Services (HHS), which performs most of its intramural R&D at the National Institutes of Health (NIH) (table 4-10).

The Department of Energy (DOE) sponsors the most FFRDCs of any agency—16 of the 36. These 16 FFRDCs performed a total of $7.5 billion of R&D in FY 2001, approximately three-fourths of all the R&D performed by FFRDCs (appendix table 4-26). First established during World War II, FFRDCs are unique organizations that help the United States government meet special long-term research or development goals that cannot be met as effectively by in-house or contractor resources. (See sidebar, "Rationales for Federal Laboratories and FFRDCs.") According to the *Federal Register,* an FFRDC is required "to operate in the public interest with objectivity and independence, to be free from organizational conflicts of interest, and to have full disclosure of its affairs to the sponsoring agency" (NARA 1990). Total R&D performed by all FFRDCs (estimated at $10.3 billion in 2002) has grown at a real annual rate of 4.5 percent from its level of $9.1 billion in 2000.

Federal R&D Funding by National Objective

In 2002 the Federal Government funded approximately twice as much R&D as that performed in Federal labs and FFRDCs. This support is estimated to be $78.2 billion, reflecting a 6.7 percent average real increase per year since 2000. This funding supports a wide range of national objectives (also termed *budget functions*); is administered by many Federal agencies; and flows to R&D performers in all sectors, from industry to universities and colleges and to nonprofit organizations.

Defense-Related R&D

Defense-related R&D, as a proportion of the nation's total R&D, has shifted substantially. From 53.6 percent in 1959, it declined to a relative low of 24.3 percent in 1980, climbed to 31.7 percent by 1987, and, coinciding with the end of the cold war, fell substantially afterward, reaching a low of 13.5 percent in 2000 (figure 4-8).[25] Despite this dramatic decline relative to nondefense R&D, the absolute level of defense R&D in 2000 still exceeded that in any year from 1953 to 1982, after adjusting for inflation. In 2000, defense-related R&D as a share of U.S. R&D began to grow again, subsequently reaching 14.9 percent of the nation's total R&D in 2002.

In 1980 the Federal budget authority for defense-related R&D was roughly equal to that for nondefense R&D[26] (figure 4-9). Although the amount of defense-related R&D has fluctuated based on changing national security concerns over the past 20 years, nondefense R&D has increased since 1983. For FY 2001 the budget authorities for defense R&D and for nondefense R&D had nearly reached parity at $45.7 and $41.0 billion, respectively. The terrorist attacks of September 11, 2001, dramatically reversed this trend and in the proposed FY 2004 budget, $66.8 billion is slated for defense-related R&D and $51.2 billion is reserved for nondefense R&D. (See sidebar, "Federal R&D for Countering Terrorism.") These amounts reflect increases of 46.2 percent in defense-related R&D and 24.7 percent in nondefense R&D over the FY 2001 levels.

Civilian-Related R&D

R&D accounts for 13.4 percent of the FY 2004 Federal nondefense discretionary budget authority of $383.0 billion.[27] Although this is less than that reserved for defense

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[25]These shares represent a distribution of performer-reported R&D data. They are distinct from the budget authority shares reported subsequently, which are based on the various functional categories constituting the Federal budget.

[26]R&D budget authority data represent a distribution of Federal source-reported data as opposed to performer-reported data.

[27]Most of the $2.2 trillion Federal budget is reserved for mandatory items such as Social Security, Medicare, pension payments, and payments on the national debt. See appendix table 4-30 for historical data on Federal outlays and R&D.

Table 4-10
Federal R&D obligations, total, intramural, and FFRDCs, by U.S. agency: FY 2003

Agency	Total R&D obligations	Intramural[a]	FFRDC	Agency intramural and FFRDC R&D obligations
	Millions of dollars			Percent of total
All Federal Government	98,608.1	24,557.7	7,534.6	32.5
Department of Defense	45,011.7	12,409.0	851.3	29.5
Department of Health and Human Services	27,551.1	5,162.4	403.9	20.2
National Aeronautics and Space Administration	8,598.3	2,149.6	1,405.3	41.3
Department of Energy	7,540.7	764.4	4,609.3	71.3
National Science Foundation	3,403.6	19.4	197.5	6.4
Department of Agriculture	1,984.3	1,367.2	0.0	68.9
Department of Commerce	1,064.5	838.0	2.9	79.0
Environmental Protection Agency	627.0	283.8	0.0	45.3
Department of Transportation	622.0	192.3	24.8	34.9
Department of the Interior	594.1	534.8	0.0	90.0
Department of Veterans Affairs	363.7	363.7	0.0	100.0
Department of Education	304.5	14.4	0.0	4.7
International Development Cooperation Agency	281.0	27.5	0.0	9.8
Department of Labor	176.8	154.9	0.0	87.6
Department of Justice	117.6	43.2	3.4	39.6
Smithsonian Institution	115.0	115.0	0.0	100.0
Department of the Treasury	80.4	64.4	0.0	80.1
Nuclear Regulatory Commission	68.0	18.7	36.1	80.6
Department of Housing and Urban Development	47.7	23.6	0.0	49.5
Social Security Administration	45.5	4.4	0.0	9.7
Library of Congress	3.5	2.5	0.0	71.4
Department of State	2.5	0.6	0.0	24.0
Federal Communications Commission	2.2	2.2	0.0	100.0
Federal Trade Commission	1.4	1.4	0.0	100.0
Appalachian Regional Commission	0.7	0.0	0.0	0.0
Broadcasting Board of Governors	0.1	0.1	0.0	100.0
National Archives and Records Administration	0.1	0.1	0.0	100.0

FFRDC federally funded research and development center

[a]Intramural activities include actual intramural R&D performance and costs associated with planning and administration of both intramural and extramural programs by Federal personnel.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003* (Arlington, VA, forthcoming).

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activities—16.7 percent of the $399.2 billion discretionary budget authority in FY 2004—over 90 percent of Federal basic research funding is for nondefense functions, accounting for a large part of the budgets of agencies with nondefense missions such as general science (NSF), health (NIH), and space research and technology [National Aeronautics and Space Administration (NASA)] (table 4-11, appendix table 4-29). Because many different agencies can support R&D programs with the same basic objective, it is useful to aggregate Federal R&D into budget functions to assess broad trends in national R&D priorities.

Space-related R&D as a percentage of total R&D reached a peak of 20.8 percent in 1965, during the height of the nation's efforts to surpass the Soviet Union in space exploration (figure 4-8). In terms of the nation's R&D performance, space-related R&D accounted for an estimated 2.5 percent of total R&D in 2002.[28] The loss of the Space Shuttle Columbia and its crew of seven on February 1, 2003, has resulted in uncertainty as to the future focus and intensity of manned missions in the U.S. space-related R&D effort. In the President's FY 2004 budget, crafted before the disaster, 55.2 percent of NASA's $15.5 billion discretionary budget was reserved for R&D.

The most dramatic change in national R&D priorities over the past 20 years has been the growing importance of health-related R&D. As illustrated in figure 4-9, health-related R&D rose from representing roughly a fourth (27.6 percent) of the Federal nondefense R&D budget allocation in FY 1982 to more than half (54.5 percent) by FY 2003.

[28]The steep drop in space-related R&D in fiscal year 2000, as depicted in figure 4-9, was the result of the National Aeronautics and Space Administration's (NASA's) reclassifying space station R&D to R&D plant.

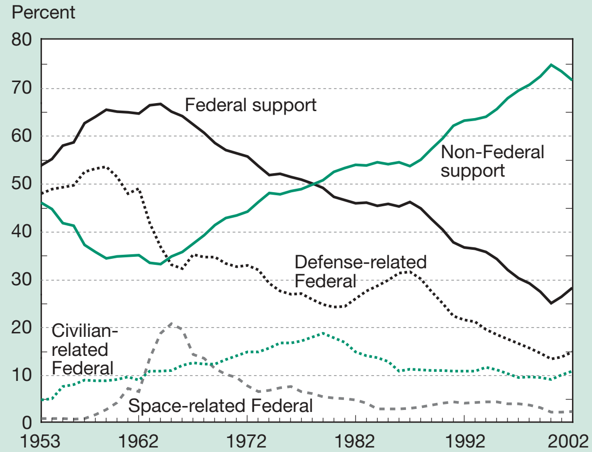
Rationales for Federal Laboratories and FFRDCs

- **Scale.** Some R&D efforts require capital expenditures, facilities, and staffing that exceed the capabilities or resources of private sector research organizations. Termed *big science,* this R&D is often compared to the Manhattan Project of World War II but today spans the spectrum of scientific exploration from medicine (e.g., the National Cancer Institute Frederick Cancer Research and Development Center in Fort Detrick, Maryland) to astronomy (e.g., NSF's National Astronomy and Ionosphere Center in Arecibo, Puerto Rico).
- **Security.** The sensitive nature of some R&D necessitates direct government supervision. Security has historically been a concern of defense-related R&D performed at Department of Defense (DOD) and Department of Energy (DOE) labs and federally funded research and development centers (FFRDCs). However, the growing focus on the threat of bioterrorism highlights that some nondefense R&D, such as that carried out by the Centers for Disease Control and Prevention, also influences national security.
- **Mission and Regulatory Requirements.** Some Federal agencies, such as the Department of Transportation and the Food and Drug Administration, must perform a certain amount of R&D to fulfill their missions. To ensure impartiality and fairness, this R&D is performed in Federal laboratories.
- **Knowledge Management.** For logistical reasons, Federal laboratories and FFRDCs are often tasked with performing long-term or mission-critical R&D. These organizations possess the institutional memory and close connection to the sponsoring agency required by these types of projects. An additional benefit of in-house expertise in R&D sponsoring agencies is the assisting role it plays in the management of extramural R&D programs.

Most of this growth occurred after 1998 when NIH's budget was set on a pace to double by 2003 (Meeks 2002).

In contrast to the steep growth in health-related R&D, the budget allocation for general science R&D has grown relatively little in the past 20 years. In fact, the growth in general science R&D (figure 4-9) is more the result of a reclassification of several DOE programs from energy to general science in FY 1998 than the result of increased budget allocations. The formation of the Department of Homeland Security (DHS) and the coincident reclassification of much of its formerly civilian R&D activities as defense R&D is a more recent example of how R&D budget function classifications can change when the mission or focus of funding agencies changes.

Figure 4-8
Federal and non-Federal share of all R&D: 1953–2002



SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations, 2003. See appendix table 4-27.

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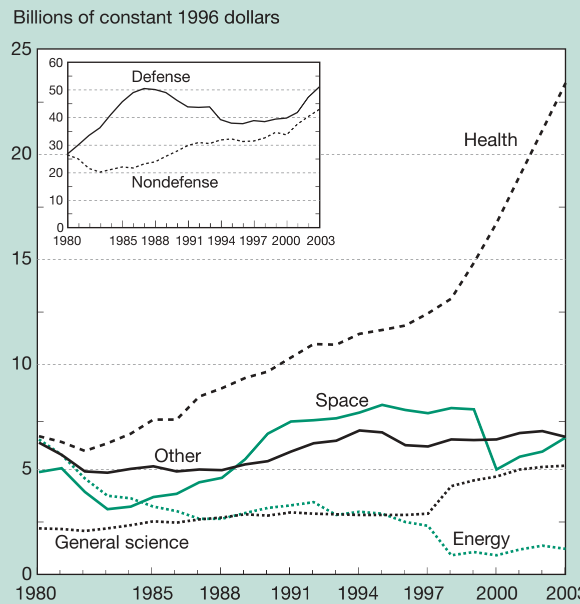
Figure 4-9
Federal R&D budget authority, by budget function: FY 1980–2003



NOTES: "Other" includes all nondefense functions not separately graphed, such as agriculture and transportation. The 1998 increase in general science and decrease in energy and the 2000 decrease in space were the results of reclassification.

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal R&D Funding by Budget Function: Fiscal Years 2001–2003,* 2002. See appendix table 4-28.

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Federal R&D for Countering Terrorism

Speaking not long after the terrorist attacks of September 11, 2001, Dr. Rita Colwell, NSF director, remarked, "the research enterprise arches and bends to national needs" (Colwell 2001). Decades of Federal research support developed a knowledge base that was quickly marshaled to address specific scientific and technological issues raised by the attacks and by the threat of future terrorist activity in the United States. Ongoing R&D that had not earlier been categorized under the rubric of homeland security or national defense found immediate applications in the aftermath of September 11. And for those needs that national R&D resources could not meet, new funds, laboratories, and programs were planned.

In fiscal year 2002, the Federal Government appropriated $36.5 billion for combating terrorism, $1.2 billion of which was R&D funding. As a point of reference, the total Federal budget for R&D activities to develop technologies to deter, prevent, or mitigate terrorist acts was less than half this amount ($511 million) in FY 2000. As figure 4-10 indicates, a large portion of the FY 2002 counterterrorism R&D was funded by defense/security agencies, most notably the Defense Advanced Research Projects Agency in DOD. The Department of Health and Human Services (HHS) was the next largest source of funds, with most of its R&D budget accounted for by the National Institutes of Health (NIH). Numerous other agencies, ranging from the Environmental Protection Agency to the Department of Justice (DOJ), supported counterterrorism R&D in FY 2002.

The Federal budget for counterterrorism R&D mushroomed in the President's FY 2003 budget request to more than $2.9 billion. More than 60 percent of this R&D was requested for HHS, specifically for bioterrorism-related R&D at NIH. Counterterrorism R&D funded by the national security community almost doubled in the FY 2003 budget request, with its emphasis on R&D to support warfighting applications and counterbioterrorism. Ongoing R&D programs at DOE in the fields of genomic sequencing; modeling and simulation; and the detection of nuclear, chemical, and biological agents were also expanded.

Although the FY 2004 budget request did not separate counterterrorism R&D from other R&D programs, the 2.5-fold increase between FY 2002 and FY 2003 appears to have been a one-time event. The FY 2004 budget proposes increases in Federal R&D investment in the priority areas of defense and homeland security, but the most prominent change from the FY 2003 budget is organizational rather than monetary. On January 24, 2003, the Department of Homeland Security (DHS) was officially established and the R&D programs of several agencies were consolidated under its management. The President's budget request reflects this consolidation and calls for a $1.0 billion R&D budget for the new department. Analysis by the American Association for the Advancement of Science reports this as a 50 percent increase over the disaggregated FY 2003

The Federal S&T Budget

In recent years, alternative concepts have been used to isolate and describe fractions of Federal support that could be associated with scientific achievement and technological progress. In a 1995 report, a National Academy of Sciences (NAS) committee proposed an alternative method of measuring the Federal Government's S&T investment (NAS 1995). According to the committee members this approach, called the Federal science and technology (FS&T) budget, might provide a better way to track and evaluate trends in public investment in R&D. The FS&T concept differed from Federal funds for research in that it did not include major systems development supported by DOD and DOE, and it contained not only research but also some development and some R&D plant.

Beginning with the FY 2000 budget, the Office of Management and Budget (OMB) has presented its concept for an FS&T budget (figure 4-11). Whereas the NAS FS&T compilation included only R&D, OMB's FS&T budget was constructed of easily tracked programs and included some non-R&D programs, such as NSF education programs and staff salaries at NIH and NSF.

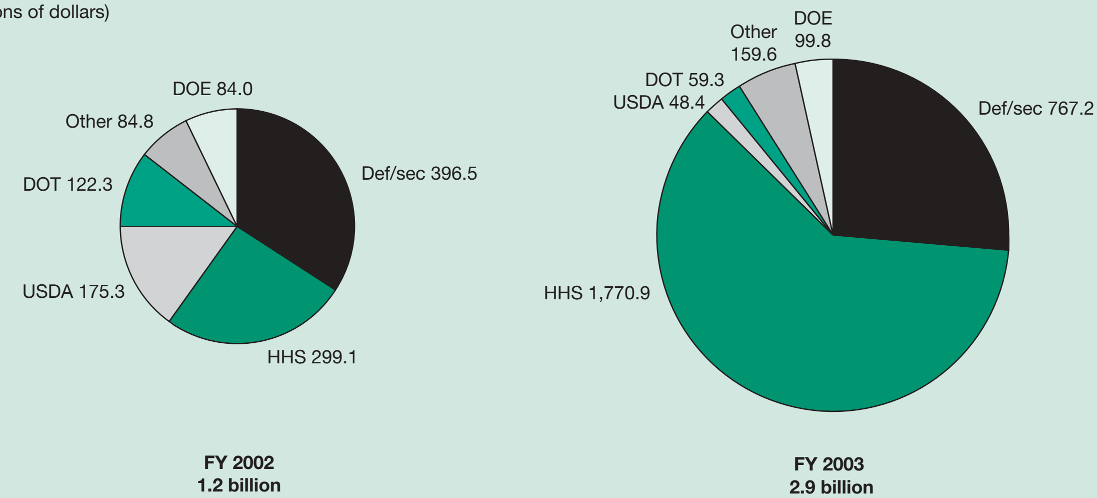
In the 2004 Budget of the United States, OMB's FS&T budget is less than half of total Federal spending on R&D because it excludes funding for defense development, testing, and evaluation. It includes nearly all budgeted Federal support for basic research in FY 2004, more than 80 percent of federally supported applied research, and about half of federally supported nondefense development (U.S. OMB 2003b).

As shown in figure 4-12, Federal R&D in the 2004 budget proposal, which includes expenditures on facilities and equipment, would reach a level of $123 billion. Of this amount, $54 billion would be devoted to basic and applied research alone. The FS&T budget would reach $59 billion and would include most of the research budget. However, differences in the definition of research and FS&T imply that not all research would be included in FS&T and vice versa. Moreover, a small proportion (10 percent) of FS&T funds would fall outside the category of Federal R&D spending.

R&D budgets of the agencies, laboratories, and programs that were brought under the aegis of DHS.

DHS is organized into four major directorates: Border and Transportation Security, Emergency Preparedness and Response, S&T, and Information Analysis and Infrastructure Protection. In addition to these directorates, the Secret Service and the Coast Guard report directly to the DHS Secretary, and the Immigration and Naturalization Service adjudications and benefits programs report directly to the Deputy Secretary as the Bureau of Citizenship and Immigration Services.

Figure 4-10
R&D budget for combating terrorism, by agency: FY 2002 and 2003
(Millions of dollars)



Def/sec Defense/security agencies; DOE Department of Energy; DOT Department of Transportation; HHS Department of Health and Human Services; USDA Department of Agriculture

SOURCE: U.S. Office of Management and Budget, *Annual Report to Congress on Combating Terrorism* (Washington, DC, 2002).

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R&D by Federal Agency

The Federal agencies with the largest R&D expenditures vary considerably in terms of how their R&D budgets are spent.[29] Agency-reported data reveal remarkable diversity in terms of the character of the R&D, who performs the R&D, and how R&D is allocated to performers. These differences reflect the diverse missions, histories, and cultures of the agencies.

Department of Defense

According to preliminary data provided by the DOD before budget developments brought about by the war in Iraq, DOD will obligate $45.0 billion, more than any other Federal agency, for R&D support in FY 2003. DOD's support represents 45.6 percent of all Federal R&D obligations (table 4-10). More than 85 percent of these funds ($38.5 billion) will be spent on development, with $33.0 billion slated for major systems development.[30] Industrial firms are expected to perform 65 percent of DOD-funded R&D in FY 2003. These firms will account for an even greater share of development funds (71 percent). DOD's R&D obligations will constitute more than 80 percent of all Federal R&D obligations to industry in FY 2003. Of DOD-funded R&D not performed by industry, government laboratories and FFRDCs are expected to perform 85 percent ($13.3 billion). According to OMB, 63 percent of DOD's basic and applied research funding was allocated using a fully competitive merit review process in 2002.[31]

[29]The data reported here on expected R&D obligations in FY 2003 were collected before recent budget negotiations and the formation of the Department of Homeland Security. See sidebar "Federal R&D for Countering Terrorism" for data on these recent developments.

[30]The Department of Defense (DOD) reports development obligations in two categories: *advanced technology development,* which is similar in nature to development funded by most other agencies, and *major systems development,* which includes demonstration and validation, engineering and manufacturing development, management and support, and operational systems development for major weapon systems.

[31]In 2002, 69 percent of all Federal research funding was allocated through competitive merit review processes. Twenty percent was merit reviewed, but competition was limited to a select pool of applicants such as Federal labs or FFRDCs. The remaining 11 percent was allocated to specific performers either at the request of Congress or because timeliness or other factors limited the feasibility of competitive selection [U.S. Office of Management and Budget (U.S. OMB) 2003b].

Table 4-11
Budget authority for R&D by Federal agency and character of work, proposed levels: FY 2004

Agency	Discretionary budget authority	R&D total	Basic research	Applied research and development	R&D share of discretionary budget
	Millions of dollars				Percent
All Federal Government	782,219	118,014	26,862	91,152	15.1
Department of Defense	379,898	62,672	1,309	61,363	16.5
Health and Human Services	66,195	28,108	14,804	13,304	42.5
National Institutes of Health	27,742	26,866	14,801	12,065	96.8
National Aeronautics and Space Administration	15,469	8,543	2,535	6,008	55.2
Department of Energy	23,376	7,559	2,593	4,966	32.3
National Science Foundation	5,481	3,690	3,486	204	67.3
Department of Agriculture	19,503	1,803	819	984	9.2
Department of Commerce	5,406	1,006	391	615	18.6
National Oceanic and Atmospheric Administration	3,325	675	312	363	20.3
National Institute for Standards and Technology	498	318	79	239	63.9
Department of the Interior	10,587	633	38	595	6.0
Department of Transportation	13,673	674	37	637	4.9
Environmental Protection Agency	7,627	607	90	517	8.0
Department of Veterans Affairs	28,057	822	495	327	2.9
Department of Education	53,137	275	1	274	0.5
Department of Homeland Security	26,697	836	47	789	3.1
International assistance programs	17,039	306	58	248	1.8
Smithsonian Institution	567	121	121	0	21.3
Tennessee Valley Authority	NA	25	NA	25	NA
Department of Labor	11,535	10	2	8	0.1
Nuclear Regulatory Commission	626	60	NA	60	9.6
Corps of Engineers	4,049	27	3	24	0.7
Department of Housing and Urban Development	31,301	51	NA	51	0.2
Department of Justice	17,697	106	33	73	0.6
Social Security Administration	3,084	30	NA	30	1.0
Postal Service	NA	47	NA	47	NA
Department of the Treasury	11,397	3	NA	3	0.0

NA not available

NOTE: Details will not add to totals for discretionary budget authority because only R&D funding agencies are listed.

SOURCE: Intersociety Working Group, *AAAS Report XXVIII: Research and Development FY 2004* (Washington, DC, 2003); and U.S. Office of Management and Budget, *Budget of the United States Government, Fiscal Year 2004* (Washington, DC, 2003).

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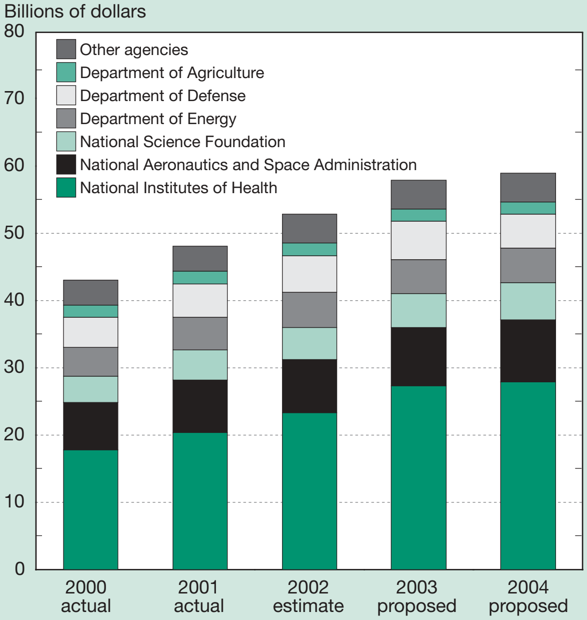
Department of Health and Human Services

HHS, the primary source of Federal health-related R&D funding (largely through NIH), will obligate the second largest amount for R&D in FY 2003 at $27.6 billion, most of which ($14.5 billion) will be for basic research. In FY 2003, HHS is expected to provide universities and colleges, the primary recipients of HHS funding, with $15.5 billion, or 67.4 percent of all Federal R&D funds obligated to universities and colleges (table 4-12). HHS will provide 75.6 percent ($4.7 billion) of all Federal R&D funds obligated to nonprofit institutions, with most of these funds going to such large research hospitals as Massachusetts General Hospital and the Dana-Farber Cancer Institute (NSF/SRS 2002). In 2002, fully competitive merit review processes were used to allocate 81 percent of HHS's basic and applied research funding.

National Aeronautics and Space Administration

The third largest agency in terms of R&D support is NASA, with R&D obligations expected to total $8.6 billion in FY 2003; 28.6 percent ($2.5 billion) will be earmarked for basic research. Although not defense related, much of the development work sponsored by NASA relies on industrial performers similar to those funded by DOD. NASA is the second largest source of industrial R&D funds, an expected $3.6 billion in FY 2003. Roughly 82 percent of NASA-funded R&D is performed either by industrial firms or in Federal labs or FFRDCs. Academic and nonprofit institutions perform the remainder. In 2002, 85 percent of NASA's basic and applied research funding was allocated using a fully competitive merit review process.

Figure 4-11
Federal science and technology budget, by agency: FY 2000–2004



SOURCES: U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government, Fiscal Year 2004* (Washington, DC, 2003); and U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government, Fiscal Year 2003* (Washington, DC, 2002).

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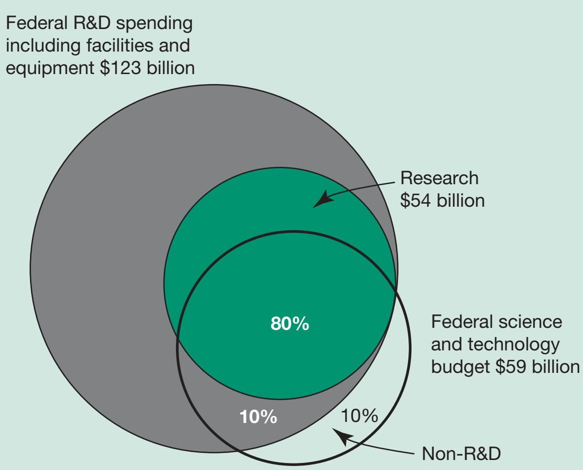
Figure 4-12
Funding concepts in FY 2004 budget proposal



NOTE: Percents represent shares of the Federal science and technology budget rounded to the nearest 10 percent.

SOURCE: U.S. Office of Management and Budget, *Analytical Perspectives, Budget of the United States Government: Fiscal Year 2004* (Washington, DC, 2003).

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Department of Energy

Of the large R&D-funding agencies, DOE relies the most on the R&D capabilities of FFRDCs, obligating 61.1 percent of its estimated $7.5 billion in FY 2003 R&D funding to FFRDCs. DOE is the largest funding source of the 36 FFRDCs, accounting for 61.2 percent of all Federal R&D obligations to FFRDCs in FY 2003. DOE's high reliance on its intramural laboratories and FFRDCs explains why the share of its research funding that was allocated using a fully competitive merit review process in 2002 was relatively low at 23 percent.

National Science Foundation

NSF is the Federal Government's primary source of funding for general S&E R&D and is expected to fund $3.4 billion in R&D in FY 2003. Of these funds, 94.2 percent are for basic research. NSF is the second largest Federal source of R&D funds to universities and colleges and is expected to provide $2.8 billion to academic researchers in FY 2003. In 2002, 95 percent of NSF's basic and applied research funding was allocated using a fully competitive merit review process.

Other Agencies

DOD, HHS, NASA, DOE, and NSF are expected to account for 93.4 percent of all Federal R&D obligations in FY 2003, with 93.9 percent for basic research, 85.6 percent for applied research, and 97.8 percent for development. Unlike those Federal agencies, the Department of Agriculture (USDA), DOC, and Department of the Interior (DOI) obligate most of their R&D funds to mission-oriented R&D conducted in their own laboratories, which are run by the Agricultural Research Service, the National Institute for Standards and Technology (NIST), and the U.S. Geological Survey, respectively.

Federal R&D Funding by Performer and Field of Science or Engineering

Federal Funding to Academia

The Federal Government has long provided the largest share of R&D funds used by universities and colleges. In the early 1980s, Federal funds accounted for roughly two-thirds of the academic total. That share dropped to 57.7 percent in 2000 but is expected to rise to 58.5 percent in 2002. Although this share of funding has not changed much in recent years, the actual amount of funding in real terms increased on average 5.1 percent per year between 1985 and 1994, 3.4 percent per year between 1994 and 2000, and 7.3 percent per year between 2000 and 2002. For more information on academic R&D, see chapter 5.

Federal Funding to Industry

The greatest fluctuation in Federal support as reported by R&D performers occurred in obligations to industry, ranging from a low of $10.4 billion (constant 1996 dollars) in 1955 (when the NSF time series began) to a high of $37.1

Table 4-12
Estimated Federal R&D obligations, by performing sector and agency funding source: FY 2003

Character of work and performer	Total obligations (millions of dollars)	Primary funding source		Secondary funding source	
		Agency	Percent	Agency	Percent
All R&D	98,608	DOD	46	HHS	28
Federal intramural laboratories	24,558	DOD	51	HHS	21
Industrial firms	36,411	DOD	81	NASA	10
Industry-administered FFRDCs	1,478	DOE	71	HHS	19
Universities and colleges	23,055	HHS	67	NSF	12
Universities and colleges FFRDCs	4,835	DOE	58	NASA	29
Other nonprofit organizations	6,261	HHS	76	NASA	9
Nonprofit-administered FFRDCs	1,222	DOE	60	DOD	33
Basic research	25,977	HHS	56	NSF	12
Federal intramural laboratories	4,411	HHS	43	USDA	15
Industrial firms	1,446	NASA	38	HHS	31
Industry-administered FFRDCs	220	HHS	76	DOE	24
Universities and colleges	14,024	HHS	65	NSF	19
Universities and colleges FFRDCs	1,984	DOE	60	NASA	27
Other nonprofit organizations	3,153	HHS	85	NSF	7
Nonprofit-administered FFRDCs	571	DOE	93	HHS	5
Applied research	27,400	HHS	45	DOD	17
Federal intramural laboratories	8,799	HHS	37	DOD	22
Industrial firms	5,119	DOD	40	NASA	38
Industry-administered FFRDCs	762	DOE	80	HHS	15
Universities and colleges	8,205	HHS	78	DOD	6
Universities and colleges FFRDCs	1,494	DOE	87	NASA	5
Other nonprofit organizations	2,598	HHS	75	NASA	8
Nonprofit-administered FFRDCs	171	DOE	57	DOD	22
Development	45,231	DOD	85	NASA	6
Federal intramural laboratories	11,347	DOD	86	NASA	6
Industrial firms	29,846	DOD	91	NASA	3
Industry-administered FFRDCs	495	DOE	78	DOD	22
Universities and colleges	826	DOD	60	NASA	16
Universities and colleges FFRDCs	1,356	NASA	58	DOE	26
Other nonprofit organizations	510	NASA	35	DOD	25
Nonprofit-administered FFRDCs	481	DOD	76	DOE	23

FFRDC federally funded research and development center; DOD Department of Defense; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; DOE Department of Energy; NSF National Science Foundation; USDA Department of Agriculture

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

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003* (Arlington, VA, forthcoming).

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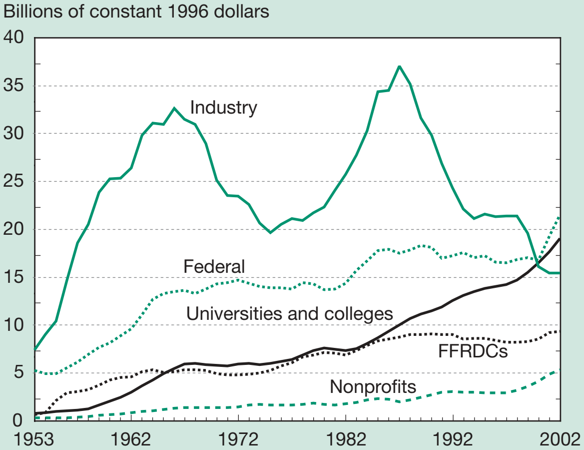
billion in 1987 (figure 4-13). Between 1998 and 2002 Federal funds for industrial R&D activities declined an annual average of 7.8 percent in real terms. Overall the Federal share of industry's performance has been steadily declining since its peak of 56.7 percent in 1959. Beginning in 1989, the amount of federally funded R&D reported by industry began to diverge from the amount reported by the Federal Government. For details on this discrepancy, see sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures.''

The industries that report the greatest amount of Federal R&D funding include the computer and electronic products industry; the professional, scientific, and technical services industry; and the aerospace industry. Companies in these three industries accounted for 87 percent of all federally funded industrial R&D reported in 2001. In contrast, this same group accounted for only 37 percent of all company-financed R&D in 2001. Approximately half of the $7.9 billion of R&D performed by companies classified in the aerospace industry came from Federal sources in 2001. In comparison, companies classified in the pharmaceuticals and medicines industry reported no federally funded research in 2001.

Federal Research Funding by Field

According to preliminary estimates, Federal obligations for research alone (excluding development) will total $53.4 billion in FY 2003. Life sciences will receive the largest por-

Figure 4-13
Federal R&D support, by performing sector: 1953–2002



FFRDC federally funded research and development center

SOURCE: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix table 4-6.

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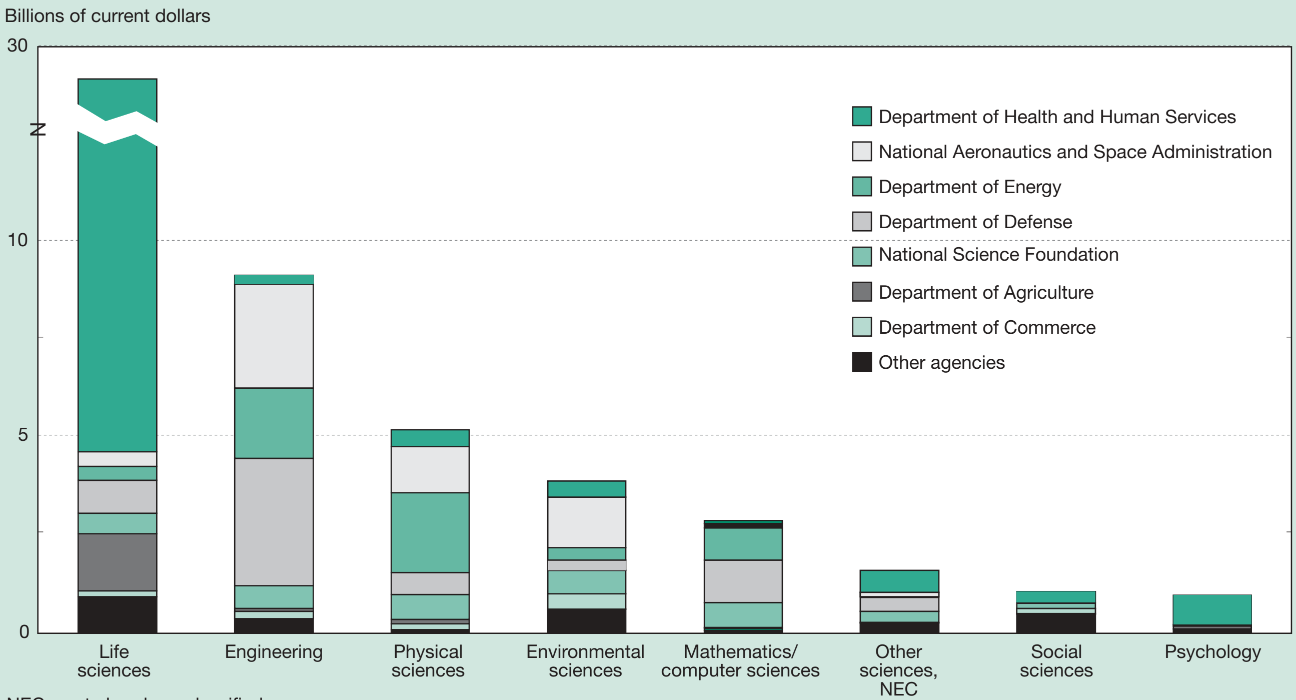
tion of this funding (53.7 percent, or $28.7 billion), most of which will be provided by HHS, followed by engineering (17.2 percent), physical sciences (9.7 percent), environmental sciences (7.3 percent), and mathematics and computer sciences (5.4 percent) (figure 4-14). Social sciences, psychology, and all other sciences will account for another 2.0, 1.8, and 3.0 percent, respectively.

HHS, primarily through NIH, will provide the largest share (50.2 percent) of all Federal research obligations in FY 2003. The next largest contributor will be DOD (12.2 percent), providing substantial funding for research in engineering ($3.3 billion) and in mathematics and computer sciences ($1.1 billion). NASA will provide 10.8 percent, primarily in the fields of engineering, environmental sciences, and physical sciences. DOE will provide 10.1 percent, primarily in the fields of physical sciences and engineering. NSF will provide 6.4 percent, contributing between $0.5 and $0.6 billion to each of the following fields: physical sciences, mathematics and computer sciences, engineering, environmental sciences, and life sciences.

Federal obligations for research have grown at different rates for different S&E fields, reflecting changes in perceived public needs in those fields, changes in the national

Figure 4-14
Federal obligations for research, by agency and major S&E field: FY 2003



NEC not elsewhere classified

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 4-33.

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

In many Organisation for Economic Co-operation and Development (OECD) countries, including the United States, total government R&D support figures reported by government agencies differ substantially from those reported by performers of R&D work. Consistent with international guidance and standards, most countries' national R&D expenditure totals and time series are based primarily on data reported by performers (OECD 2002f). This convention is preferred because performers are in the best position to indicate how much they spent conducting R&D in a given year and to identify the source of their funds. Although funding and performing series may be expected to differ for many reasons such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year), the gap between the two R&D series has widened during the past several years.

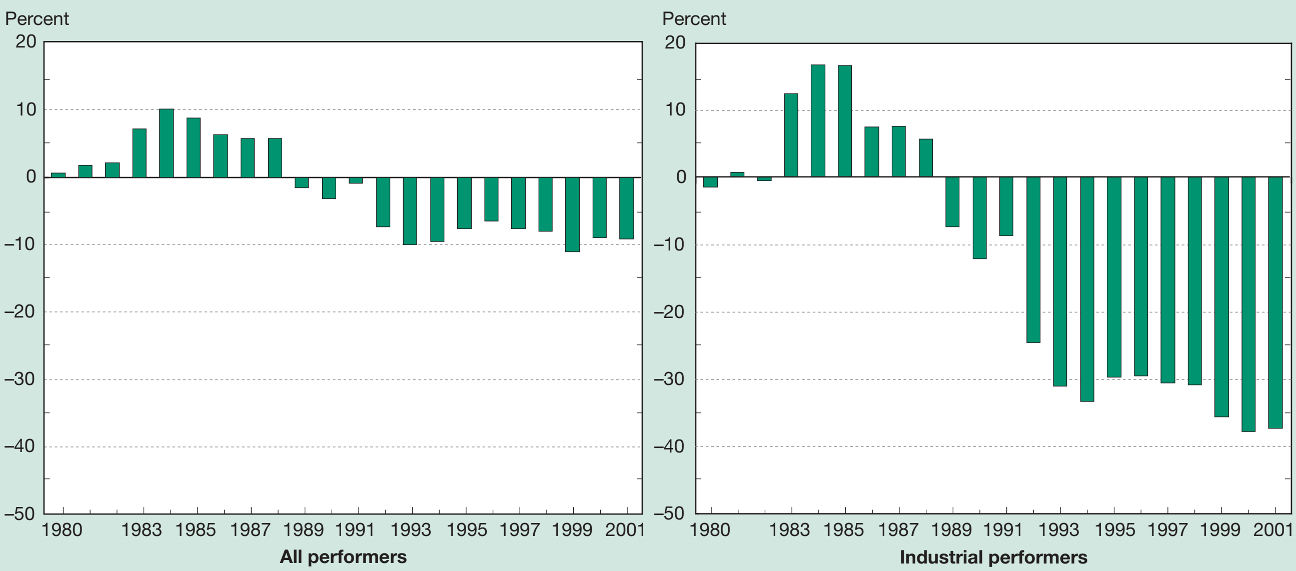
For the United States the reporting gap has become particularly acute over the past several years. In the mid-1980s, performer-reported Federal R&D exceeded Federal reports by $3 to $4 billion annually (5–10 percent of the government total). This pattern reversed itself toward the end of the decade; in 1989 the government-reported R&D total exceeded performer reports by $1 billion. The gap subsequently grew to about $7 billion by 2001. In other words, approximately 9 percent of the government total in 2001 was unaccounted for in performer surveys (figure 4-15). The difference in Federal R&D totals was primarily in DOD development funding of industry. For 2001 Federal agencies reported $27.0 billion in total R&D obligations to industrial performers, compared with $16.9 billion in Federal funding reported by industrial performers. (DOD reported industrial R&D funding of $21.4 billion, whereas industry reported using $10.0 billion of DOD's R&D funds.) Overall, industrywide estimates equal a 37 percent paper "loss" of federally reported 2001 R&D support (figure 4-15).

NSF has sponsored ongoing research and investigations into the possible causes for the data gap. Past studies have focused on the following aspects of the phenomenon:

- The relative prominence of similar divergences in the series in countries with large defense R&D expenditures [National Science Board (NSB) 1998]
- Industry interpretations and financial treatment of Federal (particularly defense-related) R&D contracts (NSB 2000)
- Federal agency R&D data collection and reporting procedures (NSB 2002)

Each investigation resulted in useful insights into the issue, but a conclusive explanation has yet to be identified. According to a recent U.S. General Accounting Office (2001b, p. 2) investigation, "Because the gap is the result of comparing two dissimilar types of financial data [Federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the Federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist."

Figure 4-15
Difference in U.S. performer-reported and agency-reported Federal R&D: 1980–2001



NOTE: Difference is defined as percentage of federally reported R&D, with a positive difference indicating that performer-reported R&D exceeds agency-reported R&D.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), special tabulations, 2003; and NSF/SRS, *Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003,* forthcoming. See appendix table 4-31.

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resources (e.g., scientists, equipment, and facilities) that have been built up in those fields over time, as well as differences in scientific opportunities across fields (appendix table 4-34). Based on preliminary estimates for FY 2003, the major field of mathematics and computer sciences has experienced the highest rate of growth in Federal obligations for research, which was 7.8 percent per year in real terms between 1982 and 2003. Life sciences had the second highest rate (6.2 percent), followed by psychology (4.6 percent); environmental sciences (3.3 percent); social sciences, including anthropology, economics, political sciences, sociology, and other areas (2.3 percent); engineering (2.2 percent); and physical sciences (1.0 percent).

The trends in Federal support for these broad fields of research, however, may not reflect trends for the smaller fields that they contain. For example, within the broad field of mathematics and computer sciences, Federal support for research in mathematics grew 3.3 percent per year in real terms between FY 1982 and FY 2001, whereas support for research in computer sciences grew 10.9 percent.[32] Within life sciences during the same period, support for biological and agricultural research grew 6.0 percent, compared with research support for medical sciences, which grew 4.3 percent. Within the physical sciences, support for astronomy grew 2.7 percent, whereas support for physics declined 0.5 percent.

Caution should be employed when examining these trends in Federal support for detailed S&E fields because Federal agencies classify a significant amount of R&D only by major S&E field such as life sciences, physical sciences, or social sciences. In FY 2001, for example, 16.6 percent of the Federal research obligations classified by major S&E field were not subdivided into detailed fields. This was less pronounced in physical sciences and in mathematics and computer sciences, in which all but 7.6 percent of the research dollars were subdivided. It was most pronounced in engineering and social sciences, in which 27.3 and 63.9 percent, respectively, of the research obligations were not subdivided into detailed fields.

Federal R&D Tax Credit

The traditional justification for tax incentives for research activities is that results from these activities, especially more basic or long-term research, are often hard to capture privately because others might benefit directly or indirectly from them. Therefore, businesses might engage in levels of research below those that would be beneficial to the nation as a whole. In this regard, direct funding and tax incentives are complementary fiscal tools. Tax incentives are thought to stimulate R&D activity generally across industries and technologies (Tassey 1996), whereas direct funding through government agencies (as well as certain industry-relevant academic research) stimulates R&D in targeted fields (e.g., health, energy, or defense) or by certain performers [e.g., Small Business Innovation Research Program (SBIR)].[33]

The Federal research and experimentation (R&E) tax credit was first established on a temporary basis in 1981 and has been renewed several times since.[34] It was last reinstated by the Tax Relief Extension Act of 1999 through June 30, 2004. The Bush administration and several congressional bills pending, as of this writing, propose to make the R&E credit permanent (Knezo 2002).

Several studies based on U.S. data from the late 1990s have concluded that a dollar in tax credit likely stimulates, on average, a dollar of additional R&D on a long-term basis, as well as smaller short-term effects (Bloom, Griffith, and Van Reenen 2002; and Hall and Van Reenen 2000). However, the studies caution that administrative costs are often ignored in most empirical studies. In addition, for a more complete assessment of this policy instrument, interactions with other components of corporate taxes and tradeoffs with other policies need to be integrated into purely cost-benefit analyses.

Structure of the Credit and Tax Data

A regular credit is provided for 20 percent of qualified research above a base amount based on the ratio of research expenses to gross receipts for 1984–88. Startup or younger companies follow different formulas. An alternative R&E credit is available for corporate fiscal years that began after June 30, 1996.[35] Both the regular and the alternative R&E credits include provisions for basic research payments paid to qualified universities or scientific research organizations above a certain base-period amount.

In 1999 (the latest year for which data are available), approximately 10,000 companies claimed $5.281 billion in R&E credits, about the same level as in 1998 (table 4-13). However, not all R&E claims are allowed because there is a limitation on the reduction of a company's total tax liability. In 1999, 267 companies claimed $540 million for basic research, about 10 percent of the total R&E credit. The 1999 basic research credits were 36 percent larger than those in 1998, but the number of claims declined by half.

Federal Budget Impact

R&E credits are tax expenditures or government revenue losses because of preferential provisions. Tax expenditures from corporate income taxes relate mostly to cost recovery for certain investments, including research activities. *Outlay-equivalent* is one of three accounting methods used to

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[32]For these subfields, the latest available data are for FY 2001.

[33]The SBIR program is discussed later in this chapter in "Small Business S&T Programs."

[34]This section covers the R&D tax credit in the United States. For R&D tax policies abroad, see the discussion of R&D promotion policies in "International R&D by Performer, Source, and Character of Work."

[35]The alternative credit is a lower rate that applies to all research expenses exceeding 1 percent of revenues or sales. The rates were raised by the 1999 Tax Relief Act to 2.65–3.75 percent. Companies may select only one of these two credit modes on a permanent basis unless the Internal Revenue Service authorizes a change. The 1999 act also extended the research credit to include R&D conducted in Puerto Rico and other U.S. possessions.

Table 4-13
Research and experimentation tax credit claims: 1990–99

Year	Billions of current dollars	Number of tax returns
1990	1.547	8,699
1991	1.585	9,001
1992	1.515	7,750
1993	1.857	9,933
1994	2.423	9,150
1995	1.422	7,877
1996	2.134	9,709
1997	4.398	10,668
1998	5.208	9,849
1999	5.281	10,020

SOURCE: U.S. Department of the Treasury, Internal Revenue Service, Statistics of Income, unpublished tabulations.

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estimate these tax expenditures.[36] This method converts R&E credits into data comparable to Federal R&D outlays.

According to this measure, tax credit claims in 1999 were equivalent to outlays of $2.625 billion, or 3.5 percent of direct Federal R&D outlays in 1999 (U.S. OMB 2000) (appendix table 4-35). Although R&E claims data for tax year 2000 are not available, the credit generated an estimated outlay equivalent of $2.510 billion, or 3.4 percent of Federal R&D outlays in 2000 (U.S. OMB 2001).

Technology Linkages: Contract R&D, Federal Technology Transfer, and R&D Collaboration

In recent decades, the speed, complexity, and multidisciplinary nature of scientific research, coupled with the increased relevance of science for industrial technology development and the demands of a globally competitive environment, have increased the importance of technology linkages for innovation and long-term competitiveness (Branscomb and Florida 1998). Although external technology sources, including university research, have long played a key role in U.S. industry innovation and competitiveness (Mowery 1983; and Rosenberg and Nelson 1994), the current environment has encouraged an innovation system increasingly characterized by networking and feedback among R&D performers, technology users, and their suppliers and across industries and national boundaries (Coombs and Georghiou 2002; and Vonortas 1997). Several Federal S&T policies have also facilitated private R&D collaboration and Federal technology transfer, as discussed in more detail throughout this section. (See sidebar, "Major Federal Legislation Related to Cooperative R&D and Technology Transfer.")

Available indicators reveal increased cross-sector linkages over the 1990s. Manufacturing companies increased contract R&D expenditures at a 4.8 average annual percent rate, in real or inflation-adjusted terms, between 1993 and 2001, a full annual percentage point higher than the growth of in-house company-funded R&D expenditures over the same period. Federal agencies reporting technology transfer data to DOC increased their invention disclosures, patent activity, and licensing in FY 2001, reflecting their unique capabilities in terms of multidisciplinary R&D and specialized facilities. Patents issued to these Federal agencies topped 1,600 in FY 2001, up 15.6 percent from FY 2000.

The other major intersectoral activity involves cooperative R&D. U.S. Federal agencies participated in more than 3,600 Cooperative R&D Agreements (CRADAs) with industrial and nonprofit organizations in FY 2001, although new CRADAs have been stable at about 1,000 annually since FY 1997. In addition, between 1991 and 2001, U.S. companies participated in more than 4,600 research and technology alliances worldwide, or about 80 percent of all such alliances involving U.S., European, Japanese, and emerging-market companies. Activity was particularly strong in IT and biotechnology.

Outsourcing and collaboration aimed at the acquisition or development of technologies may reduce costs, expedite projects, or complement internal R&D capabilities (Howells and James 2001). Activities linking business, academic, and government laboratories may take place in special-purpose settings such as science parks. (See sidebar, "U.S. Science Parks.") The following sections discuss data on contract R&D, Federal technology transfer (e.g., patent licensing), and R&D alliances involving private companies, universities, and government laboratories.

Contract R&D

Many companies have increasingly come to rely on other firms for a portion of their R&D needs. In fact, the growth rate of *contract R&D*, defined as company-funded R&D performed externally, exceeded that of company-funded R&D performed in-house in recent years, even after a decline in contract R&D expenditures in 2001. In 2001, more than 1,300 manufacturing companies (8 percent of all R&D-performing manufacturing companies in the United States) reported $4.0 billion ($3.6 billion in constant or inflation-adjusted dollars) in expenditures for contract R&D performed in the United States, compared with $4.8 billion ($4.5 billion in constant dollars) in 2000, a decline of 17.5 percent, according to NSF's Survey of Industrial Research and Development.[37] In contrast, their in-house company-funded R&D declined only 1.4 percent between 2000 and 2001. Over a longer time span, however, manufacturing companies increased contract R&D expenditures at a 4.8 average annual percentage rate in real, or inflation-adjusted, terms, a full annual percentage point higher than the growth

[36]The other two methods are *revenue loss* and *present value.* For a comparison of these methods, see U.S. OMB (2001).

[37]National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

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

- ♦ **Stevenson-Wydler Technology Innovation Act (1980)**—required Federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector.
- ♦ **Bayh-Dole University and Small Business Patent Act (1980)**—permitted government grantees and contractors to retain title to federally funded inventions and encouraged universities to license inventions to industry. The act is designed to foster interactions between academia and the business community.
- ♦ **Small Business Innovation Development Act (1982)**—established the Small Business Innovation Research (SBIR) program within the major Federal R&D agencies to increase government funding of research that has commercialization potential within small high-technology companies.
- ♦ **National Cooperative Research Act (1984)**—encouraged U.S. firms to collaborate on generic, precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures. The act was amended in 1993 by the National Cooperative Research and Production Act (NCRPA), which let companies collaborate on production activities as well as research activities.
- ♦ **Federal Technology Transfer Act (1986)**—amended the Stevenson-Wydler Technology Innovation Act to authorize cooperative research and development agreements (CRADAs) between Federal laboratories and other entities, including state agencies.
- ♦ **Omnibus Trade and Competitiveness Act (1988)**—established the Competitiveness Policy Council to develop recommendations for national strategies and specific policies to enhance industrial competitiveness. The act created the Advanced Technology Program and the Manufacturing Technology Centers within the National Institute for Standards and Technology to help U.S. companies become more competitive.
- ♦ **National Competitiveness Technology Transfer Act (1989)**—amended the Stevenson-Wydler Act to allow government-owned, contractor-operated laboratories to enter into CRADAs.
- ♦ **National Cooperative Research and Production Act (1993)**—relaxed restrictions on cooperative production activities, enabling research joint venture participants to work together in the application of technologies they jointly acquire.
- ♦ **Technology Transfer Commercialization Act (2000)**—amended the Stevenson-Wydler Act and the Bayh-Dole Act to improve the ability of government agencies to monitor and license federally owned inventions.

of in-house company-funded R&D expenditures between 1993 and 2001, reflecting the importance of outside sources of technology for a number of corporate technology objectives (appendix table 4-36).

In the manufacturing industry the overall ratio of expenditures for contract R&D to expenditures for R&D performed in-house increased from 3.3 percent in 1993 to a peak of 4.7 percent in the mid-1990s, then moderated somewhat to 3.6 percent in 2001 (figure 4-16). In 2001 the proportion was higher for chemicals manufacturing at 11.7 percent (and pharmaceuticals manufacturing at 18.7 percent) (appendix table 4-37). Within nonmanufacturing industries, the contract R&D ratios for the information sector and the professional, scientific, and technical services sector were notable at 3.3 and 7.4 percent, respectively. Within the latter industry, R&D services contracted out $1.3 billion in R&D activities in 2001, which is 12.0 percent of its $10.9 billion in internal company-funded R&D expenditures.

Of the manufacturing companies reporting contract R&D in the NSF survey in 2001, 132 companies (9.7 percent) identified $2.17 billion in R&D expenditures in terms of their R&D contractors being for-profit companies, universities and colleges, or other nonprofit organizations.[38] The highest proportion of these identified contract R&D expenditures, 92.0 percent, funded other companies, 5.9 percent funded universities and colleges, and 2.2 percent funded other nonprofit institutions. For chemical companies, the distribution of contract R&D expenditures among their R&D contractors was similar (83, 12, and 5 percent, respectively). However, among companies in the scientific R&D services sector, the share of identified contract R&D expenditures performed by universities and colleges was much higher, 35.4 percent, although still second to the 49.7 percent performed by other for-profit companies.[39] The relatively higher reliance of U.S. R&D services companies on universities and colleges as R&D subcontractors may be related to the broader set of technologies in which these companies work, complementing their internal capabilities with the wide array of scientific capabilities of universities.

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[38]National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

[39]Disclosure limitations preclude further industry-level analyses.

U.S. Science Parks

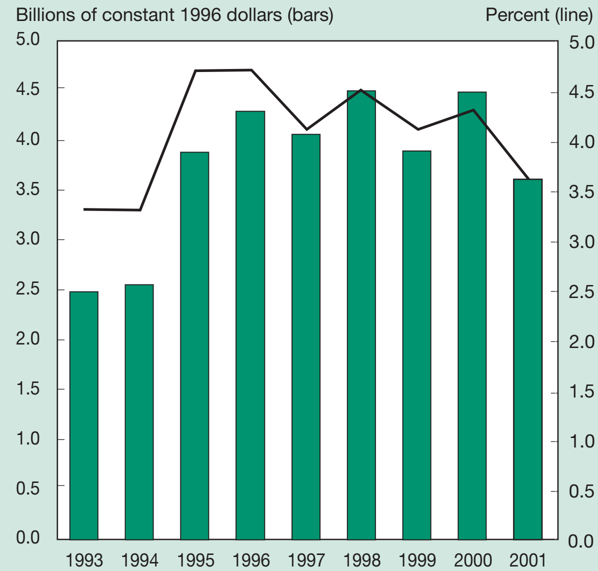
Science, or research, parks are real estate developments involving technology transfer activities. Many science parks are affiliated with or supported by universities or government agencies, and some are also business incubators, offering assistance to new technology-based companies.* Science parks affiliated with universities have been in place since the 1950s in the United States. Some of the oldest and largest parks include Stanford Research Park (Stanford, CA), established in 1951, and Research Triangle Park (Research Triangle, NC), established in 1959 (Link and Link 2003). However, the increased research and patenting output from academic R&D since the 1980s have intensified the role of industry-university linkages as avenues for knowledge diffusion and broad economic benefits.† Similarly, selected Federal laboratories house or sponsor science parks and business incubators (NRC 2003).

In an exploratory study involving 50 U.S. science parks, Link and Link (2003) analyzed parks with and without university affiliation. University-related parks were classified, for example, in terms of the presence or absence of tenant criteria regarding R&D intensity or commitment to interacting with students and faculty. Forty of the examined science parks were affiliated with a university and about a third of the parks were also business incubators. Tenant criteria of university-related parks were found to affect positively their growth in terms of participating companies and number of employees. However, the 10 science parks in their sample that had no university linkages were larger parks.

A workshop on science parks indicators sponsored by NSF in late 2002 concluded that science parks are "an important mechanism for the transfer of academic research findings, a source of knowledge spillovers, and a catalyst for national and regional economic growth" (Link 2003, p. 1). Participants also noted the need for metrics on the profile and performance of these parks. NSF is considering recommendations from workshop participants while continuing to fund a number of research projects on the topic, including exploring existing data on domestic R&D alliances in terms of university and science park affiliation.

*See chapter 6.
†See chapter 5.

Figure 4-16
Manufacturing contract R&D expenditures in United States and ratio of contract R&D expenditures to company-funded R&D performed within companies: 1993–2001



SOURCE: National Science Foundation, Survey of Industrial Research and Development, annual series. See appendix table 4-36.

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Federal S&T Programs and Technology Transfer

Concerns over U.S. industrial strength and global competitiveness in the late 1970s and early 1980s led to a series of legislative changes that collectively created an environment conducive to industry-government collaboration in technology development (Link 1999). This section discusses technology transfer and collaborative activities involving Federal laboratories. *Technology transfer* can be defined as the exchange or sharing of technical knowledge, skills, processes, or products across different organizations.[40] Technology transfer activities involving Federal laboratories include patenting, licensing, joint R&D, user-facility agreements, and technical assistance.

Technology transfer functions performed by certain Federal laboratories, namely, intramural or government-owned–government-operated laboratories, such as NIH or the Agricultural Research Service, were established by the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480). Later in the decade, the Federal Technology Transfer Act of 1986 authorized intramural labo-

[40]This section describes technology transfer activities associated with R&D performed in federally owned laboratories (hereafter, *Federal laboratories*), whether run by Federal agencies themselves or by contractors. It does not include technology transfer activities associated with federally sponsored R&D performed by *independent* extramural entities (for example, companies and universities engaged in patenting resulting from federally sponsored R&D).

ratories to enter into CRADAs[41] with industrial partners, universities, and other organizations, whereas the FY 1990 DOD Authorization Act (Public Law 101-189) extended this authority to government-owned–contractor-operated laboratories, including government-owned FFRDCs[42] (Schacht 2000). In CRADAs, Federal laboratories may share or provide personnel, services, equipment, or facilities (but not funds) with or to a private organization as part of a joint R&D project with the potential to promote industrial innovation consistent with the agency's mission. Private partners may retain ownership rights or acquire exclusive licensing rights for the developed technologies. More recently, the Technology Transfer Commercialization Act of 2000 (Public Law 106-404) enhanced the ability of Federal agencies to license (and monitor) federally owned inventions.

R&D Funding Trends in Federal Laboratories

The share of Federal R&D obligations devoted to intramural laboratories and FFRDCs declined from 39 percent in the early 1980s to the low 30s in the late 1990s (NSF forthcoming). Still, the role of Federal laboratories, either as a source of technology to be commercialized by private parties or as a research partner, is considerable. Federal laboratories offer industrial and nonprofit researchers unique capabilities, such as the ability to perform interdisciplinary research and to use expensive, specialized equipment (Bozeman 2000).

In FY 2001 the Federal Government obligated $27.3 billion, or 34 percent of $79.9 billion in Federal funds earmarked for R&D, to Federal laboratories (table 4-14), compared with $52.6 billion (66 percent of total) in R&D funding obligated to extramural performers, such as companies and universities (NSF forthcoming). Within individual agencies, the share devoted to government laboratories is largest for DOE (71.7 percent) and smallest for HHS (20.3 percent; 19.6 percent for its NIH component). Agencies with large amounts or relatively large proportions of their R&D obligations devoted to intramural and FFRDC performers have more internal outputs available for patenting and licensing than agencies that channel their R&D funds to extramural performers.

Federal agencies devoted a higher share of their funds for Federal laboratories to applied research and development than to basic research. Of the 34 percent devoted to Federal laboratories in FY 2001, less than a fourth went to basic research. Individual Federal agencies, however, varied considerably in the proportion of funds they devoted to basic research in their laboratories: 52.4 percent of HHS laboratory R&D funding (59.5 percent for its NIH component), followed by USDA (49.0 percent) and DOE (35.0 percent). DOD devoted only 5.3 percent to basic research in its laboratories. This profile of character of work at Federal laboratories, together with the various S&T emphases of these agencies, suggests that industrial partners are potentially able to use Federal facilities as a source for a variety of research outputs.

Table 4-14
Federal obligations for R&D, by selected agency, performer, and basic research component: FY 2001

Agency	Federal obligations for R&D	Intramural and FFRDCs R&D	Intramural and FFRDCs basic research	Intramural and FFRDCs R&D share of Federal R&D obligations	Intramural and FFRDCs basic research share of Intramural and FFRDCs R&D
	Millions of current dollars			Percent	
All Federal agencies	79,933.2	27,293.2	6,671.6	34.1	24.4
Top five agencies	72,746.6	24,721.4	6,056.9	34.0	24.5
DOD	35,422.6	11,073.6	587.3	31.3	5.3
DOE	6,668.0	4,779.0	1,670.5	71.7	35.0
HHS	21,341.9	4,340.5	2,275.0	20.3	52.4
NASA	7,355.0	3,267.4	906.5	44.4	27.7
USDA	1,959.1	1,260.9	617.7	64.4	49.0

DOD Department of Defense; DOE Department of Energy; FFRDC federally funded research and development center; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; USDA Department of Agriculture

SOURCE: National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development, Fiscal Years 2001, 2002, and 2003* (Arlington, VA, forthcoming).

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[41]Legislation allowing cooperative research and development agreements between private companies and Federal laboratories complemented revised antitrust regulations intended to foster intercompany collaborative R&D.

[42]See appendix table 4-26 for a list of FFRDCs, including R&D funding, location, sponsoring agency, and administrator, as of FY 2001. In general, FFRDCs may or may not be owned by the Federal Government, but most of the largest FFRDCs, such as the Department of Energy's (DOE's) FFRDCs, are owned by the Federal Government.

Table 4-15
Federal technology transfer indicators for selected agencies: FY 2001

Federal agency	Inventions disclosed		Patent applications		Patents issued	
	Number	Percent distribution	Number	Percent distribution	Number	Percent distribution
All 10 reporting	3,909	100.0	2,172	100.0	1,608	100.0
Top 5	3,780	96.7	2,090	96.2	1,566	97.4
DOD	1,005	25.7	809	37.2	619	38.5
DOE	1,527	39.1	792	36.5	605	37.6
HHS	434	11.1	255	11.7	119	7.4
NASA	696	17.8	151	7.0	159	9.9
USDA	118	3.0	83	3.8	64	4.0

DOD Department of Defense; DOE Department of Energy; HHS Department of Health and Human Services; NASA National Aeronautics and Space Administration; USDA Department of Agriculture

SOURCE: U.S. Department of Commerce, Office of the Secretary, *Summary Report on Federal Laboratory Technology Transfer; 2002 Report to the President and the Congress Under the Technology Transfer and Commercialization Act,* 2002. See appendix table 4-38.

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Federal Technology Transfer Trends

Since FY 1987, 10 Federal agencies have reported data on technology transfer to the DOC, pursuant to Federal technology transfer statutes (U.S. DOC 2002).[43] The 10 agencies reporting data were DOC, DOD, DOE, DOI, the Department of Transportation, the Environmental Protection Agency, HHS, NASA, USDA, and the Department of Veterans Affairs. In general, available metrics indicate an increased level of Federal technology transfer activities since the late 1980s. Data include inventions disclosed, federally owned patents, licenses, licensing income, and the number of CRADAs.

In FY 2001, Federal agencies reporting data on technology transfer activities logged more than 3,900 invention disclosures (table 4-15). Invention disclosures increased 9.7 percent from FY 2000, close to the 4,000 mark reached in the early and mid-1990s (figure 4-17). Patent applications increased to a peak of 2,172 in FY 2001, up 4.3 percent from FY 2000, after remaining at or just below 2,000 for most of the 1990s. Patents issued to these Federal agencies reached 1,608 in FY 2001, up 15.6 percent from FY 2000. Between FY 1997 (the first fiscal year for which these data were available from DOC) and FY 2001, a total of 7,178 patents were issued to these 10 Federal agencies.

At the agency level, DOD and DOE had the largest shares of inventions disclosed, patent applications, and patents issued in FY 2001. These two agencies accounted for 65–75 percent of those Federal technology transfer indicators among the reporting agencies. Differences in R&D funding structures and character of work may drive some of these results at the agency level. Furthermore, Federal agencies are engaged in other technology-related activities (e.g., technology procurement, safety or material standards, and technology assistance to businesses), offering other venues for technology diffusion not covered in this section.

Federal Laboratories in Collaborative Research Agreements

Two indicators of Federal laboratories' participation in research alliances show selected features of these activities: the first identifies their industrial focus, and the second describes Federal agency participation in CRADAs.

Ninety-nine R&D agreements registered from 1985 to 2001 in the *Federal Register* (11.5 percent of 861 R&D agreements) had at least one Federal laboratory partner.[44] Thirty-seven of these industry-government R&D alliances were classified in electronic and other electrical equipment and components manufacturing.[45] Ten alliances were classified in chemicals manufacturing (which includes pharmaceuticals), another 10 in industrial machinery and computer equipment manufacturing, and eight in transportation equipment manufacturing. Leyden and Link (1999) report that registered alliances with Federal laboratory partners tend to have more participants than do alliances without government partners. Federal laboratories in large alliances not only increase economies of technological scope but also reduce monitoring costs, increasing potential benefits to all members (Leyden and Link 1999).[46]

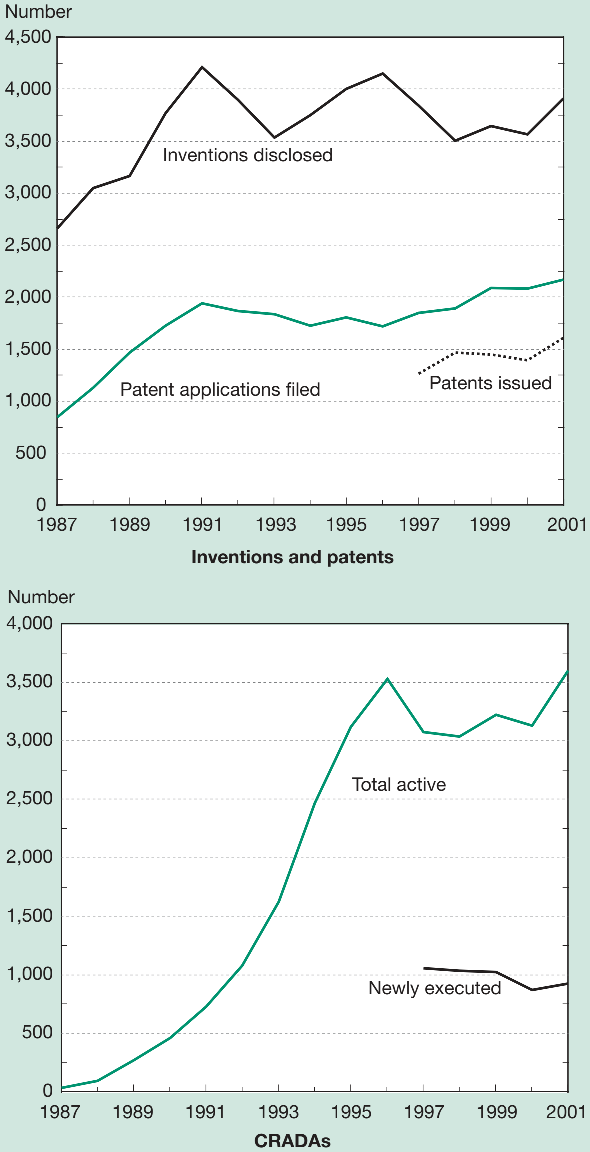
[43]Data for FY 2001 (discussed below) may not be comparable to earlier years due to changes in data reporting or scope. In particular, data from some agencies include more subcomponents or laboratories than previous years. See also Technology Transfer and Commercialization Act of 2000 in sidebar "Major Federal Legislation Related to Cooperative R&D and Technology Transfer" and U.S. General Accounting Office, *Intellectual Property—Federal Agency Efforts in Transferring and Reporting New Technology,* GAO-03-47 (Washington, DC, 2002).

[44]Cooperative Research (CORE) database, unpublished tabulations compiled by A. N. Link, University of North Carolina-Greensboro. See also "Domestic and International Technology Alliances."

[45]These 37 alliances represented 47 percent of the 78 industry-government alliances identified by Standard Industrial Classification (SIC) code in the CORE database for the 1985–2001 period.

[46]For studies on the performance or industrial impacts of industry-government alliances, see B. Bozeman and D. Wittmer, Technical roles and success of U.S. Federal laboratory-industry partnerships, *Science and Public Policy* 28, no. 4 (2001):169–178 and J. D. Adams, E. P. Chiang, and J. L. Jensen, The influence of Federal laboratory R&D on industrial research, Working Paper 7612 (Cambridge, MA: National Bureau of Economic Research, 2000).

Figure 4-17
Federal technology transfer indicators: FY 1987–2001



CRADA cooperative research and development agreement

NOTE: Data for patents issued and newly executed CRADAs were not collected prior to FY 1997.

SOURCE: U.S. Department of Commerce, Office of the Secretary, *Summary Report on Federal Laboratory Technology Transfer: 2002 Report to the President and the Congress Under the Technology Transfer and Commercialization Act*, 2002. See appendix table 4-38.

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The 10 Federal agencies reporting technology transfer activities to DOC executed 926 new CRADAs with industrial and university partners in FY 2001, up 5.9 percent from FY 2000, but little changed from the 1,000 mark since first reported in FY 1997. The 2001 increase brought the number of active CRADAs to 3,603 (figure 4-17). Three agencies accounted for more than 80 percent of active CRADAs in FY 2001: DOD, which participated in 1,965 CRADAs, or 54.5 percent of all CRADAs; DOE, which participated in 558, or 15.4 percent; and HHS, which participated in 490, or 13.6 percent.

The FY 2001 increase in active CRADAs was driven by increases in DOD and HHS CRADAs (44 and 12 percent, respectively) compared with a 19 percent decline in DOE CRADAs.[47] DOE had the largest share of CRADAs through the mid-1990s, driving the overall agency count to its FY 1996 peak, when CRADAs began their declining trend. Smaller increases in DOD CRADAs sustained the overall trend from further declines to FY 2000. Compared with other forms of technology transfer activities, cooperative research activities, both CRADAs and non-CRADA joint R&D projects, involve a number of additional managerial and organizational requirements for both agency and company participants. For agencies, an additional factor is the R&D or administrative budget devoted to technology transfer planning and management (U.S. GAO 2002).

Small Business S&T Programs

The Small Business Innovation Research (SBIR) program, created in 1982 (Public Law 97-219), leverages existing Federal R&D funding toward small companies (those with 500 or fewer employees).[48] Although larger firms dominate R&D performance in the United States, as discussed earlier in this chapter, small firms may have capabilities or incentives to innovate, which may or may not come to fruition due to a number of constraints, including financing.[49] SBIR's sister program, the Small Business Technology Transfer Program (STTR), was created in 1992 to stimulate cooperative R&D and technology transfer involving small businesses and nonprofit organizations, including universities and FFRDCs. Both programs leverage existing Federal R&D funding to small-company and nonprofit performers to stimulate innovation, technology transfer, and R&D commercialization.[50] SBIR and STTR are administered by participating agencies and coordinated by the Small Business Administration.

In SBIR, Federal agencies with extramural R&D obligations exceeding $100 million must set aside a fixed percentage of such obligations for SBIR projects. This set-aside has

[47]Recall that FY 2001 data may not be comparable to earlier years due to changes in data reporting or scope.

[48]The SBIR program was last reauthorized in December 2000 for the period through September 2008 (Public Law 106-554). This bill also requested that the National Research Council conduct a new 3-year SBIR study at five Federal agencies with SBIR budgets exceeding $50 million (DOD, Department of Health and Human Services, NASA, DOE, and NSF) to provide an assessment of SBIR's operations and impacts. The study is currently in progress. For a summary of previous policy and empirical studies, see J. Lerner and C. Kegler, Evaluating the SBIR: A literature review, In *The SBIR Program: An Assessment of the Department of Defense Fast Track Initiative* (Washington, DC: National Academy Press, 2000).

[49]For example, internal funds have been shown to significantly affect R&D activity conducted by small high-technology firms. See C. P. Himmelberg and B. C. Petersen, R&D and internal finance: A panel study of small firms in high-tech industries, *The Review of Economics and Statistics* 76, no. 1 (1994): 38–51.

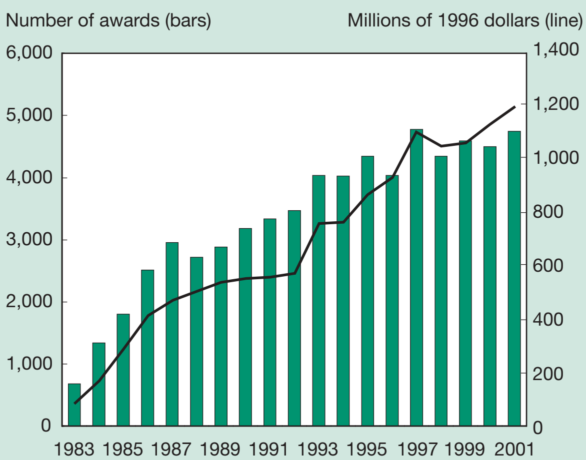
[50]The Small Business Technology Transfer Program was created by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). It was last reauthorized in October 2001 for the period through FY 2009 (Public Law 107-50).

been 2.5 percent since FY 1997. To obtain this Federal funding, a small company applies for a Phase I SBIR grant of up to $100,000 for up to 6 months to assess the scientific and technical feasibility of ideas with commercial potential. If the concept shows further potential, the company can receive a Phase II grant of up to $750,000 over a period of up to 2 years for further development. In Phase III, the innovation must be brought to market with private-sector investment and support; no SBIR funds may be used for Phase III activities.

SBIR awarded about $12 billion to 64,300 projects through FY 2001. Projects included research and commercialization activities in the areas of computers, information processing and electronics, materials, energy, environmental protection, and life sciences. In FY 2001 the program awarded $1.29 billion in R&D funding ($1.18 billion in 1996 dollars) to 4,748 projects (figure 4-18). In FY 2001, DOD led the 10 participating agencies in SBIR funding, obligating $576 million (45 percent of total SBIR funding), followed by HHS at $412 million (32 percent) in FY 2001 (appendix table 4-39).

STTR involves cooperative R&D performed jointly by a small business and a research organization and is also structured in three phases. The participating research organization must be a nonprofit institution, as defined by the Stevenson-Wydler Technology Innovation Act of 1980, or an FFRDC. Five Federal agencies with extramural R&D budgets exceeding $1 billion participate in the program: DOD, NSF, DOE, NASA, and HHS. The required set-aside has been 0.15 percent from FY 1996 to FY 2003, compared with 2.5 percent for SBIR.[51] STTR awarded about $460 million to more than 2,400 projects from FY 1994 to FY 2001, including $71.3 million ($65.1 million in 1996 dollars) to 337 projects in 2001. DOD and HHS are the largest agency participants (appendix table 4-40).

Figure 4-18
SBIR awards and funding: 1983–2001



SBIR Small Business Innovation Research

SOURCE: U.S. Small Business Administration, *Small Business Innovation Research Program Annual Report,* various years. See appendix table 4-39.

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The Advanced Technology Program

The Advanced Technology Program (ATP), sponsored by DOC's National Institute of Standards and Technology (NIST), was established by the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418; 15 USC, Section 278n) to promote the development and commercialization of generic or broad-based technologies. The program provides funding for high-risk R&D projects through a competitive process on a cost-share basis with private-company participants.

From ATP's inception through FY 2002 more than 1,300 companies, nonprofit institutions, and universities participated in 642 projects costing $3.8 billion, which were funded about equally by ATP and industry (appendix table 4-41). Over the same period, 447 projects (70 percent) were single-company projects and 195 (30 percent) were joint ventures; two-thirds of participants were members of joint ventures. Participants pursued projects in five technology areas: biotechnology, electronics, IT, advanced materials and chemistry, and manufacturing.

In FY 2002, 61 R&D projects costing $289 million were initiated, with about 54 percent funded by ATP and the balance funded by participants. Public Law 108-7 appropriated $180 million for the program for FY 2003, a decline of 2.4 percent from FY 2002 (Schacht 2003). At the time of this writing, the Bush administration's FY 2004 budget calls for the suspension of new awards and requests funding only for administrative and close-out expenses (U.S. OMB 2003a).

Domestic and International Technology Alliances

Over the past 2 decades, U.S. firms have not only turned to technology outsourcing but also increased their participation in technology alliances domestically and globally. *Technology alliances* can be defined as collaborative relationships or partnerships among legally distinct parties that involve joint R&D or technology development activities.[52]

Technology alliances allow firms to share R&D costs, pool technical and market risks, and complement and further develop internal capabilities (Vonortas 1997). Collaborative networks are not without risks, however. Unintended transfer of proprietary technology is always a concern for businesses. Cultural differences among different industries, public partners (government or academic), or international partners present additional difficulties in managing alliances. Lastly, public-private collaboration presents challenges for intellectual property policy and concerns for the free flow of basic scientific knowledge.[53]

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[51]The Small Business Technology Transfer Program's set-aside percentage is scheduled to increase to 0.3 percent from FY 2004 forward (Public Law 107-50). For further details on this program, see U.S. GAO (2001a).

[52]In principle, alliances differ from external sourcing of existing technologies, such as patent licensing or contract R&D, in that the former involve some kind of joint R&D activity. In practice, however, a single technology project may involve both of these broad types of linkages.

[53]For example, see M. P. Feldman, I. Feller, J. E. L. Bercovitz, and R. M. Burton, Understanding evolving university-industry relationships, In M. P. Feldman and A. Link, eds., *Technology Policy for the Knowledge-Based Economy* (Boston: Kluwer Academic Press, 2001).

Types of Technology Alliances

Technology alliances can be classified and analyzed according to several criteria (Hagedoorn, Link, and Vonortas 2000). In terms of their organizational structure, they can be classified as *equity alliances,* or research joint ventures (RJVs), in which two or more partners form a separate business entity with long-term objectives. In contrast, *nonequity alliances* are mostly contractual agreements governing short-term projects. By membership profile, they may be private-private alliances (involving only business partners such as suppliers, customers, or competitors) or public-private alliances (involving government laboratories and universities).

Technology alliances may focus on a number of innovation-related activities, ranging from industrywide issues such as basic or precompetitive research, standards settings, or regulatory issues (Tassey 1997) to firm-specific projects. They can also range from longer term learning and capabilities-building activities to shorter term development projects closer to commercialization goals. These varied goals, together with firm-specific characteristics (e.g., size, age, internal organization, and R&D capabilities) and the underlying technology and market characteristics, affect the choice of partners and the organizational structure of these alliances.

Dedicated databases tracking these developments and sponsored in part by NSF include the Cooperative Research (CORE) database, housed at the University of North Carolina at Greensboro, and the Cooperative Agreements and Technology Indicators database, compiled by the Maastricht Economic Research Institute on Innovation and Technology (CATI-MERIT). The CORE database covers U.S.-based alliances and RJVs recorded in the *Federal Register,* pursuant to the provisions of the National Cooperative Research Act, as amended.[54] Trends in the CORE database are illustrative only, because the registry is not intended to be a comprehensive count of cooperative activity by U.S.-based firms. The CATI-MERIT database covers international technology agreements and is based on announcements of alliances and tabulated according to the country of ownership of the parent companies involved.[55]

Domestic Research Partnerships

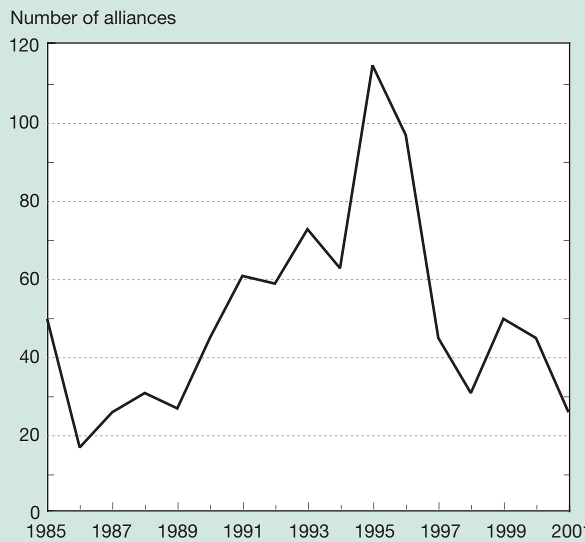
A total of 861 technology alliances were registered in the CORE database from 1985 to 2001. The database shows the following trends:

- ♦ In 2001 there were 26 new technology alliances, compared with 45 in 2000. New filings increased between 1986 and 1995, when they peaked at 115 (figure 4-19). Brod and Link (2001) developed a statistical model to explain the trends in RJV filings, including the decline after 1995. They found that filings are likely to be countercyclical. In particular, they argue that "[w]hen the economy is strong and…R&D is growing, firms may rely less on cooperative research arrangements…than when the economy is weak and internal resources are more constrained" (p. 109).
- ♦ About half of the technology alliances in 1985–2001 involved activities classified in three industrial areas: electronic and electrical equipment (18 percent), communication services (16 percent), and transportation equipment (15 percent).
- ♦ Fifteen percent (125 of 861) of these alliances involved a U.S. university as a research member, whereas about 12 percent (99 of 861) included a Federal laboratory.

International Technology Alliances

The data from the CATI-MERIT database are annual counts of new technology alliances formed by domestic and multinational corporations and their subsidiaries or affiliates worldwide. Most of the alliances recorded in the database were owned by, and/or had R&D partners located in, the

Figure 4-19
Domestic technology alliances: 1985–2001



NOTE: Data are annual counts of new technology alliances registered under the National Cooperative Research and Production Act.

SOURCE: University of North Carolina–Greensboro, Cooperative Research (CORE) database, special tabulations.

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[54]Cooperative Research (CORE) database, unpublished tabulations compiled by A. N. Link, University of North Carolina–Greensboro. Restrictions on multifirm cooperative research relationships were loosened by the National Cooperative Research Act (NCRA) in 1984 (Public Law 98-462) after concerns about the technological leadership and international competitiveness of American firms in the early 1980s. This law was enacted to encourage U.S. firms to collaborate on generic, precompetitive research. However, to gain protection from antitrust litigation, NCRA requires firms engaging in research joint ventures (RJVs) to register them with the Department of Justice. In 1993 the National Cooperative Research and Production Act (NCRPA, Public Law 103-42) extended legal protection to collaborative production activities.

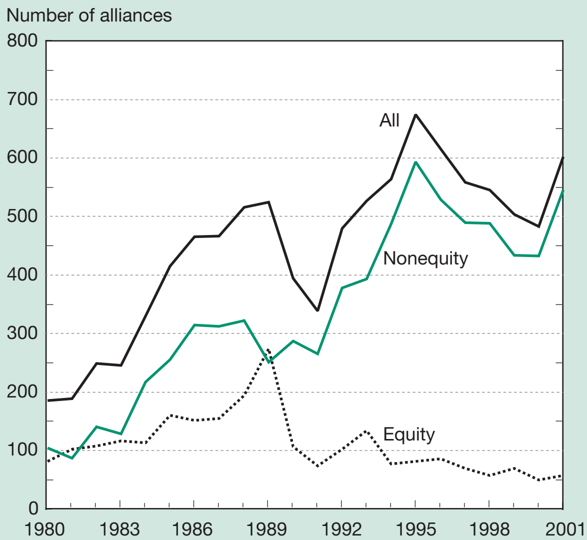
[55]The Cooperative Agreements and Technology Indicators (CATI) database is compiled by the Maastricht Economic Research Institute on Innovation and Technology (MERIT) in the Netherlands. CATI is a literature-based database that draws on sources such as newspapers, journal articles, books, and specialized journals that report on business events. Agreements involving small firms and certain technology fields are likely to be underrepresented. Another limitation is that the database draws primarily from English-language materials.

United States, Western Europe, and Japan, the so-called Triad regions.[56]

From 1991 to 2001, there were 5,892 new technology alliances formed worldwide in six major sectors: information technology (IT), biotechnology,[57] advanced materials, aerospace and defense, automotive, and (nonbiotech) chemicals. This total includes 602 alliances formed in 2001, a 25 percent increase from 483 in 2000 (figure 4-20). This is the first increase since a 19.5 percent increase in 1995 to its all-time high of 674 technology alliances.

The majority of these alliances were organized as nonequity, or contractual, agreements (figure 4-20). In particular, the share of nonequity alliances increased from 61 percent in 1980–90 to 86 percent in 1991–2001. The more flexible and project-based organization of nonequity agreements favors activities in highly dynamic high-technology sectors such as IT and biotechnology research and product development, as opposed to more mature technology sectors (Hagedoorn 2001). Indeed, these two sectors are the top technology sectors of these alliances.

Figure 4-20
International technology alliances worldwide, by type of alliance: 1980–2001



NOTE: Data are annual counts of new technology alliances worldwide.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators database, special tabulations. See appendix table 4-42.

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The participation by U.S.-owned companies and their subsidiaries is considerable. About 80 percent (4,646 of 5,892) of the 1991–2001 technology alliances worldwide involved at least one U.S.-owned company (table 4-16), up from two-thirds between 1980 and 1990. About half of the U.S. alliances between 1991 and 2001 (or 39 percent of the all countries total) were alliances exclusively among U.S.-owned companies. Thirty-four percent of the U.S. alliances (27 percent of the total) were formed between U.S.- and European-owned companies. European companies participated in 2,604 (44 percent of 5,892) technology alliances during the period 1991–2001, up from 1,989 alliances in 1980–1990. However, contrary to the pattern for U.S. companies, the majority of European technology alliances were between U.S.- and European-owned companies, as opposed to alliances exclusively among European-owned companies and subsidiaries. Japanese companies participated in 779 technology alliances worldwide between 1991 and 2001, down from 1,013 alliances between 1980 and 1990, according to the CATI-MERIT database.

IT was the major focus among most ownership categories shown in table 4-16 during 1990–2001. Notably, 46 percent of the alliances owned exclusively by U.S. companies in 1991–2001 were focused on IT activities. In contrast, the most frequent technology activity of U.S.-European alliances was biotechnology at 33 percent (table 4-16). (The IT share for U.S.-European alliances was the second largest at 21 percent.) Indeed, biotechnology alliances began to outpace IT alliances in 2000 (figure 4-21), driven by intense activity in this sector by U.S. and European companies (van Beuzekom 2001). In 1995 a new breed of alliance combining IT and biotechnology activities emerged in the database. From 1995 to 2001, a total of 46 alliances performed activities in areas such as bioinformatics applications. U.S. companies participated in 37 (80 percent) of these alliances, including 19 with European firms.

International R&D Trends and Comparisons

Increasingly, the international competitiveness of a modern economy is defined by its ability to generate, absorb, and commercialize knowledge. Most nations have accepted that economic policy should focus not only on improving quality and efficiency but also on promoting innovation. Absolute levels of R&D expenditures are important indicators of a nation's innovative capacity and are a harbinger of future growth and productivity. Indeed, investments in the R&D enterprise strengthen the technological base on which

[56]The country assignment for the data subsequently discussed is based on the headquarters of the ultimate parent company of the alliance members, not on the location of the members. Classification by technology is not exclusive because an alliance may perform activities and be classified in more than one technology. The data were revised from previous editions to include exclusively joint research or development agreements, R&D contracts, equity joint ventures, and research corporations. Previous counts included cross-holdings (where two companies take a minority interest in each other), mutual second sourcing, and cross-licensing agreements. This change, however, did not affect overall trends. Separately, the data now provide detail on the structure of the alliances in terms of equity and nonequity arrangements. For conceptual, policy, and measurement issues regarding indicators of technology alliance, see J. de la Mothe and A. N. Link, *Networks, Alliances, and Partnerships in the Innovation Process* (Boston: Kluwer Academic Press, 2002); J. E. Jankowski, A. N. Link, and N. S. Vonortas, *Strategic Research Partnerships: Proceedings From an NSF Workshop*, NSF 01-336 (Arlington, VA: National Science Foundation, 2001); and B. Bozeman and J. S. Dietz, Strategic research partnerships: Constructing policy-relevant indicators, *Journal of Technology Transfer* 26 (2001):385–393.

[57]This technology classification includes pharmaceutical biotechnology.

Table 4-16
International technology alliances worldwide, by regional ownership and technology focus: 1991–2001

Ownership categories	All technologies	Information technology	Biotechnology
		Counts	
Alliances by companies from all countries	5,892	2,471	1,829
U.S.-owned only	2,297	1,133	699
U.S.-Europe owned	1,562	516	609
Europe-owned only	637	154	217
U.S.-Japan owned	439	259	93
U.S.-NT owned	348	159	90
Europe-NT owned	213	59	60
Europe-Japan owned	192	86	32
Japan-owned only	96	55	8
NT-owned only	56	20	15
Japan-NT owned	52	30	6
Selected groupings			
Alliances by U.S. companies	4,646	2,067	1,491
Alliances by European companies	2,604	815	918
Alliances by Japanese companies	779	430	139
Alliances by NT companies	669	268	171
		Percent distribution	
Ownership profile			
Alliances by companies from all countries	100	100	100
U.S.-owned only	39	46	38
U.S.-Europe owned	27	21	33
Europe-owned only	11	6	12
U.S.-Japan owned	7	10	5
U.S.-NT owned	6	6	5
Europe-NT owned	4	2	3
Europe-Japan owned	3	3	2
Japan-owned only	2	2	0
NT-owned only	1	1	1
Japan-NT owned	1	1	0
Selected groupings			
Alliances by U.S. companies	79	84	82
Alliances by European companies	44	33	50
Alliances by Japanese companies	13	17	8
Alliances by NT companies	11	11	9
Technology profile			
Alliances by companies from all countries	100	42	31
U.S.-owned only	100	49	30
U.S.-Europe owned	100	33	39
Europe-owned only	100	24	34
U.S.-Japan owned	100	59	21
U.S.-NT owned	100	46	26
Europe-NT owned	100	28	28
Europe-Japan owned	100	45	17
Japan-owned only	100	57	8
NT-owned only	100	36	27
Japan-NT owned	100	58	12
Selected groupings			
Alliances by U.S. companies	100	44	32
Alliances by European companies	100	31	35
Alliances by Japanese companies	100	55	18
Alliances by NT companies	100	40	26

NT non-Triad (country or region other than United States, Europe, and Japan)

NOTES: Percents may not sum to total because of rounding. Data are annual counts of new technology alliances formed by domestic and multinational corporations worldwide. Alliances may be classified in more than one technology. Country assignment is based on headquarters of ultimate parent company of alliance members, not on location of members. Data were revised from previous editions to include exclusively joint research or development agreements, R&D contracts, equity joint ventures, and research corporations. Previous counts included cross-holdings (two companies take minority interest in each other), mutual second sourcing, and cross-licensing agreements. This change, however, had little effect on overall trends. See appendix table 4-42.

SOURCE: Maastricht Cooperative Agreements and Technology Indicators database, Economic Research Institute on Innovation and Technology, unpublished tabulations.

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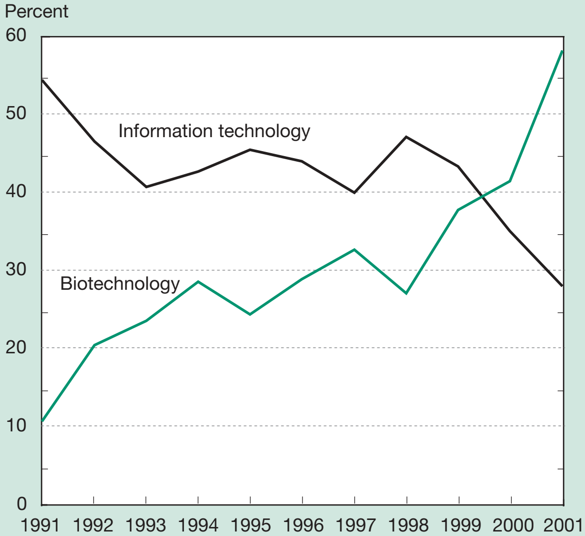
Figure 4-21
Information technology and biotechnology shares of international technology alliances: 1991–2001



SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators database, special tabulations. See appendix table 4-42.

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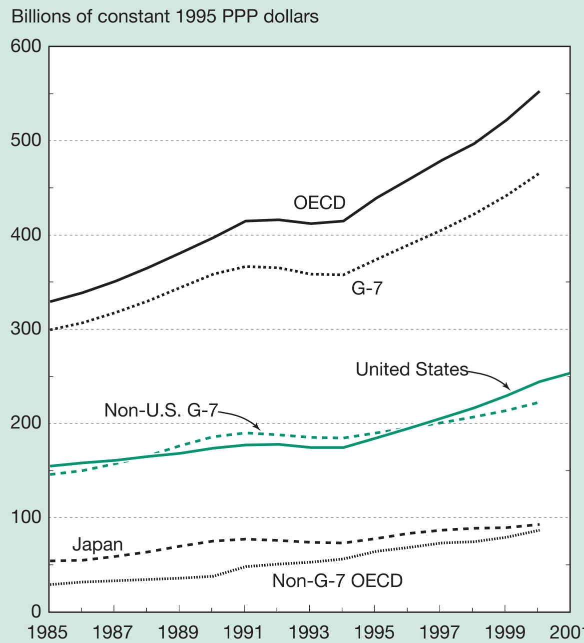
economic prosperity increasingly depends worldwide. The relative strength of a particular country's current and future economy and the specific scientific and technological areas in which a country excels are further revealed through comparison with other major R&D-performing countries. This section compares international R&D spending patterns. Topics include absolute and relative expenditure trends, the structure of R&D performance and funding across sectors, the foci of R&D activities within sectors, and government research-related priorities.

Most of the R&D data presented in this section are from reports to the Organisation for Economic Co-operation and Development (OECD), the most reliable source for such international comparisons. However, an increasing number of non-OECD countries and organizations now collect and publish internationally comparable R&D statistics, which are reported at various points in this section.

Absolute Levels of Total R&D Expenditures

Worldwide R&D performance is concentrated in a few industrialized nations. Of the $603 billion in estimated 2000 R&D expenditures for the 30 OECD countries, fully 85 percent is expended in only 7 countries (OECD 2002d).[58] These estimates are based on reported R&D investments (for defense and civilian projects) converted to U.S. dollars with purchasing power parity (PPP) exchange rates.[59] (See sidebar, "Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data.") R&D expenditures in the United States alone account for roughly 44 percent of all OECD member countries' combined R&D investments; R&D investments in the United States are 2.7 times greater than investments made in Japan, the second largest R&D-performing country. More money was spent on R&D activities in the United States in 2000 than in the rest of the G-7 countries (Canada, France, Germany, Italy, Japan, and the United Kingdom) combined. (See figure 4-22 and appendix table 4-43 for inflation-adjusted PPP R&D totals for OECD and G-7 countries.) South Korea is the only other country that accounted for a substantial share of the OECD total (3.1 percent in 2000, which was higher than expenditures in either Canada or Italy). In only four other countries (the Netherlands, Australia, Sweden, and Spain) did R&D expenditures exceed 1 percent of the OECD R&D total (OECD 2002d).[60]

Figure 4-22
U.S., G-7, and OECD countries R&D expenditures: 1985–2001



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

NOTE: Non-U.S. G-7 countries are Canada, France, Germany, Italy, Japan, and the United Kingdom.

SOURCE: OECD, *Main Science and Technology Indicators,* 2002. See appendix table 4-43.

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[58]Current members of the Organisation for Economic Co-operation and Development (OECD) are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.

[59]Although purchasing power parities (PPPs) technically are not equivalent to R&D exchange rates, they better reflect differences in countries' research costs than do market exchange rates.

[60]Data for 2000 were unavailable for Sweden, but in 1999 it accounted for 1.4 percent of the OECD total.

Although non-OECD countries also fund and perform R&D, most of these national R&D efforts are comparatively small. In 2000, for example, R&D expenditures in China and Russia totaled $50.3 and $10.6 billion (PPP dollars), respectively, and nondefense R&D expenditures in Israel totaled $5.6 billion (PPP dollars) (OECD 2002d). Among non-OECD members of Red Iberomericana de Indicadores de Ciencia y Tecnologia (RICYT), the largest R&D expenditures are reported for Brazil ($4.6 billion in U.S. dollars at market exchange rates in 1999), Argentina ($1.3 billion in 2000), Chile ($0.4 billion in 2000), and Colombia ($0.2 billion in 2000) (RICYT 2002). The combined R&D expenditures of these seven countries (approximately $73 billion) would raise the OECD world total by about 12 percent, and about two-thirds would be derived from China alone.

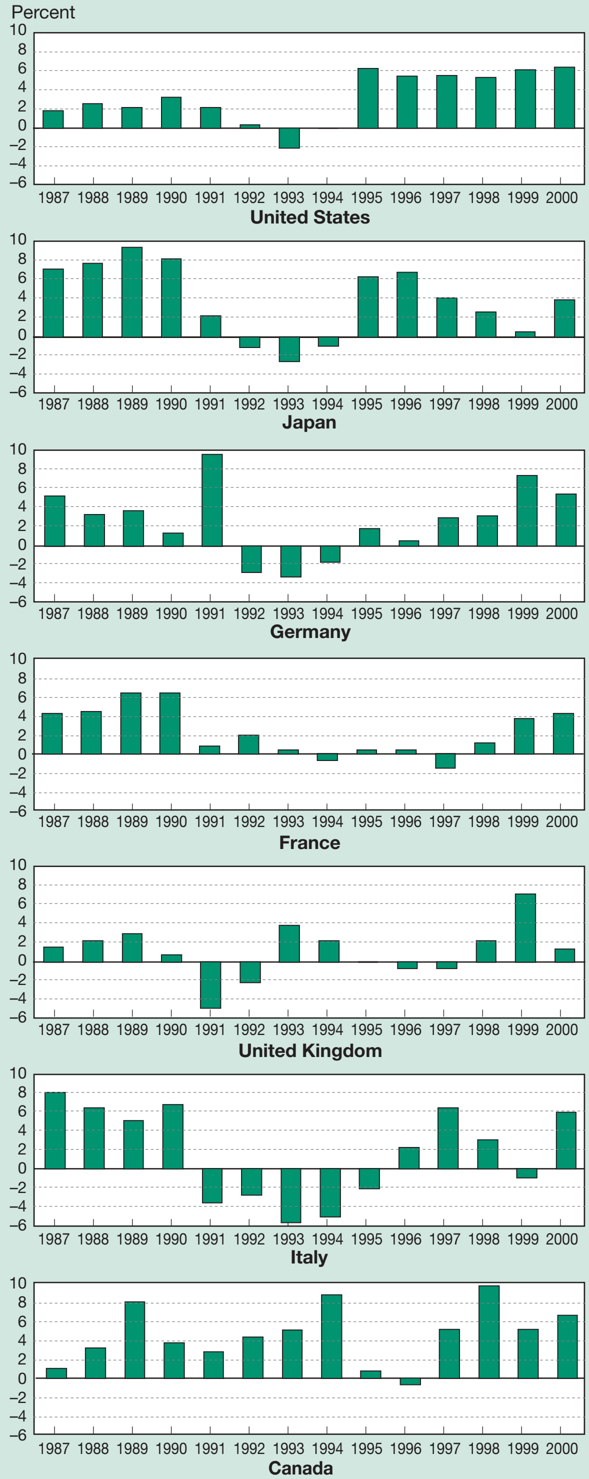
In terms of relative shares, U.S. R&D expenditures in 1984 reached historical highs of 55 percent of the G-7 total and 47 percent of the OECD total.[61] As a proportion of the G-7 total, U.S. R&D expenditures declined steadily to a low of 48 percent in 1991 and then increased to 52 percent in 2000. (See figure 4-22 for actual expenditure totals.) The U.S. share of total OECD expenditures for R&D has increased similarly. By 1994 the U.S. share had dropped to 42 percent of the OECD R&D total, partly the result of several countries joining OECD (thereby increasing the OECD R&D totals). The U.S. share climbed back to 44 percent of the OECD total by 2000 as a result of robust R&D growth in the United States.

Most of the increase in the U.S. percentage of total G-7 R&D expenditures after the early 1990s initially resulted from a worldwide slowing in R&D performance that was more pronounced in other countries. Although U.S. R&D spending stagnated or declined for several years in the early to mid-1990s, the reduction in real R&D spending in most of the other large R&D-performing countries was more striking. In Japan, Germany, and Italy, inflation-adjusted R&D spending fell for 3 consecutive years (1992, 1993, and 1994) at a rate exceeding the similarly falling rate in the United States[62] (OECD 2002d). In the late 1990s, R&D spending rebounded in several G-7 countries and in the United States. Because annual R&D growth was generally stronger in the United States than elsewhere (figure 4-23), however, the U.S. percentage of total G-7 R&D spending continued to increase. Although the slowdown in the technology market in 2001 and 2002 has had a global reach, it remains to be seen

[61]OECD maintains R&D expenditure data that can be categorized into three periods: (1) 1981 to the present (data are properly annotated and of good quality); (2) 1973 to 1980 (data are probably of reasonable quality, and some metadata are available); and (3) 1963 to 1972 [data are questionable for most OECD countries (with notable exceptions of the United States and Japan), many of which launched their first serious R&D surveys in the mid-1960s]. The analyses in this chapter are limited to data for 1981 and subsequent years.

[62]The United Kingdom similarly experienced 3 years of declining real R&D expenditures, but its slump took place in 1995, 1996, and 1997. The falling R&D totals in Germany were partly a result of specific and intentional policies to eliminate redundant and inefficient R&D activities and to integrate the R&D efforts of the former East Germany and West Germany into a united German system.

Figure 4-23
Rate of change in total inflation-adjusted R&D spending: 1987–2000



NOTES: Data for Japanese R&D in 1996 and later years may not be consistent with data in earlier years because of changes in methodology. Germany data for 1987–90 are for West Germany.

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix table 4-43.

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Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data

Comparisons of international R&D statistics are hampered because R&D expenditures are denominated in the performing country's currency. Two approaches are commonly used to normalize the data and facilitate aggregate R&D comparisons: (1) dividing R&D by GDP, which results in indicators of relative effort according to total economic activity and circumvents the problem of currency conversion, and (2) converting all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation that permits only gross national comparisons. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D investments, but it entails choosing an appropriate currency conversion series.

Market Exchange Rates and Purchasing Power Parity Rates

Because (for all practical purposes) no widely accepted R&D-specific exchange rates exist, the choice is between market exchange rates (MERs) and purchasing power parities (PPPs) (OECD 2002d). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

Market Exchange Rates. At their best, MERs represent the relative value of currencies for goods and services that are traded across borders; that is, MERs measure a currency's relative international buying power. Sizable portions of most countries' economies do not engage in international activity, however, and major fluctuations in MERs greatly reduce their statistical utility. MERs also are vulnerable to a number of distortions, including currency speculation, political events such as wars or boycotts, and official currency intervention, which have little or nothing to do with changes in the relative prices of internationally traded goods.

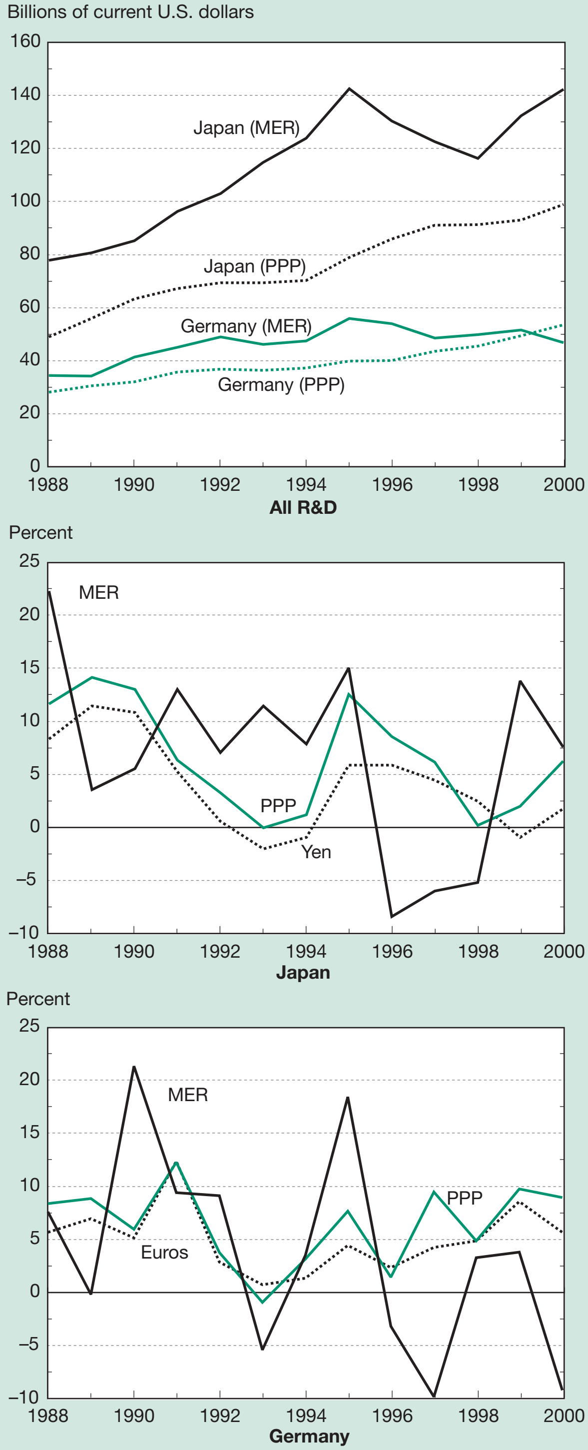
PPP Rates. Because of the MER shortcomings described above, the alternative currency conversion series of PPPs was developed (Ward 1985). PPPs take into account the cost differences across countries of buying a similar basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is, therefore, representative of total GDP across countries. When the PPP formula is applied to current R&D expenditures of other major performers, such as Japan and Germany, the result is a substantially lower estimate of total R&D spending than that given by MERs (figure 4-24). For example, Japan's R&D in 1998 totaled $91 billion based on PPPs and $116 billion based on MERs, and the German R&D expenditure was $45 billion on PPPs and $50 billion on MERs. (In comparison, the U.S. R&D expenditure was $226 billion in 1998.)

PPPs are the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official R&D tabulations of the Organisation of Economic Co-operation and Development (OECD). Unfortunately, they are not available for all countries and currencies. They are available for all OECD countries, however, and are therefore used in this report.

Exchange Rate Movement Effects

Although the goods and services included in the market basket used to calculate PPP rates differ from the major components of R&D costs—fixed assets as well as wages of scientists, engineers, and support personnel—they still result in a more suitable domestic price converter than one based on foreign trade flows. Exchange rate movements bear little relationship to changes in the cost of domestically performed R&D (figure 4-24). When annual changes in Japan's and Germany's R&D expenditures are converted to U.S. dollars with PPPs, they move in tandem with such funding denominated in their home currencies. Changes in dollar-denominated R&D expenditures converted with MERs exhibit wild fluctuations that are unrelated to the R&D purchasing power of those investments. MER calculations indicate that, between 1988 and 2000, German and Japanese R&D expenditures each increased twice by 15 percent or more. In reality, nominal R&D growth was only a fourth to a third of those rates in either country during this period. PPP conversions generally mirror the R&D changes denominated in these countries' home currencies.

Figure 4-24
R&D expenditures and annual changes in R&D estimates, Japan and Germany: 1988–2000



MER market exchange rate
PPP purchasing power parity

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix tables 4-2 and 4-43.

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whether the sharp slowdown in U.S. R&D expenditures in 2001 and 2002 will be as pronounced internationally.

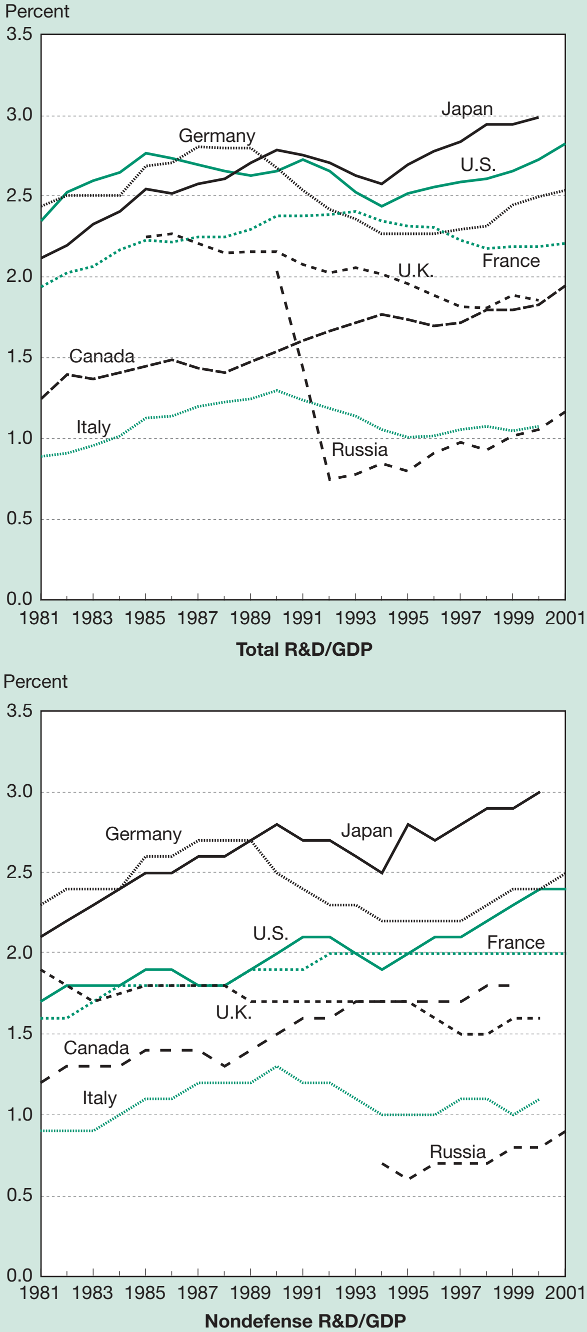
Trends in Total R&D/GDP Ratios

One of the first and now one of the more widely used indicators of a country's R&D intensity is the ratio of R&D spending to GDP (Steelman 1947) (figure 4-25). For many of the G-8 countries (that is, the G-7 countries plus Russia), the latest R&D/GDP ratio is no higher now than it was at the start of the 1990s, which ushered in a period of slow growth or decline in their overall R&D efforts.[63] The United States and Japan reached 2.7 and 2.8 percent, respectively, in 1990–91. As a result of reduced or level spending by industry and government in both countries, the R&D/GDP ratios declined several tenths of a percentage point, to 2.4 and 2.6, respectively, in 1994 before rising again to 2.7 and 3.0 percent in 2000. Growth in industrial R&D accounted for much of the recovery in each of these countries. However, the steady increase in Japan's R&D/GDP ratio in 1994–2000 is also partially a result of anemic economic conditions overall: GDP fell in both 1998 and 1999 with only a marginal increase in 2000, so that even level R&D spending resulted in a slight increase in its R&D ratio (OECD 2002d).

Among the remaining six G-8 countries, three (Germany, Canada, and Russia) display recent increases in their economy's R&D/GDP ratio, and three (the United Kingdom, France, and Italy) report an R&D/GDP ratio that has remained stable or has declined. In Germany the R&D/GDP ratio fell from 2.8 percent at the end of the 1980s, before reunification, to 2.3 percent in 1994 before rising to 2.5 percent in 2001. Canada's R&D/GDP ratio also rose in the late 1990s from 1.7 percent in 1996 to 1.9 percent in 2001. The end of the cold war and collapse of the Soviet Union had a drastic effect on Russia's R&D intensity. R&D spending in Russia was estimated at 2.0 percent of GDP in 1990; that figure plummeted to 1.4 percent in 1991 and then tumbled further to 0.7 percent in 1992. Moreover, the severity of this R&D decline is masked somewhat: although the R&D share was falling, it also was a declining share of a declining GDP. By 1999 the R&D/GDP ratio in Russia had inched back to about 1.0 percent; it accelerated to 1.2 percent in 2001 as R&D performance in the country grew by more than 30 percent in real terms over those 2 years. In comparison, the R&D/GDP ratio slipped slightly in the United Kingdom in the late 1990s to 1.9 percent in 2000. Between 1997 and 2001, the R&D/GDP ratio fluctuated narrowly at 2.2 and 1.1 percent in France and Italy, respectively.

[63]A country's R&D spending and therefore its R&D/GDP ratio is a function of several factors in addition to its commitment to supporting the R&D enterprise. Especially because the majority of R&D is performed by industry in each of these countries, the structure of industrial activity can be a major determinant of a country's R&D/GDP ratio. For example, economies with high concentrations in manufacturing (which traditionally have been more R&D intensive than nonmanufacturing or agricultural economies) have different patterns of R&D spending. See "Industrial Sector" for further discussion of such considerations.

Figure 4-25
R&D share of GDP, selected countries: 1981–2001



GDP gross domestic product
U.K. United Kingdom
U.S. United States

SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix tables 4-43 and 4-44.

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Overall, the United States ranked fifth among OECD countries in terms of reported R&D/GDP ratios (table 4-17). Israel (not an OECD member country), devoting 4.4 percent of its GDP to R&D, led all countries, followed by Sweden (3.8 percent), Finland (3.4 percent), Japan (3.0 percent), and Iceland (2.9 percent). In general, nations in Southern and Eastern Europe tend to have R&D/GDP ratios below 1.5 percent, whereas Nordic nations and those in Western Europe report R&D spending shares greater than 1.5 percent. In a broad sense, the reason for such patterns has much to do with overall funding patterns and macroeconomic structures.

In practically all OECD countries, the business sector finances most of the R&D. However, OECD countries with relatively low R&D/GDP ratios tend to be relatively low-income countries, where government funding tends to provide a larger proportion of the R&D support than it provides in countries with high R&D/GDP ratios. Furthermore, the private sector in low-income countries often has a low concentration of high-technology industries, resulting in low overall R&D spending and therefore low R&D/GDP ratios. Indeed, a strong link exists between countries with high incomes that emphasize the production of high-technology goods and services and those that invest heavily in R&D activities (OECD 2000).[64] This highlights that R&D/GDP ratios are most useful when comparing countries with national S&T systems of comparable maturity and development.

Outside the European region, R&D spending has intensified considerably since the early 1990s. Several Asian countries, most notably South Korea and China, have been particularly aggressive in expanding their support for R&D and S&T-based development. In Latin America and the Pacific region, other non-OECD countries also have attempted to increase R&D investments substantially during the past several years. Even with recent gains, however, most non-European (non-OECD) countries invest a smaller share of their economic output in R&D than do OECD members (with the exception of Israel). All Latin American countries for which such data are available report R&D/GDP ratios below 1 percent (table 4-17). This distribution is consistent with broader indicators of economic growth and wealth. However, many of these countries also report additional S&T-related expenditures on human resources training and S&T infrastructure development that are not captured in R&D or R&D/GDP data (RICYT 2002).

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

Although the R&D intensities of many countries have changed little over the past decade, there have been significant changes in the composition of their R&D. One indicator

[64]See OECD (1999) for further discussion of these and other broad R&D indicators.

Table 4-17
R&D share of gross domestic product, by country/economy: 1997–2001

Country/economy	Percent	Country/economy	Percent
Total OECD (2000)	2.24	Italy (2000)	1.07
European Union (2000)	1.88	New Zealand (1999)	1.03
Israel (2001)	4.43	China (2000)	1.00
Sweden (1999)	3.78	Spain (2001)	0.97
Finland (2000)	3.37	Brazil (1999)	0.87
Japan (2000)	2.98	Cuba (2000)	0.82
Iceland (2001)	2.90	Hungary (2000)	0.80
United States (2001)	2.71	Portugal (1999)	0.76
South Korea (2000)	2.65	Greece (1999)	0.67
Switzerland (2000)	2.64	Poland (2001)	0.67
Germany (2001)	2.53	Slovak Republic (2001)	0.65
France (2001)	2.20	Turkey (2000)	0.64
Singapore (2001)	2.11	Chile (2000)	0.54
Denmark (1999)	2.09	Mexico (1999)	0.43
Taiwan (2000)	2.05	Argentina (2001)	0.42
Netherlands (2000)	1.97	Romania (2001)	0.40
Belgium (1999)	1.96	Panama (1999)	0.35
Canada (2001)	1.94	Bolivia (2000)	0.28
Austria (2001)	1.91	Costa Rica (1998)	0.27
United Kingdom (2000)	1.85	Uruguay (1999)	0.26
Australia (2000)	1.53	Colombia (2000)	0.24
Slovenia (2000)	1.52	Trinidad and Tobago (1997)	0.14
Norway (2001)	1.46	Nicaragua (1997)	0.13
Czech Republic (2001)	1.31	Ecuador (1998)	0.08
Ireland (1999)	1.21	El Salvador (1998)	0.08
Russian Federation (2001)	1.16	Peru (1999)	0.08

OECD Organisation for Economic Co-operation and Development

NOTES: Civilian R&D only for Israel and Taiwan. Data are presented for the latest available year, in parentheses.

SOURCES: OECD, Main Science and Technology Indicators database, 2002; and Iberomerican Network of Science and Technology Indicators, *Principales Indicadores de Ciencia y Tecnologia Argentina 2001* (Buenos Aires, 2002).

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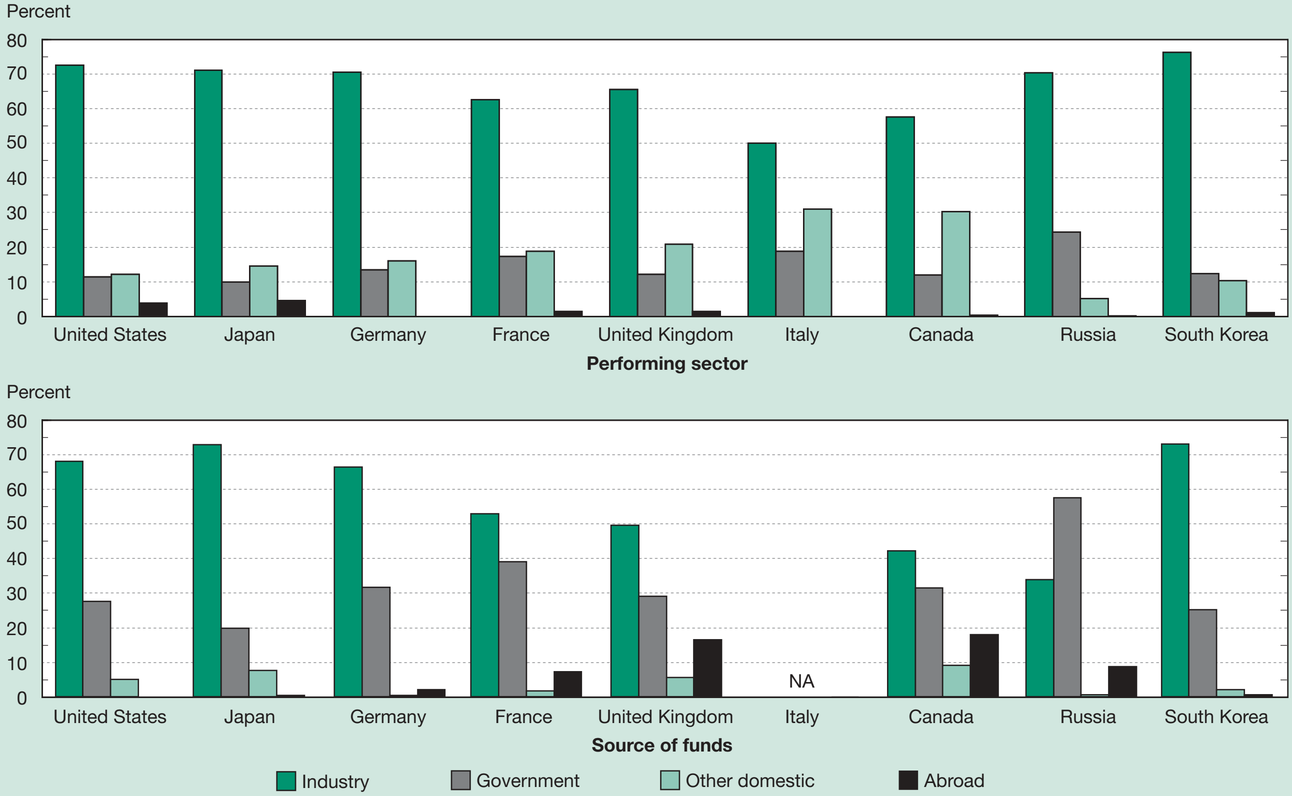
of these changes is the relative increase in nondefense R&D. Although defense-related R&D does result in spillovers that produce social benefits, nondefense R&D is more directly oriented toward national scientific progress, standard-of-living improvements, economic competitiveness, and commercialization of research results. Indeed, conclusions about a country's relative standing may differ dramatically, depending on whether total R&D expenditures include or exclude defense-related expenditures; for some countries, the relative emphasis has shifted over time. Among G-8 countries, the inclusion of defense-related R&D has had little impact on R&D totals for Japan, Germany, Italy, and Canada, where defense-related R&D represents 5 percent or less of the national total. In other countries, defense has accounted for a more significant proportion of the national R&D effort, although this proportion has generally declined since the end of the cold war. Between 1988 and 2000, the defense share of the R&D total:

- ♦ Fell from 31 to 14 percent in the United States
- ♦ Fell from 19 to 8 percent in France
- ♦ Fell from 16 to 15 percent in the United Kingdom
- ♦ Accounted for approximately 24 percent of the Russian R&D total in 2000

Consequently, if current trends persist, the distinction between defense and nondefense R&D expenditures in international comparisons may become less important. In absolute dollar terms, nondefense R&D spending is still considerably larger in the United States than in other countries. In 2000 (the latest year for which comparable international R&D data are available for most OECD countries), U.S. nondefense R&D was more than twice that of Japan's and was equivalent to 97 percent of the non-U.S. G-7 countries' combined nondefense R&D total (appendix table 4-44).

In terms of R&D/GDP ratios, the relative position of the United States is somewhat less favorable when only nondefense R&D is included in the metric. Japan's nondefense R&D/GDP ratio (3.0 percent) exceeded the U.S. ratio (2.4 percent) in 2000, as it has for years (figure 4-25 and appendix table 4-44). In 2001, Germany's nondefense R&D/GDP ratio (2.5 percent) slightly exceeded the U.S. ratio (2.4 percent). The 2001 nondefense ratio for France (2.0 percent) was slightly below the U.S. ratio. In 1999–2000, ratios for the United Kingdom (1.6 percent in 2000), Canada

Figure 4-26
R&D expenditures for selected countries, by performing sector and source of funds: 2000 or 2001



NA not available

NOTES: Separate data on foreign sources of R&D funding are unavailable for the United States but are included in the sector totals. In most other countries, "foreign sources of funding" is a distinct and separate funding category. For some countries (such as Canada), foreign firms are the source of a large amount of foreign R&D funding, which is reported as funding from abroad. In the United States, industrial R&D funding from foreign firms is reported as industry. Data for Japan, France, United Kingdom, and Italy are for 2000. Data for the United States, Germany, Canada, Russia, and South Korea are for 2001.

SOURCES: Organisation for Economic Co-operation and Development, special tabulations, 2003; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources,* annual series. See appendix table 4-45.

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(1.8 percent in 1999), and Italy (1.1 percent in 2000) were considerably lower than U.S. ratios. In 2001 the nondefense R&D/GDP ratio for Russia (0.9 percent) was less than half the U.S. ratio.

International R&D by Performer, Source, and Character of Work

R&D performance patterns by sector are broadly similar across countries, but national sources of support differ considerably. In nearly all OECD countries, government has provided a declining share of all R&D funding during the past 2 decades, and the industrial share of R&D funding has increased considerably. The emphases of industrial R&D efforts, however, differ across countries, as do governmental R&D priorities and academic S&E field research emphases, as described subsequently in this chapter.

Government and industry together account for roughly 80 percent or more of the R&D funding in each of the G-8 countries, although the respective contributions vary substantially across countries.[65] In recent years, the industrial sector provided more than 70 percent of R&D funds in Japan, 68 percent in the United States, 66 percent in Germany, 53 percent in France, 49 percent in the United Kingdom, and 44 percent in Canada[66] (figure 4-26). In Russia, industry provided approximately 34 percent of the nation's R&D funding. Government provided the largest share of Russia's

[65]In accordance with international standards, the following sectors are recognized sources of funding: all levels of government combined, business enterprises, higher education, private nonprofit organizations, and funds from abroad. Because data on foreign sources of R&D funding are unavailable for the United States, the figures reported for the share of industrial R&D funding in the United States include funding from both foreign and domestic sources.

[66]Canada and the United Kingdom both report relatively large amounts of R&D funding from abroad, much of which originates from business enterprises. Therefore, industry's shares of R&D funding for these countries are particularly understated compared with those for the United States. Distribution of R&D by source of funds was not available for Italy for 2000. In earlier years, government sources accounted for more than half of Italy's R&D, industry accounted for more than 40 percent, and foreign sources funded the remainder.

R&D (57 percent), as it did in Italy in past years (more than 50 percent in 1999). In the remaining six countries, government was the second largest source of R&D funding, ranging from 20 percent (in Japan) to 39 percent (in France) of the total. In each of these eight countries, government provided the largest share of the funds used for academic R&D performance (appendix table 4-45).

The industrial sector dominates R&D performance in each of the G-8 countries (figure 4-26). Industry's share of R&D performance for the 2000–2001 period ranged from 50 percent in Italy to a little more than 70 percent in the United States, Japan, Germany, and Russia. During the same period, industry's share was between 57 and 66 percent in Canada, France, and the United Kingdom. Most of the industrial R&D in these countries was funded by industry. Government's share of funding for industrial R&D ranged from as little as 2 percent in Japan and Canada to 49 percent in Russia (appendix table 4-45). In the other G-8 countries, government funded between 7 and 11 percent of industrial R&D.

In all of the G-8 countries except Russia, the academic sector was the second largest R&D performer (about 12 to 31 percent of the performance total in each country).[67] Academia often is the primary location of research (as opposed to R&D) activities, however. Government was the second largest R&D performer in Russia (accounting for 24 percent of that nation's R&D effort). Government also performed a larger proportion of R&D in France, which operates some sizable government laboratories.

South Korea, with total R&D expenditures in excess of either Canada or Italy, has R&D distributions by performing sector and source of funds very similar to those of the United States. Industry performed an even greater share of South Korea's R&D (76 percent) than it did in any of the G-8 countries and was also the largest source of R&D funding in South Korea (accounting for 73 percent of all funding). The South Korean government provided most of the remaining R&D funding (25 percent of all funding). About 45 percent of government R&D funding in South Korea went to government performers of R&D, with the remainder going primarily to academic (29 percent) and industrial performers (25 percent).

Academic Sector

In many OECD countries, the academic sector is a distant second to industry in terms of national R&D performance. Among G-8 countries, universities accounted for as little as 5 percent of Russia's R&D total to more than 31 percent of Italy's.[68]

Source of Funds. For most of these countries, the government is now, and historically has been, the largest source of academic research funding. However, in each of the G-8 countries for which historical data exist (except Russia), the government's share has declined during the past 20 years, and industry's share has increased. Specifically, the government's share, including both direct government support for academic R&D and the R&D component of block grants to universities, has fallen by 8 percentage points or more in five of the G-7 countries since 1981 (except in France and Italy, where the government's share of academic R&D dipped by 6 and 2 percentage points, respectively).[69] In comparison, and as an indication of an overall pattern of increased university-firm interactions (often intending to promote the commercialization of university research), the proportion of academic R&D funded by industry for these seven countries combined climbed from 2.6 percent of the academic R&D total in 1981 to 5.2 percent in 1990 and to 6.0 percent in 1999. In Germany, more than 11 percent of university research was funded by industry in 2000 (table 4-18).

S&E Fields. Most countries supporting a substantial level of academic R&D (at least $1 billion PPPs in 1999) devote a larger proportion of their R&D to engineering, social sciences, and humanities than does the United States[70] (table 4-19). Conversely, the U.S. academic R&D effort emphasizes the medical sciences and natural sciences relatively more than do many other OECD countries.[71] The latter observation is consistent with the emphases in health and

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[67]The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants (not to be confused with basic research) provided by all levels of government to the academic sector. Therefore, at least conceptually, the totals include academia's separately budgeted research and research undertaken as part of university departmental R&D activities. In the United States, the Federal Government generally does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. On the other hand, a fair amount of state government funding probably does support departmental research at public universities in the United States. Data on departmental research, considered an integral part of instructional programs, generally are not maintained by universities. U.S. totals are thus underestimated relative to the R&D effort reported for other countries.

[68]Country data are for 2000 or 2001 (appendix table 4-45).

[69]Whereas GUF block grants are reported separately for Japan, Canada, and European countries, the United States does not have an equivalent GUF category. In the United States, funds to the university sector are distributed to address the objectives of the Federal agencies that provide the R&D funds. Nor is GUF equivalent to basic research. The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each individual higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds for which can be assigned to specific socioeconomic categories). In the United States, the Federal Government (although not necessarily state governments) is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere. In each of the European G-7 countries, GUF accounts for 50 percent or more of total government R&D to universities and for roughly 45 percent of the Canadian government academic R&D support. Thus, these data indicate not only relative international funding priorities but also funding mechanisms and philosophies regarding the best methods for financing research.

[70]The national emphases in particular S&E fields differ across countries. Most of the internationally comparable data on field-specific R&D are reported for the academic sector.

[71]In international S&E field compilations, the natural sciences comprise math and computer sciences, physical sciences, environmental sciences, and all life sciences other than medical and agricultural sciences. Note also that the U.S. academic R&D effort is considerably larger than in any other country and that the U.S. total ($26 billion PPP) is comparable to the combined R&D total ($28 billion PPP) of the other seven countries listed in table 4-19.

Table 4-18
Academic R&D expenditures, by country and source of funds: 1981, 1990, and 2000
(Percent)

Country and source of funds	1981	1990	2000
Canada			
Government	78.8	75.0	59.9
Other	17.1	20.0	31.2
Industry	4.1	5.0	8.9
France			
Government	97.7	92.9	91.5
Other	1.0	2.2	5.8
Industry	1.3	4.9	2.7
Germany			
Government	98.2	92.1	85.9
Other	0.0	0.0	2.5
Industry	1.8	7.9	11.6
Italy[a]			
Government	96.2	96.7	94.4
Other	1.1	0.9	0.8
Industry	2.7	2.4	4.8
Japan			
Government	57.8	51.2	50.2
Other	41.2	46.5	47.3
Industry	1.0	2.3	2.5
United Kingdom			
Government	81.3	73.5	64.7
Other	15.9	18.9	28.2
Industry	2.8	7.6	7.1
United States			
Government	74.1	66.9	65.0
Other	21.5	26.2	27.9
Industry	4.4	6.9	7.1

[a]Italian data are for 1999.

SOURCES: Organisation for Economic Co-operation and Development, Science and Technology Statistics database, 2003; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series).

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biomedical sciences for which the United States (and in particular NIH and U.S. pharmaceutical companies) is known.

Industrial Sector

Industrial firms account for the largest share of total R&D performance in each of the G-8 countries. However, the purposes to which the R&D is applied differ somewhat, depending on the overall industrial composition of each country's economy. Funding patterns for industrial R&D also differ from country to country, with respect to both domestic sources of funds as well as the relative proportion of foreign funding.

Sector Focus. The structure of a country's industrial activity can be a major determinant of the level and change in industrial R&D spending. National variations in such spending can result from differences in absolute output, industrial structure, and R&D intensity. Countries with the same size economy could have vastly different R&D expenditure levels (and R&D/GDP ratios). Differences might depend on the share of industrial output in the economy, as illustrated in figure 4-27 for the G-8 countries, South Korea, and China. Highly aggregated sector distributions can be deceiving, however, as some nations have much higher concentrations of R&D-intensive industries such as pharmaceutical manufacture as opposed to food processing. And even individual firms in the same industries can devote substantial resources to specific R&D activities in one country and to other activities in another country. Table 4-20 shows recent distributions of industrial R&D performance in the G-8 countries and South Korea, Sweden, Finland, and the European Union.[72]

The sector distribution of U.S. industrial R&D performance is among the most widespread and diverse among OECD members. The accumulated knowledge stock, well-developed S&T infrastructure, and large domestic market in the United States have enabled it to invest and become globally competitive in numerous industries rather than just a few industries or niche technologies. In 2000 no U.S. industrial sector accounted for more than the 13 percent of

[72]Similar industrial R&D details for Israel and Iceland (which report the highest and fifth highest R&D/GDP ratios in the world, respectively) were not available from OECD harmonized databases (OECD 2002a).

Table 4-19
Shares of academic R&D expenditures, by country and S&E field: 1998 or 1999

Field	United States	Japan	Germany	Australia	South Korea	Spain	Sweden	Russia
	Billions of 1995 PPP dollars							
Total academic R&D	25.7	13.4	7.5	1.9	1.5	1.8	1.6	0.4
	Percent distribution							
Total academic R&D								
NS&E	93.7	65.6	78.4	73.0	91.6	77.9	76.3	88.3
Natural sciences	41.8	11.4	29.2	27.5	18.5	39.4	21.0	59.0
Engineering	15.5	25.0	20.3	16.1	49.1	18.7	21.9	26.7
Medical sciences	29.1	24.6	24.7	22.8	17.0	14.2	27.4	1.7
Agricultural sciences	7.4	4.6	4.2	6.6	7.0	5.6	6.1	0.9
Social sciences and humanities	6.3	34.4	20.6	27.0	8.4	22.1	17.6	11.7
Social sciences	6.3	NA	8.5	19.5	NA	14.8	11.5	6.6
Humanities	NA	NA	12.1	7.6	NA	7.3	6.1	5.1
Academic NS&E								
NS&E	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Natural sciences	44.6	17.3	37.3	37.7	20.2	50.6	27.5	66.8
Engineering	16.5	38.2	25.9	22.1	53.6	24.0	28.7	30.2
Medical sciences	31.0	37.5	31.5	31.2	18.5	18.2	35.9	1.9
Agricultural sciences	7.9	7.0	5.3	9.0	7.7	7.2	7.9	1.1

NA detail not available but included in totals
NS&E natural sciences and engineering
PPP purchasing power parity

NOTES: Percents may not sum to 100 because of rounding. Data for Australia, South Korea, and Russia are for 1998; all other data are for 1999.

SOURCES: Organisation for Economic Co-operation and Development, Science and Technology Statistics database, 2003; and Centre for Science Research and Statistics, *Russian Science and Technology at a Glance: 2000* (Moscow, 2001).

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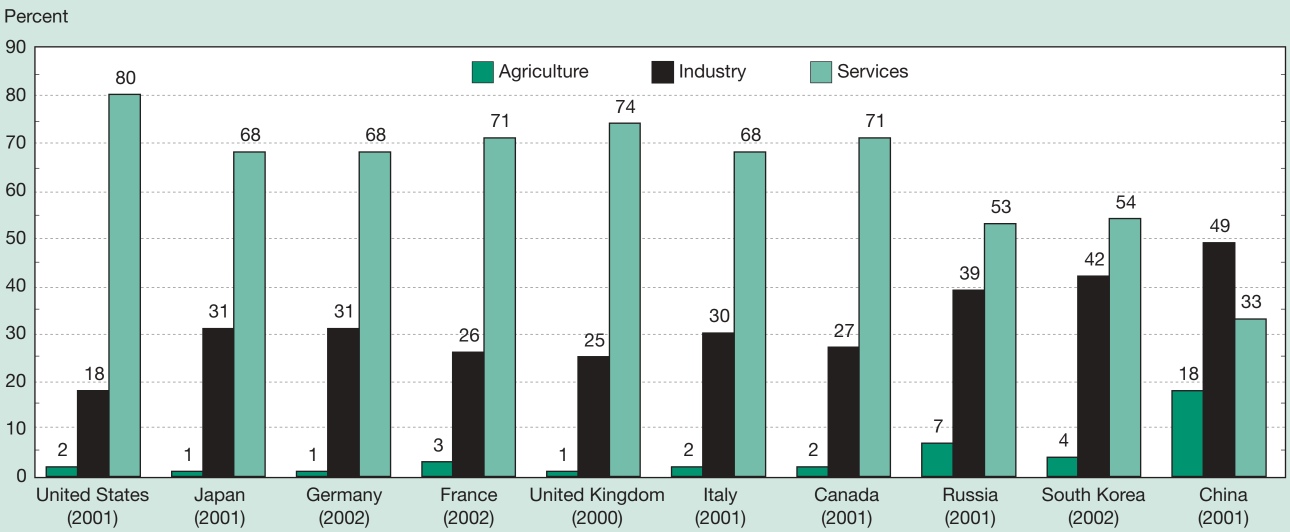
Figure 4-27
Composition of GDP for selected countries, by sector: 2000, 2001, or 2002



GDP gross domestic product

NOTES: Government purchases are included in sector shares. In 2001, government purchases represented 12.4 percent of U.S. GDP.

SOURCE: Central Intelligence Agency, *The World Fact Book 2002*, http://www.cia.gov/cia/publications/factbook/index.html.

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Table 4-20
Industrial R&D, by industry sector for selected countries: Selected years, 1997–2000

Industry	United States (2000)	Canada (2000)	Germany (2000)	France (1999)	Italy (2000)	Japan (2000)	United Kingdom (2000)	Russian Federation (1997)	South Korea (2000)	Sweden (1999)	Finland (2000)	European Union (1999)
	Billions of PPP dollars											
Total	199.5	9.0	37.4	19.2	7.4	69.7	17.8	5.7	14.1	5.9	3.1	101.7
	Percent distribution											
All business enterprise	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Manufacturing	64.9	67.3	91.3	85.7	79.9	95.0	80.2	36.8	83.7	85.4	85.0	84.3
Food, beverages, and tobacco	0.8	1.0	0.6	1.8	1.3	2.4	2.3	0.1	1.4	0.9	1.6	1.7
Textiles, fur, and leather	0.1	0.7	0.6	0.5	0.3	0.7	0.3	0.1	0.9	0.1	0.4	0.5
Wood, paper, printing, and publishing	1.6	1.3	0.4	0.4	0.3	1.1	0.3	0.2	0.4	2.4	3.5	0.7
Coke, refined petroleum products, and nuclear fuel	0.6	0.5	0.1	1.4	0.9	0.3	1.6	0.5	2.0	0.2	0.8	0.8
Chemicals (less pharmaceuticals)	4.2	1.4	10.9	6.1	5.1	8.1	5.9	1.8	4.7	1.6	2.4	NA
Pharmaceuticals	6.5	6.1	6.1	13.2	8.6	6.9	24.7	0.2	1.4	16.5	5.0	NA
Rubber and plastic products	0.8	0.4	1.7	2.8	1.8	2.4	0.5	0.3	1.4	0.7	1.9	1.7
Nonmetallic mineral products	0.4	0.1	1.2	1.3	0.3	1.6	0.4	0.2	0.5	0.2	0.6	0.9
Basic metals	0.3	1.4	0.7	1.4	0.4	2.8	0.5	1.1	1.3	2.0	1.0	1.0
Fabricated metal products	1.0	1.1	1.4	1.0	0.6	1.1	0.6	0.2	0.6	0.3	2.2	1.1
Machinery NEC	3.4	2.2	9.5	4.5	7.5	9.3	6.1	11.9	2.8	8.7	7.6	7.6
Office, accounting, and computing machinery	5.2	4.8	1.9	1.9	1.1	10.8	1.0	0.0	7.1	0.7	0.1	1.8
Electrical machinery	1.9	1.4	3.0	3.7	2.3	9.8	3.7	1.3	1.7	1.4	4.6	3.1
Electronic equipment (radio, television, and communications)	12.9	28.8	10.7	12.5	19.3	18.8	8.9	3.2	36.7	23.4	49.2	13.5
Instruments, watches, and clocks	9.6	1.3	4.9	6.7	2.9	4.5	4.2	0.8	1.0	5.7	2.7	4.6
Motor vehicles	9.3	1.9	29.6	13.4	15.4	12.4	7.5	3.2	14.3	17.0	0.4	16.1
Other transport equipment (less aerospace)	0.6	0.1	1.0	0.6	1.2	0.3	2.0	3.0	1.9	0.5	0.6	1.0
Aerospace	5.2	12.3	6.6	11.8	10.5	0.8	9.5	8.7	2.9	2.9	0.1	7.6
Furniture, other manufacturing NEC	0.4	0.6	0.5	0.8	0.2	0.9	0.2	0.0	0.8	0.2	0.3	0.5
Recycling	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	NA	0.2	NA
Electricity, gas, and water	0.1	1.6	0.3	2.5	0.2	0.9	1.4	0.5	1.8	0.6	1.2	NA
Construction	0.1	0.2	0.2	0.9	0.2	1.7	0.3	0.9	3.7	0.4	1.0	NA
Agriculture and mining	NA	NA	NA	NA	NA	NA	NA	3.3	NA	NA	NA	NA
Services	34.4	29.0	7.8	9.1	19.7	2.1	16.6	58.5	10.5	12.8	12.0	13.0
Wholesale, retail trade, motor vehicle repair, etc.	12.6	7.3	NA	0.0	0.4	NA	NA	0.0	0.3	0.2	0.1	NA
Hotels and restaurants	NA	NA	NA	0.0	0.0	NA	NA	0.0	0.0	NA	NA	NA
Transport and storage	0.1	0.2	NA	3.6	0.1	0.2	NA	0.5	0.5	0.0	0.5	NA
Communications	0.7	0.9	NA	NA	0.1	NA	5.9	0.7	3.6	2.6	6.1	NA
Financial intermediation (including insurance)	2.0	1.9	NA	NA	1.2	NA	NA	0.0	0.0	NA	NA	NA
Computer and related activities	7.4	6.2	NA	2.5	2.5	1.9	5.3	1.1	3.9	4.5	3.8	3.7
Research and development	7.0	10.5	2.5	NA	12.9	NA	3.7	44.9	0.3	4.8	NA	NA
Other business activities NEC	NA	1.9	NA	3.0	2.2	NA	1.1	0.4	1.8	0.6	0.3	2.2
Community, social, and personal service activities, etc.	NA	NA	NA	NA	0.2	NA	0.1	10.9	0.2	0.0	1.2	NA

NA not available separately
NEC not elsewhere classified
PPP purchasing power parity

NOTES: Data for communications industry in United States include only telecommunications R&D. Analytical Business Enterprise Research and Development (ANBERD) data not available for Switzerland. Data are for years listed under country names.

SOURCES: Organisation for Economic Co-operation and Development (OECD), ANBERD database, 2002; and OECD, *R&D Efforts in China, Israel, and Russia: Some Comparisons With OECD Countries* (Paris, 2000).

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total industrial R&D concentrated in the electronic equipment manufacturing sector. In comparison, most of the other countries displayed somewhat higher sector concentrations. For example, 20 percent or more of industrial R&D was concentrated in electronic equipment manufacturing in Finland (at 49 percent of its industry total), South Korea (37 percent), Canada (29 percent), and Sweden (23 percent). Indeed, the electronic equipment sector was among the largest performers of industrial R&D in 7 of the 11 countries shown and was the second largest performer of industrial R&D for the entire European Union. Among other manufacturing sectors, motor vehicles in Germany and pharmaceuticals in the United Kingdom accounted for 20 percent or more of total R&D performance, which was consistent with general economic production patterns. [See OECD (2001) for a harmonized historical series on industrial R&D expenditures in several OECD countries.]

One of the more significant trends in both U.S. and international industrial R&D activity has been the growth of R&D in the service (nonmanufacturing) sector. According to the internationally harmonized data in table 4-20, this sector accounted for 34 percent of total industrial R&D performance in the United States in 2000.[73] A number of other countries also reported substantial increases in their service sector R&D expenditures during the past 25 years. Among G-7 countries, nonmanufacturing shares of total industrial R&D increased about 5 percentage points in France and Italy and 13 percentage points in the United States, United Kingdom, and Canada from the early 1980s to the late 1990s (Jankowski 2001). In each of these three English-speaking countries, computer and related services account for a substantial share of the service R&D totals. (See sidebar, "R&D in the ICT Sector.") Furthermore, the service sector appears to be an important locus of industrial R&D activity in several countries, reflecting in part the growth in outsourcing and greater reliance on contract R&D in lieu of in-house performance, as well as intramural R&D in these industries.

According to national statistics for recent years, the nonmanufacturing sector accounted for less than 10 percent of total industrial R&D performance in only three of the G-7 countries (Germany, France, and Japan). Among the countries listed in table 4-20, the service sector share ranged from as little as 2 percent in Japan to 59 percent in Russia. The latter figure, however, primarily occurred because specialized industrial research institutes perform a large portion of Russia's industrial and governmental R&D and are classified under "research and development" within the service sector. Apart from these institutes, the manufacturing-nonmanufacturing split in Russia's industrial R&D would be similar to ratios in the United States [American Association for the Advancement of Science and Centre for Science Research and Statistics (AAAS/CSRS) 2001].

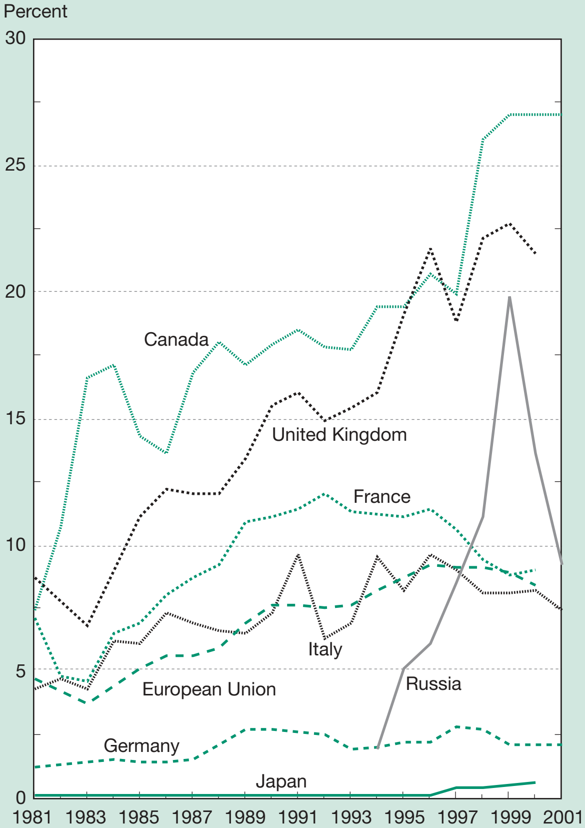
[73]As previously discussed, the recent growth in R&D in the U.S. trade industry reflects statistical procedures more than actual R&D activity in wholesale and retail trade companies.

Source of Funds. Most of the funding for industrial R&D in each of the G-8 countries is provided by industry itself. As is the situation for OECD countries overall, government financing accounts for a small and declining share of total industrial R&D performance within G-7 countries. (See "Government Sector.") Government financing shares ranged from as little as 2 percent of industrial R&D performance in Japan to 11 percent in Italy (appendix table 4-45). (For recent historical reasons, Russia was the exception to this pattern among the G-8 countries, with government accounting for 49 percent of its industry total.) In the United States in 2001, the Federal Government provided about 9 percent of the R&D funds used by industry, and the majority of that funding was obtained through DOD contracts.

Foreign sources of R&D funding increased in many countries between 1981 and 2001 (figure 4-28). The role of foreign funding in R&D varied from country to country, accounting for as little as 0.4 percent of industrial R&D in Japan to as much as 27 percent in Canada in recent years. This foreign funding predominantly came from foreign corporations but also included funding from foreign governments and other foreign organizations. The growth of this funding primarily reflects the increasing globalization of industrial R&D activities. For European countries, however, the growth in foreign sources of R&D funds may also reflect the expansion of coordinated European Community efforts to foster cooperative shared-cost research through its European Framework Programmes.[74] Although the growth pattern of foreign funding has seldom been smooth, it accounted for more than 20 percent of industry's domestic performance totals in Canada and the United Kingdom and almost 10 percent of industrial R&D performed in France and Russia between 1981 and 2001 (figure 4-28). Such funding takes on even greater importance in many of the smaller OECD countries as well as in less industrialized countries (OECD 1999). The recent global slowdown in industrial R&D spending may be reflected in a decline in foreign funding as a share of domestic industrial R&D in the most recent years' data for Italy, the United Kingdom, and Russia. Although data exist on foreign sources of R&D funding for other countries, there are no data on foreign funding sources of U.S. R&D performance. However, the importance of international investment for U.S. R&D is highlighted by the fact that approximately 13 percent of funds spent on industrial R&D performance

[74]Since the mid-1980s, European Community (EC) funding of R&D has become increasingly concentrated in its multinational Framework Programmes for Research and Technological Development (RTD), which were intended to strengthen the scientific and technological bases of community industry and to encourage it to become more internationally competitive. EC funds distributed to member countries' firms and universities have grown considerably. The EC budget for RTD activities has grown steadily from 3.7 billion European Currency Units (ECU) in the First Framework Programme (1984–87) to an estimated 15 billion ECU for the Fifth Framework Programme (1998–2002). The institutional recipients of these funds tend to report the source as "foreign" or "funds from abroad." Eurostat, *Statistics on Science and Technology in Europe: Data 1985–99* (Luxembourg: European Communities, 2001).

Figure 4-28
Industrial R&D financed by foreign sources: 1981–2001



SOURCE: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators,* 2002. See appendix table 4-46.

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in 2000 were estimated to have come from majority-owned affiliates of foreign firms investing domestically.[75]

Government Sector

As in the United States, in most countries the government sector performs much less R&D than it funds. And, also as in the United States, the role of the government as a performer of R&D has been shrinking internationally. The government sector accounted for 13 percent of the OECD R&D performance total as recently as 1995. This share fell to 10 percent of OECD members' combined R&D performance in 2000 (OECD 2002a) and equaled 24 percent or (usually much) less in each of the G-8 countries (appendix table 4-45).

Government R&D Funding Totals. A significant trend in the G-7 and other OECD countries has been the decline in government R&D funding relative to R&D funding from the private sector. In 2000, less than 30 percent of all R&D funds were derived from government sources, down considerably from the 44 percent share reported in 1981[76] (figure 4-29). Part of the relative decline reflects the effects of budgetary constraints, economic pressures, and changing priorities in government funding (especially the relative reduction in defense R&D in several of the major R&D-performing countries, notably France, the United Kingdom, and the United States). This trend also reflects the absolute growth in industrial R&D funding as a response to increasing international competitive pressures in the marketplace, irrespective of government R&D spending patterns. Both of these considerations are reflected in funding patterns for industrial R&D performance. In 1982, government provided 23 percent of the funds used by industry in conducting R&D within OECD countries, whereas by 2000 government's share of the industrial R&D total had fallen by almost two-thirds, to 8 percent of the total.

Government R&D Priorities. A breakdown of public expenditures by major socioeconomic objectives provides insight into government priorities that differ considerably across countries and shift over time.[77] Within OECD, the defense share of governments' R&D financing total declined annually from 44 percent in 1986 to 29 percent in 1999 (table 4-21). Much of this decline was driven by the U.S. experience: 54 percent of the U.S. Government's $98 billion R&D investment during 2002 was devoted to national defense, down from its 69 percent share in 1986.

Concurrent with the changes in overall defense/nondefense R&D shares, notable shifts occurred in the composition of OECD countries' governmental nondefense R&D support during the past 2 decades. In terms of the broad socioeconomic objectives to which government programs are classified in various international reports (OECD 2001 and 2002g), government R&D shares increased most for health and the environment and for various nondirected R&D activities (identified in table 4-21 as *other purposes*).[78] Growth in health-related R&D financing was particularly strong in the United States, whereas many of the other OECD countries reported relatively higher growth in environmental

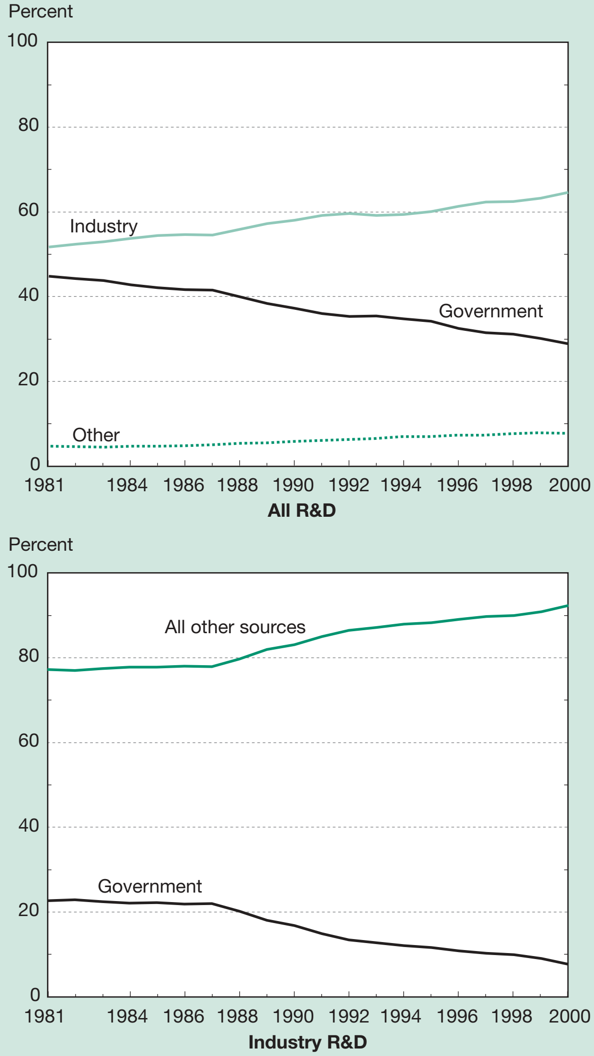
[75]The figures used here to approximate foreign involvement are derived from the estimated percentage of U.S. industrial performance undertaken by majority-owned (i.e., 50 percent or more) nonbank U.S. affiliates of foreign companies. The U.S. foreign R&D totals represent industry funding based on foreign ownership regardless of originating source, whereas the foreign totals for other countries represent flows of foreign funds from outside the country to any of its domestic performers. (See "R&D Investments by Multinational Corporations.")

[76]Among all OECD countries, the government sector accounts for the highest funding share in Portugal (63 percent of its 2000 R&D total) and the lowest share in Japan (20 percent in 2000).

[77]Data on the socioeconomic objectives of R&D funding are generally extracted from national budgets. Because budgets already have their own methodology and terminology, these R&D funding data are subject to comparability constraints not placed on other types of international R&D data sets. Notably, although each country adheres to the same criteria for distributing their R&D by objective, as outlined in OECD's Frascati Manual (OECD 2002f), the actual classification may differ among countries because of differences in the primary objective of the various funding agents.

[78]Health and environment programs include human health, social structures and relationships, control and care of the environment, and exploration and exploitation of the Earth. R&D for *other purposes* in table 4-21 includes nonoriented research, other civil research, and research financed from GUF (e.g., the estimated R&D content of block grants to universities described in the earlier discussion of the academic sector.).

Figure 4-29
Sources of R&D expenditures in OECD countries: 1981–2000



OECD Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators,* 2002. See appendix table 4-47.

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research programs. Indeed, as is indicated from a variety of R&D metrics, the emphasis on health-related research is much more pronounced in the United States than in other countries. In 2001 the Federal Government devoted 25 percent of its R&D investment to health-related R&D, making such activities second in priority only to defense.[79]

The relative shift in emphasizing nondirected R&D reflects government priority setting during a period of fiscal austerity and constraint. With fewer discretionary funds available to support R&D, governments have tended to conduct activities that are traditionally in the government sphere of responsibility and for which private funding is less likely to be available. For example, basic research projects are inextricably linked to higher education. [See Kaiser et al. (1999) for a description of recent efforts to make higher education R&D data more internationally comparable.] Conversely, the relative share of government R&D support for economic development programs declined considerably from 38 percent in 1981 to 23 percent in 1999. Economic development programs include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy, all activities for which privately financed R&D is more likely to be provided without public support, although the focus of such private and public support would undoubtedly differ somewhat.

Differing R&D activities are emphasized in each country's governmental R&D support statistics.[80] As noted above, defense accounts for a relatively smaller government R&D share in most countries than in the United States. In recent years, the defense share was relatively high in the United Kingdom, Russia, and France at 46, 44, and 30 percent, respectively, but was less than 12 percent each in Germany, Italy, Canada, and Japan. South Korea expended 16 percent of its $6 billion government R&D budget on defense-related activities (figure 4-32). Japan committed 27 percent of its non-GUF governmental R&D support to energy-related activities, reflecting the country's historical concern about its high dependence on foreign sources of energy. In Canada 14 percent of the government's non-GUF R&D funding was directed toward agriculture. Space R&D received considerable support in France and Russia (13 and 10 percent, respectively), whereas industrial production and technology accounted for 15 percent or more of governmental R&D funding in Canada, Germany, Italy, and South Korea. Industrial production and technology is the leading socioeconomic objective for R&D in South Korea, accounting for 30 percent of all government R&D. This funding is primarily oriented toward the development of science-intensive industries and is aimed at increasing economic efficiency and technological development.[81] Industrial technology programs accounted for 12 percent of the Japanese total but less than 1 percent of the U.S. total (figure 4-32). The latter figure, which includes mostly R&D funding by NIST, is understated relative to most other countries as a result of data compilation differences. In part, the low U.S. industrial development share reflects the expectation that firms will finance industrial R&D

[79]Most of the health-related R&D is classified as research, whereas about 90 percent of defense R&D is classified as development.

[80]For the purpose of cross-country comparisons, the shares reported here and in figure 4-32 have been calculated after removing research financed from general university funds (GUF). These shares thus represent government R&D funds dedicated to specific socioeconomic objectives. Shares including GUF can be found in appendix table 4-48. In 2000–2001 the GUF portion of total national governmental R&D support was 44 percent in Italy, 39 percent in Germany, 35 percent in Japan, and between 22 and 29 percent in the United Kingdom, Canada, and France. South Korea and Russia are like the United States in that they do not report GUF.

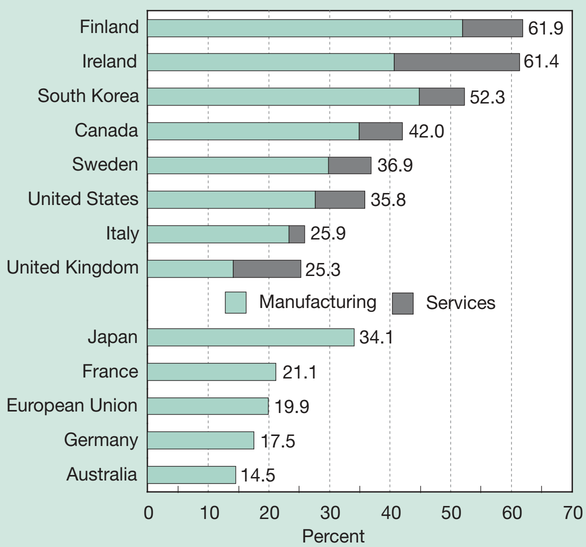
[81]Historically, Russia has also devoted a large share of government R&D to industrial development. Fully 27 percent of the government's 1998 R&D budget appropriations for economic programs were used to assist in the conversion of the country's defense industry to civil applications [American Association for the Advancement of Science and Centre for Science Research and Statistics (AAAS/CSRS) 2001].

R&D in the ICT Sector

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

- Manufacturing industries: 30 (Office, accounting, and computer machinery), 32 (Manufacture of radio, television, and communications equipment apparatus), and 33 (Manufacture of medical, precision and optical instruments, watches, and clocks)
- Services industries: 64 (Post and communications) and 72 (Computer and related activities) (OECD 2002e)

Figure 4-30
Industrial R&D, by ICT sector, for selected countries: 1999 or 2000



ICT information and communications technologies

NOTES: Data for European Union, France, Sweden, and Ireland are for 1999. All other data are for 2000. ICT service-sector R&D data are not available for Japan, France, European Union, Germany, and Australia.

SOURCE: Organisation for Economic Co-operation and Development, DSTI/EAS Division, Analytical Business Enterprise Research and Development database, 2002.

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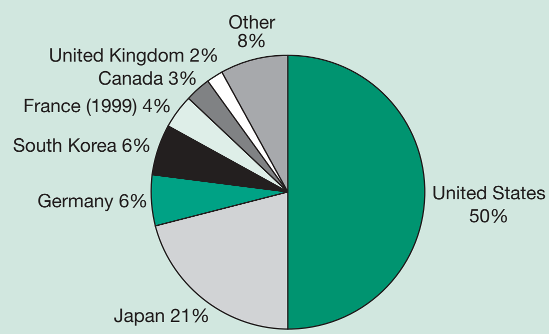
In 1999 and 2000, the ICT sector accounted for more than a fourth of total business R&D expenditures in most OECD countries and, as shown in figure 4-30, more than half of total business R&D in Finland, Ireland, and South Korea. According to these internationally comparable tabulations, ICT industries accounted for 36 percent of the industrial R&D in the United States and 34 percent of the Japanese total. Of the large European economies, the United Kingdom comes closest to matching the ICT R&D concentration of the United States and Japan, with a particularly high concentration of ICT services R&D. For a discussion of R&D alliances in the ICT sector, see “International Technology Alliances.”

Although several other OECD member countries had much higher concentrations of R&D in manufacturing ICT industries than the United States in 2000, the United States still accounted for half of all OECD-wide R&D expenditures in ICT manufacturing (figure 4-31). Japan and South Korea, which have historically emphasized ICT manufacturing, accounted for more than a fourth of the total, with the larger OECD members making up the bulk of the remainder.

Figure 4-31
OECD-wide ICT manufacturing R&D, by selected country: 2000



ICT information and communications technologies
OECD Organisation for Economic Co-operation and Development

NOTE: Figure based on only 19 OECD countries.

SOURCE: OECD, *Measuring the Information Economy* (Paris, 2002).

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Table 4-21
Government R&D support for defense and nondefense purposes, all OECD countries: 1981–99
(Percent)

Year	Defense	Nondefense R&D budget shares: Total	Health and environment	Economic development programs	Civil space	Other purposes
1981	35.6	64.4	19.7	37.6	9.9	32.8
1982	38.1	61.9	19.4	37.7	8.6	34.3
1983	39.9	60.1	19.3	36.8	7.7	36.2
1984	41.8	58.2	20.1	36.0	7.9	36.0
1985	43.4	56.6	20.5	35.6	8.6	35.3
1986	44.4	55.6	20.5	34.5	8.8	36.2
1987	44.1	55.9	21.2	32.3	9.8	36.7
1988	43.4	56.6	21.6	30.7	10.2	37.6
1989	41.9	58.1	21.8	29.7	11.0	37.6
1990	39.9	60.1	22.0	28.7	11.9	37.4
1991	36.9	63.1	22.0	28.1	12.0	38.0
1992	35.6	64.4	22.1	26.9	12.1	38.9
1993	35.6	64.4	22.1	26.0	12.3	39.6
1994	33.1	66.9	22.4	25.1	12.4	40.1
1995	31.2	68.8	22.4	24.3	12.1	41.1
1996	30.9	69.1	22.6	24.2	11.9	41.3
1997	30.7	69.3	22.8	24.5	11.4	41.3
1998	30.0	70.0	23.5	22.6	11.4	42.5
1999	29.3	70.7	24.4	23.1	10.6	41.8

OECD Organisation for Economic Co-operation and Development

NOTE: Nondefense R&D classified as "other purposes" consists largely of general university funds (GUF) and nonoriented research programs.

SOURCE: OECD, Main Science and Technology Indicators database, 2002.

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activities with their own funds; in part, government R&D that may be indirectly useful to industry is often funded with other purposes in mind such as defense and space (and is therefore classified under other socioeconomic objectives).

Compared with other countries, Germany, France, and Italy invested relatively heavily in nonoriented research at 26, 25, and 24 percent, respectively, of non-GUF government R&D appropriations. The United States government invested 6 percent of its R&D budget in nonoriented research, largely through the activities of NSF and DOE.

Character of R&D Activities

Given the variations in international R&D activities by performing sector, source of funding, and industrial focus, it follows that countries would differ in terms of the character of their R&D activities. The proportion of a country's R&D expenditures classified as basic research, applied research, or development not only reflects the sectoral structure of its national system of R&D but also indicates differences in national priorities, traditions, and incentive structures. The character of the R&D performed in a nation can change as a result of market forces and policy decisions.

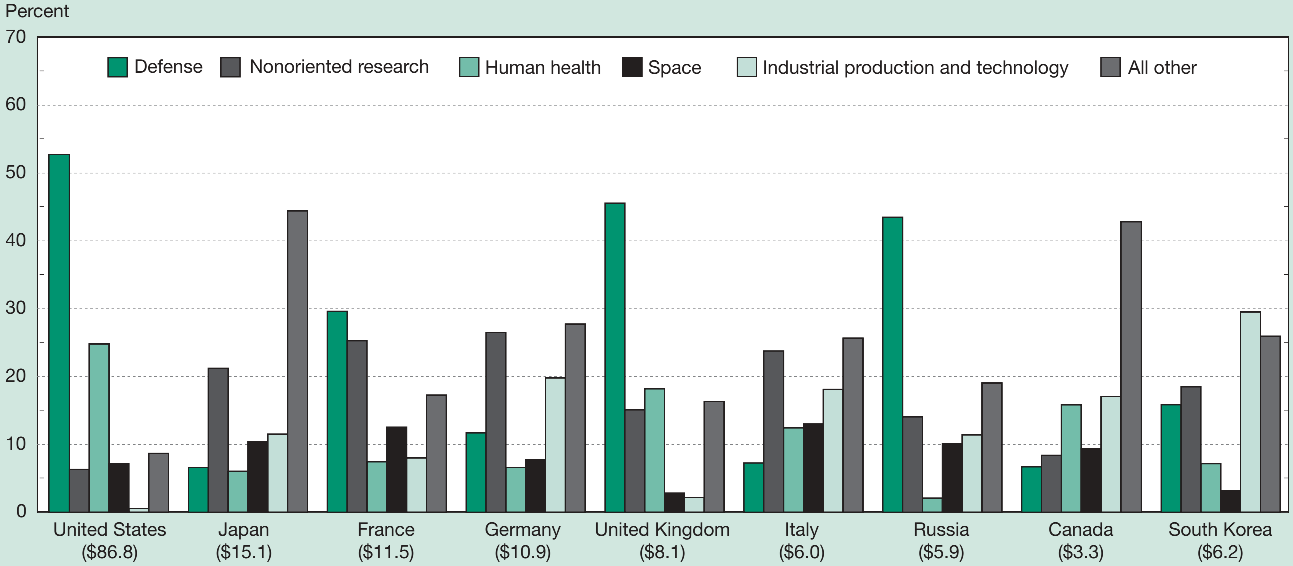
R&D classification by character of work often involves a greater element of subjective assessment than other R&D indicators and hence only a third of the OECD member countries (and Russia) have reported character of work shares for 1998 or later.[82] Rather than resulting from surveys, the data are often estimated in large part by national authorities.[83] Nonetheless, where these data exist, they help differentiate the national innovation systems of different countries in terms of how their R&D resources contribute to advancing scientific knowledge and developing new technologies.

Most of the countries that report R&D character-of-work distributions emphasize development, followed by applied research and then basic research (figure 4-33). In four of the countries shown (United States, Japan, South Korea, and Russia), development accounted for at least 60 percent of national R&D, with most of the experimental development work under way in their respective industrial sectors. In all of these countries except Russia, the majority of development funding comes from the industrial sector, mirroring the U.S. pattern described earlier in this chapter. In Russia, the

[82]For a discussion of these issues see the sidebar "Choice of the 'Right' R&D Taxonomy Is a Historical Concern" in *Science and Engineering Indicators 2002* [National Science Board (NSB) 2002].

[83]The magnitude of the amounts estimated as basic research also is affected by how R&D expenditures are estimated by national authorities. International R&D survey standards recommend that both capital and current expenditures be included in the R&D estimates, including amounts expended on basic research. Each of the non-U.S. countries displayed in figure 4-33 includes capital expenditures on fixed assets at the time they took place (OECD 1999). All U.S. R&D data reported in the figure include depreciation charges instead of capital expenditures. U.S. R&D plant data (not shown in the figure) are distinct from current fund expenditures for R&D.

Figure 4-32
Non-GUF government R&D support, by socioeconomic objectives, G-8 countries, and South Korea: 2000 or 2001



GUF general university funds

NOTES: Dollar amounts listed under country names represent total government R&D support less GUF in billions of U.S. purchasing power parity dollars. Data for France, United Kingdom, and Canada are for 2000; data for all other countries are for 2001. R&D is classified according to its primary government objective, although it may support any number of complementary goals. For example, defense R&D with commercial spinoffs is classified as supporting defense, not industrial development. "All other" is dominated by energy research in Japan and by agricultural production and technology research in Canada and Russia.

SOURCE: Organisation for Economic Co-operation and Development, special tabulations, 2003. See appendix table 4-48.

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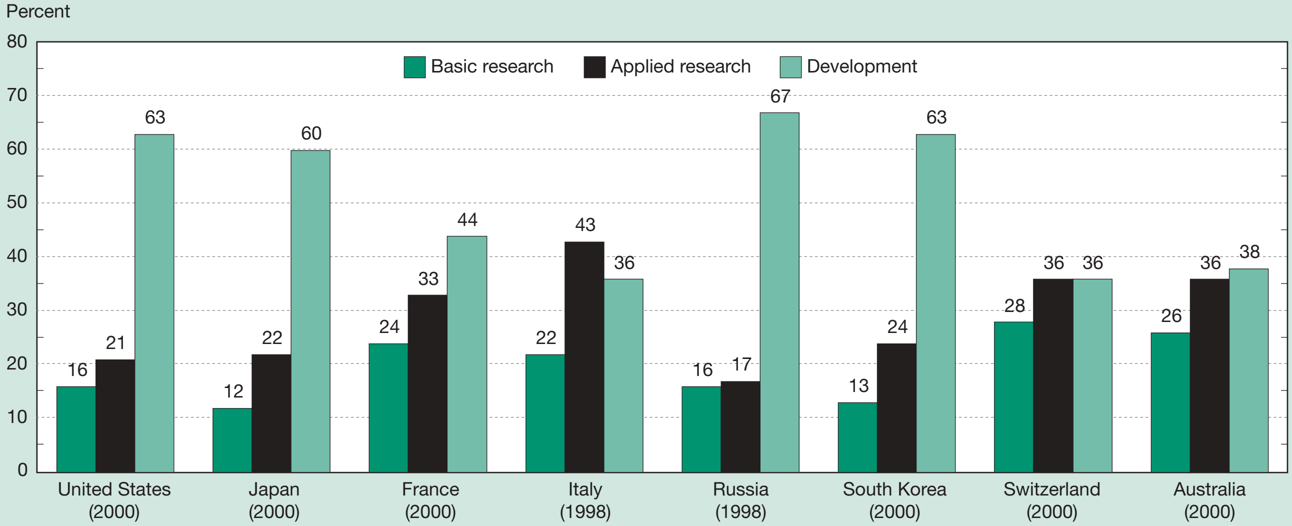
Figure 4-33
R&D expenditures of selected countries, by character of work: 1998 or 2000



NOTES: Character of work for 6 percent of Japan's R&D is unknown. Percents may not sum to 100 because of rounding.

SOURCES: Organisation for Economic Co-operation and Development, *Basic Science and Technology Statistics,* vol. 2002-1 (Paris, 2002); Centre for Science Research and Statistics, *Russian Science and Technology at a Glance 2000*, 2001; and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, VA, annual series).

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government funds the majority of all R&D, including the R&D performed by its industrial sector. This emphasis on development was not nearly as pronounced in the other countries shown, where it ranged from 44 percent of national R&D in France to as little as 36 percent in Switzerland and Italy.

The European countries for which data are available tended to emphasize basic and applied research in lieu of development.[84] France, Italy, and Switzerland each focused more than half of their R&D expenditures on research (basic plus applied). The Czech Republic and Poland, lower-income European countries, both reported more than 30 percent of national R&D expenditures dedicated to basic research. Switzerland, a small high-income country boasting the highest number of Nobel prizes, patents, and science citations per capita worldwide, devoted more than 60 percent of its R&D to basic and applied research in 2000 despite having an industrial R&D share (74 percent) comparable to the United States and Japan. The differences among the Swiss, U.S., and Japanese character-of-work shares reflect both the high concentration of chemical and pharmaceutical R&D in Swiss industrial R&D as well as the "niche strategy" of focusing on specialty products adopted by many Swiss high-technology industries.

China, mirroring the pattern set by its dynamic neighbors Japan, Singapore, and Korea, devotes only a small fraction (5 percent) of its growing R&D effort to basic research, favoring applied R&D aimed at immediate economic development. Separate data are also available for Taiwan, where basic research accounts for 10 percent of all R&D and industry accounts for an even greater share of R&D performance (64 percent) than in China (60 percent).

R&D Promotion Policies

Many countries, regarding S&T as important both for economic growth and for general public welfare, have developed strategies for promoting domestic R&D activity, high-technology industries, and innovation. These strategies incorporate a variety of policy measures ranging from direct government spending on R&D and technology to tax policies and intellectual property policies.

Public Funding for R&D. Government spending on R&D has continued to increase at a rate faster than inflation across OECD. A number of governments have set explicit goals to increase R&D activity even further:

- ♦ Austria intends to increase its share of R&D expenditure in gross national product (GNP) to 2.5 percent by 2005.
- ♦ Canada has set a goal to raise its ranking of 15th in R&D/GDP ratio among OECD countries to 5th by 2010.
- ♦ South Korea established its first 5-year S&T plan in 1997, in which it set a goal to increase the share of the total government budget allocated to R&D to 5 percent by 2002. Although South Korea failed to achieve this goal, it increased the R&D share substantially from 3.6 percent in 1998 to 4.7 percent in 2002.
- ♦ Norway intends to raise its absolute level of R&D funding to the OECD average by 2005.
- ♦ Spain aims to increase its R&D spending as a share of GNP to 1.29 percent by 2003, up from 0.9 percent in 1990.
- ♦ The European Council has set a goal for the European Union as a region to devote 3 percent of GDP, on average, to R&D by 2010 (OECD 2002g).

R&D Tax Policies. In many OECD countries, the government not only provides direct financial support for R&D activities but also uses indirect mechanisms such as tax relief to promote national investment in S&T. Indeed, tax treatment of R&D is broadly similar among OECD countries, with some variations in the use of R&D tax credits (OECD 1996 and 2002g). The two main features of the R&D tax instruments are:

- ♦ An allowance for the deduction of industrial R&D expenditures from taxable income in the year they are incurred (exists in almost all OECD countries, including the United States)
- ♦ An additional R&D tax credit or incentive, with a rising trend in the use of incremental credits (exists in about half of OECD countries, including the United States). Incremental credits provide additional incentives for firms to increase their R&D spending over past levels. (See "Federal R&D Tax Credit.")

In addition, several OECD countries have special provisions that favor R&D in small and medium-size enterprises (SMEs). In recent years, some OECD countries have made significant changes to their R&D tax policies in an attempt to further encourage private investment in R&D:

- ♦ In 2002 Norway introduced a tax plan offering SMEs a 20 percent tax allowance for both internal and external R&D expenditures.
- ♦ The United Kingdom enacted a tax plan in 2000 that allows SMEs to deduct 150 percent of R&D expenditures.
- ♦ Australia has enhanced its R&D tax incentives, which now allow firms to deduct 125 percent of all R&D expenditures and 175 percent of the labor-cost component of incremental increases in R&D.
- ♦ Spain recently enacted a 10 percent increase in the deduction of R&D investments and broadened the scope of the incentive to include capital investments related to innovation and the costs of acquiring technology in the form of patents or licenses in addition to R&D investments (OECD 2002g).

A growing number of R&D tax incentives are being offered in OECD countries, including the United States, at the subnational (provincial and state) levels. See Poterba (1997)

[84] The most current character-of-work data available from OECD sources for Germany are for 1993. The United Kingdom compiles this type of data only for the industry and government sectors, not for higher education or its nonprofit sector, the traditional locus of basic research activities.

for a discussion of international elements of corporate R&D tax policies.

Intellectual Property Policy and Technology Transfer. The large increase in patenting at U.S. universities and colleges following the passage of the Bayh-Dole Act in 1980 has led several OECD countries to review or modify their own policies regarding ownership of technology developed with public funding. OECD notes that one of the main impacts of these policies has been "to raise awareness of and support for technology transfer, especially within the hierarchy of PROs [publicly financed research organizations] and among researchers and graduate students" (OECD 2002g, p. 182). For more information about trends in patenting at U.S. colleges and universities, see chapter 5.

R&D Investments by Multinational Corporations

International R&D investments by multinational corporations (MNCs), such as overseas R&D spending and R&D joint ventures and alliances, support long-term activities aimed at the development of new products and technological capabilities. The resulting technological linkages across firms and geographic regions are increasingly vital in the fast-paced environment of scientific research and global market competition. International R&D spending links are particularly strong between U.S. and European pharmaceuticals, computers, and transportation equipment companies.[85] In recent years, the United States has attracted large investments by foreign R&D-performing companies. Foreign-owned R&D in the United States grew at a real average annual rate of 10.8 percent from 1994 to 2000, mostly as a result of mergers and acquisitions, compared with an average annual growth rate of 6.9 percent for U.S.-owned R&D overseas. This section analyzes data on foreign direct investment (FDI) in R&D (see sidebar, "Foreign Direct Investment in R&D"), including activity by foreign-owned companies in the United States, parent companies of U.S. MNCs, and U.S. overseas affiliates in terms of investing or host countries, their industrial focus, and implications for the ownership structure of U.S. R&D. Major findings were:

- Foreign-owned firms conducting R&D in the United States accounted for $26.1 billion (13 percent) of the $199.5 billion in total industrial R&D expenditures in the United States in 2000. This share fluctuated between 11 and 13 percent during the period 1994–2000.
- In 2000 about two-thirds of foreign-owned R&D in the United States was performed in three industries: chemicals and pharmaceuticals, computer and electronic products, and transportation equipment. Seven countries invested $1 billion or more in R&D in the United States in 2000: Germany, the United Kingdom, Switzerland, Japan, Canada, France, and the Netherlands, accounting

[85]Much like trends in international technology alliances discussed earlier in this chapter.

Foreign Direct Investment in R&D

Statistics on overseas R&D activity by U.S. companies or by foreign-owned companies in the United States are part of operations data associated with U.S. direct investment abroad (USDIA) and foreign direct investment in the United States (FDIUS), respectively. The term foreign direct investment (FDI) is used below and throughout this section to refer to either type of direct investment. Direct investment refers to the ownership of productive assets outside the home country by multinational corporations (MNCs). More specifically, the U.S. Bureau of Economic Analysis (BEA) defines direct investment as ownership or control of 10 percent or more of the voting securities of a business in another country. FDI can be examined using either direct investment position and related capital inflows/outflows data (balance of payments method) or economic activities of foreign affiliates of MNCs (financial and operations data). This section uses the latter set of indicators, including gross product, sales, employment, and R&D expenditures, to analyze *majority-owned* affiliates (those in which the ownership stake of parent companies is more than 50 percent).

Most FDI involves overseas production, marketing, and distribution, not R&D-oriented activities. Increasingly, however, companies have been expanding knowledge-based technology development activities abroad in search of synergies and location-specific expertise. Other incentives include R&D costs considerations and the support of foreign production sites (Kumar 2001; and Niosi 1999). The incentives, goals, and character of overseas R&D activities can be summarized in two broad categories: (1) *market seeking,* or *home-base exploiting,* supporting the development of new markets and foreign production sites, and (2) *asset-seeking,* or *home-base augmenting,* pursuing science-based technologies and capabilities (Bas and Sierra 2002; Kuemmerle 1999; and von Zedtwitz and Gassmann 2002). In the first category, MNCs aim to use and profit from proprietary knowledge overseas by transferring and adapting technologies for local markets, emphasizing product development expenditures. The second category targets the development of long-term innovative capabilities by taking advantage of novel or complementary knowledge located elsewhere. The latter is a more recent development within the internationalization of R&D activities, driven by the demands of knowledge-based competition, particularly among OECD countries (Niosi 1999).

The tradeoffs and complementarities between these two broad objectives affect not only the relative emphasis of research versus development activities in technology-intensive MNCs but also location and organizational decisions (e.g., proximity to production and/or research clusters, stand-alone R&D facilities, contractual alliances), financing mechanisms (e.g., parent-company funding, venture capital, government grants), and technical personnel needs.

for about 90 percent of all R&D expenditures by foreign-owned firms in the United States.

- Parent companies of U.S. MNCs accounted for two-thirds of the R&D spending by all industrial R&D performers in the United States in 2000. In that year, these parent companies had R&D expenditures of $131.6 billion in the United States, whereas their majority-owned foreign affiliates (MOFAs) had R&D expenditures of $19.8 billion for a total of $151.3 billion in global R&D expenditures.
- Two-thirds of the R&D performed overseas in 2000 by U.S.-owned companies ($13.2 billion of $19.8 billion) took place in six countries: the United Kingdom, Germany, Canada, Japan, France, and Sweden. At the same time, emerging markets such as Singapore, Israel, Ireland, and China were increasingly attracting R&D activities by U.S. subsidiaries. In 2000, each of these emerging markets reached U.S.-owned R&D expenditures of $500 million or more, levels considerably higher than those in 1994.
- Three manufacturing sectors dominated overseas R&D activity by U.S.-owned companies: transportation equipment, computer and electronic products, and chemicals and pharmaceuticals. These are the same three industries that accounted for most foreign-owned R&D in the United States, implying a high degree of R&D globalization in these industries.

Foreign-Owned R&D Spending in the United States

Overview

The economic presence of foreign-owned companies in the United States is substantial. In 2000, majority-owned U.S. affiliates of foreign companies—affiliates operating in the United States in which the ownership stake of foreign direct investors is more than 50 percent—had a gross product (value added) of $449.4 billion, sales of $2.1 trillion, and almost 5.6 million employees in the United States, according to data from the U.S. Bureau of Economic Analysis (BEA)[86] (table 4-22). These affiliates accounted for 6.0 percent of U.S. private-industry GDP and 4.9 percent of U.S. private employment in 2000 (Zeile 2002).

R&D spending by majority-owned U.S. affiliates of foreign companies (hereafter, *foreign-owned R&D*) reached $26.1 billion in 2000, an increase of 8.6 percent over 1999 expenditures.[87] In 2000, foreign-owned R&D spending accounted for 13 percent of the $199.5 billion in total industrial R&D expenditures in the United States, according to NSF's Survey of Industrial Research and Development.[88] This share fluctuated between 11 and 13 percent between 1994 and 2000. Note that the share of foreign-owned R&D spending in 2000 (13 percent) was more than twice the comparable share of U.S. private-industry gross product and employment, reflecting significant activity in R&D-intensive industries.

Investing Country and Industry Analysis

Relatively few investing countries account for most of the foreign-owned R&D in the United States. In 2000, European-owned subsidiaries accounted for $18.6 billion (71 percent) of foreign-owned R&D in the United States (figure 4-34), a share comparable with their 67 percent share in foreign-owned gross product in the United States. The corresponding R&D shares for Canadian- and Asia/Pacific-owned subsidiaries were 14.0 and 10.9 percent, respectively. In particular, R&D activities by U.S. affiliates of foreign companies were dominated by seven investing countries with $1 billion or more in R&D expenditures (table 4-22). These top countries accounted for about 90 percent of all foreign-owned R&D in the United States, a somewhat higher percentage than their corresponding shares of gross product (value added), sales, and employment (82, 73, and 80 percent, respectively). German- and British-owned subsidiaries accounted for about 20 percent each of the total foreign-owned R&D spending in the United States in 2000, followed by Canadian-owned affiliates with 14 percent. Relative to gross product, German-, Canadian-, and Swiss-owned companies, respectively, were the most R&D-intensive subsidiaries (table 4-22).

Foreign-owned R&D in the United States is performed primarily in manufacturing. In 2000 about two-thirds was performed in three industries: 27 percent in chemicals (of which 80 percent was in pharmaceuticals), 24 percent in computer and electronic products (of which three-fourths was in communications equipment), and 12 percent in transportation equipment, mostly in motor vehicles. Electrical equipment and components and machinery accounted for 7 and 3 percent, respectively, of foreign-owned R&D in the United States (table 4-23 and appendix table 4-50). The information sector and the professional, technical, and scientific services sector each represented 3 percent of this U.S. total in 2000, exhibiting little change from 1999.

Firms from some investing countries are particularly active in certain industries. In 2000, 80 percent of R&D performed by Swiss-owned subsidiaries in the United States was performed by chemical and pharmaceutical affiliates, compared with 38 and 24 percent, respectively, for British- and German-owned subsidiaries (table 4-23). In contrast, more than a fourth of Japanese-owned R&D was performed by companies classified in computer and electronic products.[89]

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[86]U.S. Bureau of Economic Analysis (BEA), Survey of Foreign Direct Investment in the United States, 2000. Available at http://www.bea.gov/bea/di/di1fdiop.htm. BEA data used in this section exclude data for depository institutions. All data are on a fiscal year basis. Estimates for 2000 are preliminary. For the methodology of BEA's Survey of Foreign Direct Investment in the United States, see http://www.bea.gov/bea/di/fddscrpt.htm.

[87]R&D spending data in this section are based on R&D *performance,* which refers to R&D spending according to who conducts the R&D activity, whether for the performer itself or for others, regardless of funding source.

[88]National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

[89]Further industry-country analysis is precluded by disclosure limitations.

Table 4-22
Selected operating data for majority-owned U.S. affiliates of foreign companies: 2000

Investing country	Gross product (billions of current U.S. dollars)	Sales (billions of current U.S. dollars)	Employment (millions of employees)	R&D spending (billions of current U.S. dollars)	Investing country share of R&D spending (percent)	R&D/gross product ratio (percent)
All countries	449.4	2,053.0	5.56	26.1	100.0	5.8
Top seven countries	368.2	1,492.8	4.46	23.4	89.8	6.4
Germany	54.0	308.2	0.69	5.6	21.5	10.4
United Kingdom	100.1	331.2	1.10	5.0	19.2	5.0
Switzerland	34.0	120.0	0.46	3.0	11.5	8.9
Japan	62.2	429.7	0.70	2.6	10.0	4.2
Canada	36.3	159.3	0.56	3.7	14.0	10.1
France	38.9	144.4	0.40	2.1	8.2	5.5
Netherlands	42.6	D	0.55	1.4	5.2	3.2

D data withheld to avoid disclosing operations of individual companies

NOTE: Majority-owned U.S. affiliates of foreign companies are affiliates in the United States owned more than 50 percent by foreign direct investors.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of Foreign Direct Investment in the United States, annual series, http://www.bea.gov/bea/di/di1fdiop.htm.

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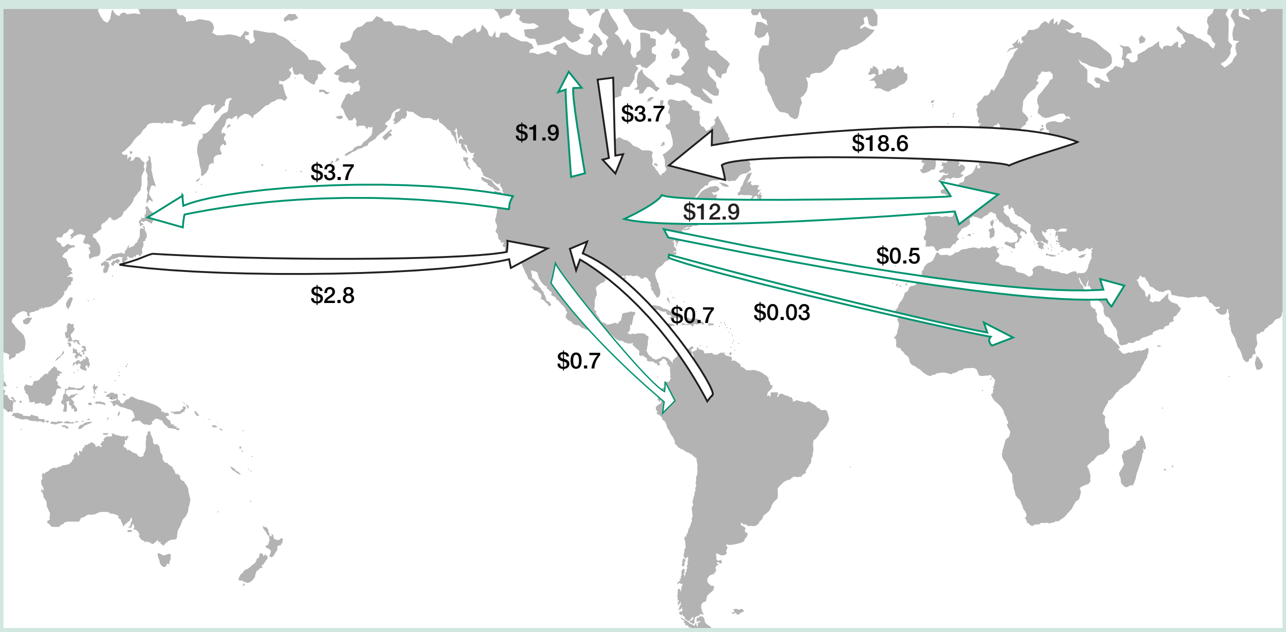
Figure 4-34
Foreign-owned R&D in United States and U.S.-owned R&D overseas, by investing/host region: 2000
(Billions of current U.S. dollars)



SOURCES: U.S. Bureau of Economic Analysis, *Foreign Direct Investment in the United States*, annual series; and U.S. Bureau of Economic Analysis, *U.S. Direct Investment Abroad,* annual series. See appendix tables 4-49 and 4-51.

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The shares of computer and electronic products as well as transportation equipment in foreign-owned R&D spending are comparable with their shares in total company-funded industrial R&D spending in the United States, according to data from NSF's Survey of Industrial Research and Development.[90] However, the share of chemicals in foreign-owned R&D was more than twice the share of chemicals in overall industrial R&D in the United States (11 percent in 2000).[91] This difference suggests the appeal of the United States as a center for chemicals and pharmaceuticals R&D for major foreign

[90]National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

[91]National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, 2003. Available at http://www.nsf.gov/sbe/srs/indus/start.htm.

Table 4-23
R&D performed by majority-owned affiliates of foreign companies in United States, by selected NAICS industry of affiliate and region/country: 2000
(Millions of current U.S. dollars)

Region/country	All industries	Manufacturing: Total	Manufacturing: Chemicals	Manufacturing: Machinery	Manufacturing: Computer and electronic products	Manufacturing: Electrical equipment	Manufacturing: Trans-portation equipment	Nonmanufacturing: Information	Nonmanufacturing: Professional, technical, scientific services
All countries	26,089	20,554	7,023	868	6,182	1,714	3,206	790	818
Canada	3,664	D	D	5	D	D	66	D	72
Europe	18,610	15,025	6,645	D	D	1,305	3,028	D	188
France	2,135	1,750	416	30	D	D	101	D	50
Germany	5,610	5,273	1,347	139	D	D	D	D	3
Netherlands	1,366	1,303	419	3	D	2	D	0	D
Switzerland	3,013	2,702	2,391	46	34	D	0	D	D
United Kingdom	5,018	3,279	1,888	D	D	78	221	319	41
Asia and Pacific	2,840	1,463	315	D	738	21	102	4	556
Japan	2,617	1,383	D	74	706	10	102	4	555
Latin America and other Western Hemisphere	735	478	—	0	39	D	D	0	0
Africa	D	D	0	0	0	0	0	D	0
Middle East	D	88	40	0	43	0	0	D	—

— less than $500,000

D data withheld to avoid disclosing operations of individual companies

NAICS North American Industry Classification System

NOTES: Data are preliminary 2000 estimates for majority-owned (more than 50 percent) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Data include expenditures for R&D conducted by foreign affiliates, whether for themselves or for others under contract. Data exclude expenditures for R&D conducted by others for affiliates under contract.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of Foreign Direct Investment in the United States, annual series, http://www.bea.gov/bea/di/di1fdiop.htm. See appendix tables 4-49 and 4-50.

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companies, reflecting asset-seeking FDI goals. At the same time, the share of the gross product of these foreign-owned chemical affiliates in total foreign-owned gross product in the United States (9.1 percent) was much higher than the overall chemical industry share in U.S. (private industry) GDP in 2000 (2.1 percent), indicating substantial production activity by these affiliates (U.S. BEA 2003). These observations suggest that R&D investments by foreign chemical companies in the United States are likely pursuing both market- and asset-seeking objectives.

U.S. MNCs and Overseas R&D Spending

Overview

The economic reach of *U.S. MNCs*—defined as U.S. parent companies and their foreign affiliates—is considerable.[92] According to BEA data, U.S. MNCs had a gross product of $2.70 trillion, sales of $9.03 trillion, and 31.20 million employees worldwide in 2000 (table 4-24). Parent companies of U.S. MNCs (hereafter, *U.S. MNC-parent companies*) had R&D expenditures of $131.6 billion in 2000, whereas their MOFAs had R&D expenditures (hereafter, *U.S.-owned overseas R&D*) of $19.8 billion for a total of $151.3 billion in global R&D expenditures.[93]

Between 1994 and 2000, R&D spending by MOFAs grew at a faster rate (6.9 percent real average annual rate) than that of their U.S. parents (4.3 percent).[94] The percentage of total R&D spending by U.S. MNCs that was performed abroad by their MOFAs increased from 11.5 percent in 1994 to 13.1 percent in 2000. However, the 2000 R&D spending share of MOFAs within the worldwide operations of U.S.

[92]BEA defines *parent company* of a U.S. multinational corporation (MNC) as an entity (individual, branch, partnership, or corporation), resident in the United States, that owns or controls at least 10 percent of the voting securities, or equivalent, of a foreign business enterprise [R. J. Mataloni, Jr., U.S. multinational companies: Operations in 2000, *Survey of Current Business* (December 2002): 111–131]. This section is based on data for U.S. nonbank MNC-parent companies and their majority-owned nonbank foreign affiliates.

[93]According to the NSF Survey of Industrial Research and Development, R&D abroad reached $17.9 billion in 2001, up 2.3 percent from $17.5 billion in 2000 (appendix tables 4-54 and 4-55). Note, however, that the 2000 estimate for R&D abroad reported in the NSF survey differs from that reported in BEA's Survey of Direct Investment Abroad because of methodological differences in the surveys. For more information, see the NSF website at http://www.nsf.gov/sbe/srs/sird/start.htm and the BEA website at http://www.bea.gov/bea/di/usdscrpt.htm.

[94]See appendix tables 4-51, 4-52, and 4-53 for historical data and selected industry detail for R&D performed by U.S. MNCs. In this section, data for R&D expenditures of U.S. MNC-parent companies include R&D performed for the Federal Government.

Table 4-24
Selected data for U.S. multinational corporation parent companies and their MOFAs: 2000

Parent companies and MOFAs	Gross product		Sales		R&D spending		Employees	
	Billions of current dollars	Percent distribution	Billions of current dollars	Percent distribution	Billions of current dollars	Percent distribution	Millions	Percent distribution
Total	2,695.3	100	9,033.9	100	151.3	100	31.2	100
U.S. parents	2,089.4	78	6,547.1	72	131.6	87	23.2	74
MOFAs.................	605.9	22	2,486.9	28	19.8	13	8.1	26

MOFA majority-owned foreign affiliate of U.S. parent company

NOTES: Details may not sum to totals because of rounding. MOFAs are affiliates in which combined ownership of all U.S. parents is more than 50 percent.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm.

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MNCs was approximately half of their share in employment and sales and a little more than half of their share in gross product (value added) (table 4-24). This shows a relative preference by parents of U.S. MNCs for domestically based R&D performance compared with other activities, which is consistent with the behavior of MNCs based in other advanced economies (Niosi 1999). The high concentration of R&D expenditures by U.S. MNCs at home results in a significant role of these parent companies as R&D performers in the United States. U.S. MNC-parent companies accounted for two-thirds of the R&D spending by all industrial R&D performers in the United States in 2000.[95] In comparison, the gross product of U.S. MNC-parent companies accounted for about a fifth of U.S. (private industry) GDP in 2000, according to BEA.[96]

Host Country and Industry Analysis

Two-thirds of the R&D performed overseas in 2000 by MOFAs of U.S. companies ($13.2 billion of $19.8 billion) took place in six countries: the United Kingdom, Germany, Canada, Japan, France, and Sweden (table 4-25).[97] On a regional basis, the European region accounted for approximately two-thirds ($12.9 billion) of all U.S-owned overseas R&D; the Asia/Pacific region ($3.7 billion, or 18.9 percent) outpaced Canada ($1.9 billion, or 9.5 percent) as a locale for U.S.-owned overseas R&D (figure 4-34).

In 2000, approximately three-fourths of U.S.-owned overseas R&D was performed in three manufacturing sectors: transportation equipment ($5.7 billion, or 29 percent), computer and electronic products ($4.9 billion, or 25 percent), and chemicals ($4.3 billion, or 22 percent, most of which, 83 percent, was in pharmaceuticals)[98] (table 4-25). Compared with 1999, the share of computer and electronic products increased 3 basis points, mostly at the expense of chemicals, whereas the transportation equipment share was little changed. Information as well as professional, technical, and scientific services represented 2 and 6 percent, respectively, of overseas R&D in 2000, compared with 1 and 5 percent, respectively, in 1999. Certain emerging markets play an increasing role in U.S.-owned overseas R&D. The 10 locations shown in table 4-26 hosted $3.5 billion (18 percent) in R&D expenditures by MOFAs of U.S. parent companies in 2000, compared with $1.3 billion (11 percent) in 1994. Furthermore, U.S.-owned R&D expenditures in these 10 countries increased by 15.9 percent annually (real average annual growth) from 1994 to 2000, compared with 6.9 percent annual growth for the aggregate of all host countries. For some of these locations, the real average annual increases were much higher, albeit from smaller levels of R&D activity.

The change in the relative overseas R&D rankings of these emerging markets are significant, indicating a selective diffusion of global R&D activities beyond traditional areas, likely aimed at adapting products to local markets and regulations, complemented by local know-how and human R&D resources. For example, U.S. subsidiaries in Singapore, Israel, Ireland, Taiwan, and South Korea with activities in computer and electronic product manufacturing spent a total of $1.2 billion in R&D in 2000, or 25 percent of $4.9 billion of U.S.-owned overseas R&D in this industry. A third of the combined $555 million in R&D expenditures by U.S. subsidiaries in Mexico and Brazil was devoted to transportation equipment R&D.

[95]Note, however, that BEA's definition of U.S. MNC-parent companies does not rule out parent companies that are owned by foreign companies. About 13 percent of the published R&D expenditures for U.S. MNC-parent companies were also part of the R&D expenditures of majority-owned affiliates of foreign companies in the U.S. in 2000, and in 1999, according to BEA estimates.

[96]Ned Howenstine, Chief, Research Branch, International Investment Division, U.S. BEA, personal communication with author, 8 April 2003. To match the industrial basis for foreign direct investment statistics, GDP data used in this comparison refer to U.S. private GDP excluding depository institutions and private households.

[97]Data for U.S.-owned R&D in the United Kingdom are for 1999; most 2000 data were unavailable because of disclosure limitations.

[98]Note that these are the same three industries that accounted for most foreign-owned R&D in the United States, implying a high degree of R&D internationalization in these industries.

Table 4-25
R&D performed overseas by majority-owned foreign affiliates of U.S. parent companies, by selected NAICS industry of affiliate and region/country: 2000
(Millions of current U.S. dollars)

			Manufacturing					Nonmanufacturing	
Region/country	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment	Trans-portation equipment	Information	Professional, technical, scientific services
All countries	19,758	17,822	4,254	764	4,878	331	5,744	383	919
Canada	1,874	1,735	272	13	194	18	1,086	3	30
Europe	12,938	11,699	3,152	509	2,085	250	4,264	255	589
France	1,445	1,356	726	57	225	14	153	1	21
Germany	3,105	3,067	235	159	460	126	1,852	2	2
Sweden	1,335	1,230	D	23	D	D	D	D	D
United Kingdom[a]	4,000	3,250	1,092	147	512	6	1,128	19	582
Asia and Pacific	3,727	3,478	684	204	2,174	D	187	105	D
Japan	1,433	1,277	560	152	450	15	19	D	D
Latin America and other Western Hemisphere	665	561	125	29	114	D	207	D	69
Africa	27	24	20	2	0	0	1	—	0
Middle East	527	324	1	8	312	0	0	D	D

— less than $500,000
D data withheld to avoid disclosing operations of individual companies
NAICS North American Industry Classification System

[a]Data are for 1999. Data for all countries include unpublished 2000 data rather than the 1999 data.

NOTES: Data are preliminary 2000 estimates for majority-owned (more than 50 percent) nonbank affiliates of nonbank U.S. parents by country of ultimate beneficial owner and industry of affiliate. Data include expenditures for R&D conducted by foreign affiliates, whether for themselves or for others under contract. Data exclude expenditures for R&D conducted by others for affiliates under contract.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm. See appendix table 4-51.

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Table 4-26
R&D performed overseas by majority-owned foreign affiliates of U.S. companies in selected economies: 1994 and 2000
(Millions of current U.S. dollars)

	1994		2000	
Location	Rank	R&D	Rank	R&D
Singapore	14	167	8	548
Israel	16	96	9	527
Ireland	8	396	10	518
China	30	7	11	506
Hong Kong	19	51	14	341
Mexico	13	183	16	305
Brazil	10	238	17	250
Malaysia	20	27	19	214
Taiwan	15	110	21	143
South Korea	26	17	22	131

NOTE: Rank refers to the relative position of the host country in terms of the amount of U.S.-owned R&D expenditures.

SOURCE: U.S. Bureau of Economic Analysis, U.S. Department of Commerce, Survey of U.S. Direct Investment Abroad, annual series, http://www.bea.gov/bea/di/di1usdop.htm.

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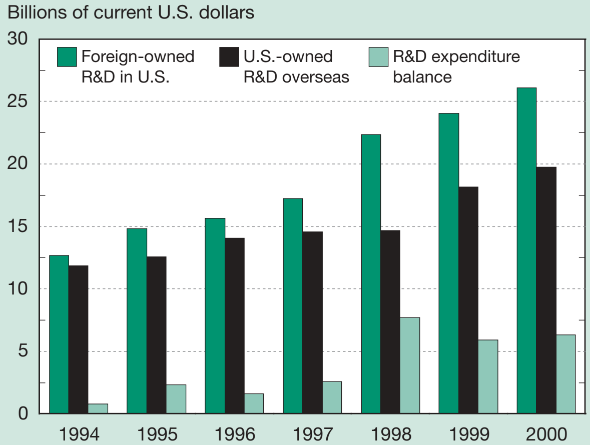
R&D Expenditure Balance

Foreign-owned R&D expenditures in the United States grew at a real average annual rate of 10.8 percent from 1994 to 2000, compared with an average annual growth rate of 6.9 percent for U.S.-owned overseas R&D. In 1998–2000 annual foreign-owned R&D spending in the United States exceeded U.S.-owned overseas R&D spending by at least $5 billion (figure 4-35), or more than 3 percent of total industrial R&D in the United States. In 2000 the difference, or expenditure balance, was $6.3 billion, down from a record $7.7 billion in 1998. At the regional level, R&D expenditures by European-owned companies in the United States outpaced overseas R&D spending by U.S. subsidiaries in Europe by $5.7 billion in 2000 (figure 4-34).

U.S.-owned companies in the United States and abroad, and foreign-owned affiliates in the United States, may have a combination of local and foreign sources of R&D funding. However, data on international funding sources for industrial R&D in the United States are generally unavailable. Both dimensions, ownership structure and funding sources, and how they may affect each other, are necessary for a fuller characterization of the international character of U.S. R&D activities. The Bureau of the Census, which conducts

Figure 4-35
Foreign-owned R&D in United States, U.S.-owned R&D overseas, and R&D expenditure balance: 1994–2000



NOTE: R&D expenditure balance equals foreign-owned R&D in the United States minus U.S.-owned R&D overseas.

SOURCES: U.S. Bureau of Economic Analysis, *Foreign Direct Investment in the United States,* annual series; and U.S. Bureau of Economic Analysis, *U.S. Direct Investment Abroad,* annual series. See appendix tables 4-49 and 4-51.

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the NSF Survey of Industrial Research and Development, and BEA, which conducts the FDI surveys, are engaged in a data-linking project aimed at a more detailed profile of U.S R&D performance and funding.

Conclusion

The resurgence in R&D investment in the United States from 1994 to 2000 slowed almost entirely by 2002. An uncertain economy rocked by turbulence in financial markets and terrorism led to reduced output in both the manufacturing and service sectors as well as subsequent slowdowns in R&D expenditures in many sectors. At the same time, the Federal Government's role grew in terms of both R&D funding and performance, reversing the decade-long divergence of private and public funding of R&D.

Recent acts of terrorism and military mobilizations have reversed a declining trend in the U.S. Government's share of defense-related R&D. Other countries throughout the world have maintained their focus on nondefense R&D and have attempted to take proactive steps toward intensifying and focusing their national R&D activity. These steps range from increasing general government spending to fostering high-technology industrial clusters.

The locus of R&D activities is also shifting as a reflection of broad technological changes and new scientific research opportunities. Industrial R&D is increasingly undertaken in service (versus manufacturing) industries, and much of the industrial R&D growth has occurred in biotechnology and IT. Moreover, Federal research funds have shifted markedly toward the life sciences during the past several years.

In addition to R&D performance and funding, the organization of R&D activities also has undergone substantial change. At the corporate level, R&D activities are increasingly globally driven by the need to support or develop markets and foreign production sites and the need for science-based technologies. A parallel trend is the increasing reliance on external technology sources and R&D alliances to share costs, risks, and resources and promote the development of innovative capabilities, increasingly relevant for long-term competitiveness.

These issues not only affect the performance and policy implications of R&D activity in the United States and overseas but also present new challenges for the development of S&T indicators (National Research Council 2000). In part to address these challenges, NSF, through the Bureau of the Census, which conducts the NSF Survey of Industrial Research and Development, and BEA, which conducts the international investment surveys, have initiated a statistical linking project to further explore the international composition of R&D activity in the United States. Fuller investigations and tracking of the apparent growth in the web of partnerships among firms, universities, and Federal agencies and laboratories in conducting R&D are warranted. An understanding of this dynamic and changing scenario is essential in a U.S. economy increasingly driven by the production, diffusion, and exploitation of science-based knowledge.

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