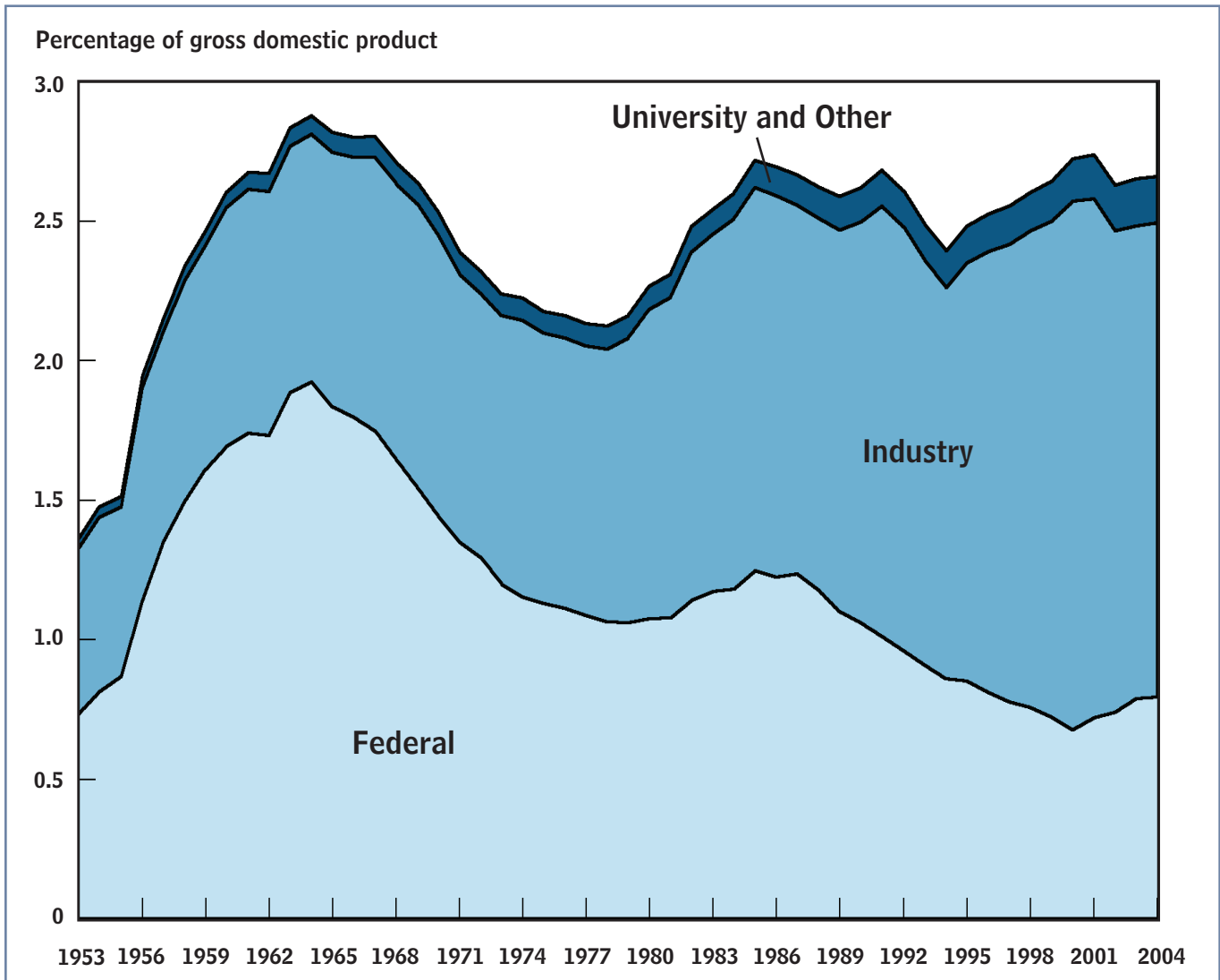
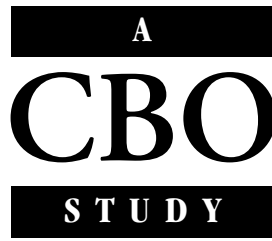


Federal Support for Research and Development



JUNE 2007

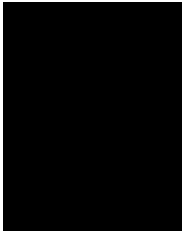


Federal Support for Research and Development

June 2007

Note

Unless otherwise noted, all years are calendar years.



Preface

For fiscal year 2007, lawmakers have provided about \$137 billion in budget authority to support federal research and development (R&D) activities. In addition, tax preferences are in place to encourage the private sector to increase its R&D spending. (Under one such preference, the research and experimentation tax credit, firms in 2004 claimed \$5.6 billion.) This Congressional Budget Office (CBO) study, prepared at the request of the Ranking Member of the Senate Committee on the Budget, examines recent trends in federal support for research and development and the current state of knowledge about the economic effects of that support. In keeping with CBO's mandate to provide objective, impartial analysis, the report contains no recommendations.

Sheila Campbell of CBO's Microeconomic Studies Division wrote the paper under the supervision of Joseph Kile and David Moore. Bob Arnold, Megan Carroll, Juan Contreras, Robert Dennis, J. Michael Gilmore, Pamela Greene, Douglas Hamilton, Arlene Holen, Daniel Hoople, Donald Marron, William Randolph, Philip Webre, and Thomas Woodward, all of CBO, commented on earlier versions of the study, as did Stephen Merrill of the National Academies, David Mowery of the University of California, Berkeley, and Paul Romer of Stanford University. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Leah Mazade edited the study, and Loretta Lettner proofread it. Angela Z. McCollough produced drafts of the report; Maureen Costantino designed the cover and prepared the study for publication. Lenny Skutnik printed the initial copies, Linda Schimmel coordinated the print distribution, and Simone Thomas prepared the electronic version for CBO's Web site (www.cbo.gov).



Peter R. Orszag
Director

June 2007



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Summary

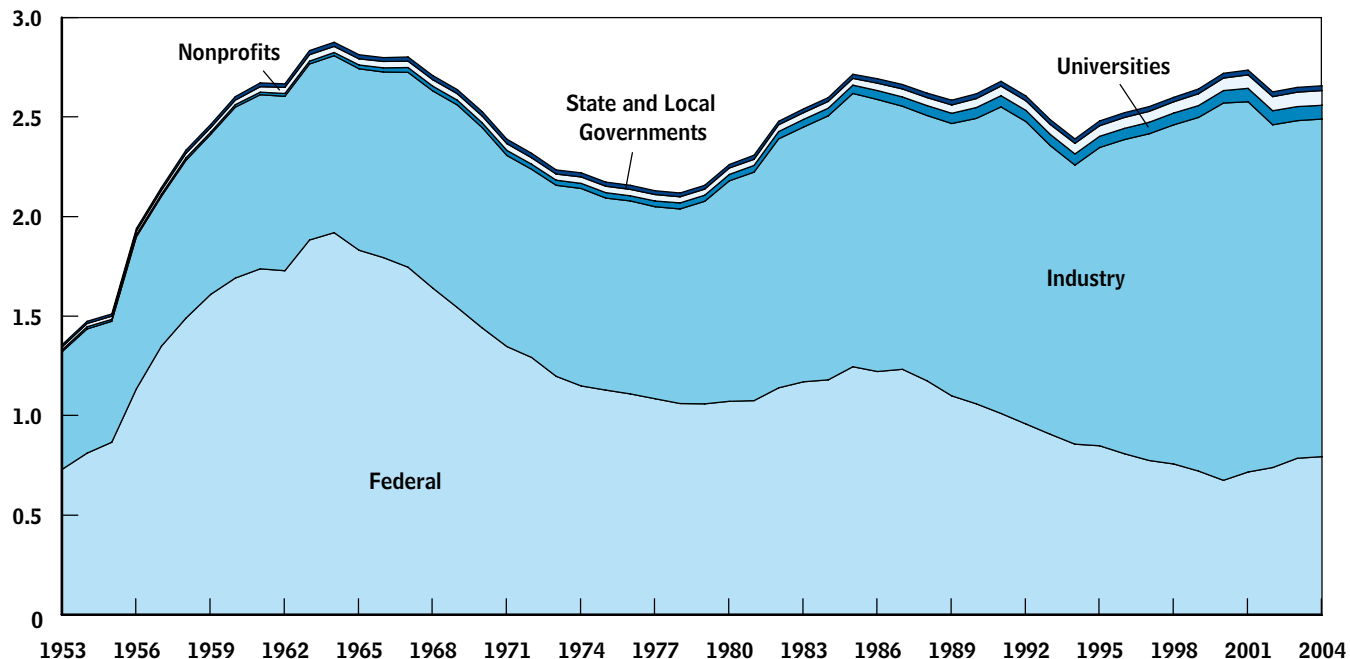
New knowledge and continuing innovation have been major factors in increasing economic well-being. Private businesses are the largest sponsors of research and development (R&D) in the United States, producing the discoveries that in turn lead to new products and services and the growth of productivity; however, the federal government has long provided significant support for R&D activities to both supplement and encourage private efforts. The government finances research and development through spending—fiscal year 2007 appropriations for R&D activities total \$137 billion—and tax benefits that give businesses an incentive to increase their R&D spending.

Studies of federally supported research and development provide multifaceted but incomplete answers to questions about those governmental activities: whether the current level of spending is appropriate, what returns taxpayers receive for public investment in R&D, and whether funds are allocated to areas of inquiry and projects that will provide the highest return on that investment. Results of the Congressional Budget Office's (CBO's) economic analysis of federal support for R&D and its review of trends in the data over time indicate the following:

- Over the 1953–2004 period as a whole, federal spending for R&D has grown, on average, as fast as the overall economy. Spending rose rapidly in the 1950s and early 1960s, reaching almost 2 percent of gross domestic product (GDP) in 1964, a peak that coincided with the acceleration of the U.S. space program. Since then, with the exception of a period in the 1980s—when an expansion of national defense activities prompted more funding for research and development—federal R&D spending has generally declined as a share of GDP.
- Distinguishing between research and development is important in evaluating the effectiveness of the government's R&D spending and the benefits it may provide. Research (particularly basic research) may be conducted without a specific commercial purpose in mind, but it may nevertheless have large “spillovers” in the economy because the knowledge it produces may be useful not only to researchers in other fields but also to businesses seeking to develop new products and production processes. Development occurs closer to a product's introduction so that its benefits go more directly to innovating firms and their customers. The federal government funds about half of all research in the United States but only 17 percent of development. Since the early 1980s, federal spending for research has grown more steadily and more quickly than federal spending for development.
- Federal funding of research—particularly of basic research—is generally viewed favorably because of its large potential for spillovers and the corresponding economic benefits. Nonetheless, the economic returns to basic research are difficult to measure because the progress that results from research may be hard to identify or to value and the interval between the research and its application to a product or process is sometimes long.
- Studies of federal spending for basic research in the past, particularly studies of research conducted at academic institutions, have estimated that the average returns from that spending exceed the returns that might have been gained had those resources been put to other uses. Additional federal spending could generate comparable benefits, although the returns to individual projects are likely to vary. Also, the gains from large increases in spending might be constrained if sufficient scientific and technical workers and facilities were not available.

Summary Figure 1.**U.S. Spending for Research and Development, by Funding Source**

(Percentage of gross domestic product)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

- In recent years, the share of federal research funding allocated to the life sciences has expanded, an emphasis supported by the high rates of returns to life sciences research that some studies have reported. But other studies indicate that researchers reach across disciplines for new ideas and tools, which would suggest that supporting research over a wide range of scientific fields is an important element in generating an economic return from federal research funding.
- Federal spending for development has generally focused on accomplishing public missions, most prominently that of national defense. Although in the past that spending has generated some commercially viable spin-off technologies, such by-products are largely unpredictable. A consideration of how supported projects would contribute to their stated mission therefore provides the best guidance to policymakers who are responsible for deciding whether to spend public funds for those activities.
- In 2004, the research and experimentation (R&E) tax credit drew claims of \$5.6 billion from firms, a small

amount compared with the funds that lawmakers have appropriated for R&D activities. Studies have found that the credit has the desired effect of boosting R&D spending by businesses; however, those studies do not compare the benefits derived from the increase in research and development with the potential benefits from other uses of the forgone revenues. In addition, the results of those studies may be overstated because firms have an incentive to classify as many expenses as possible as credit-eligible research, even if those expenses are not associated with new R&D activities.

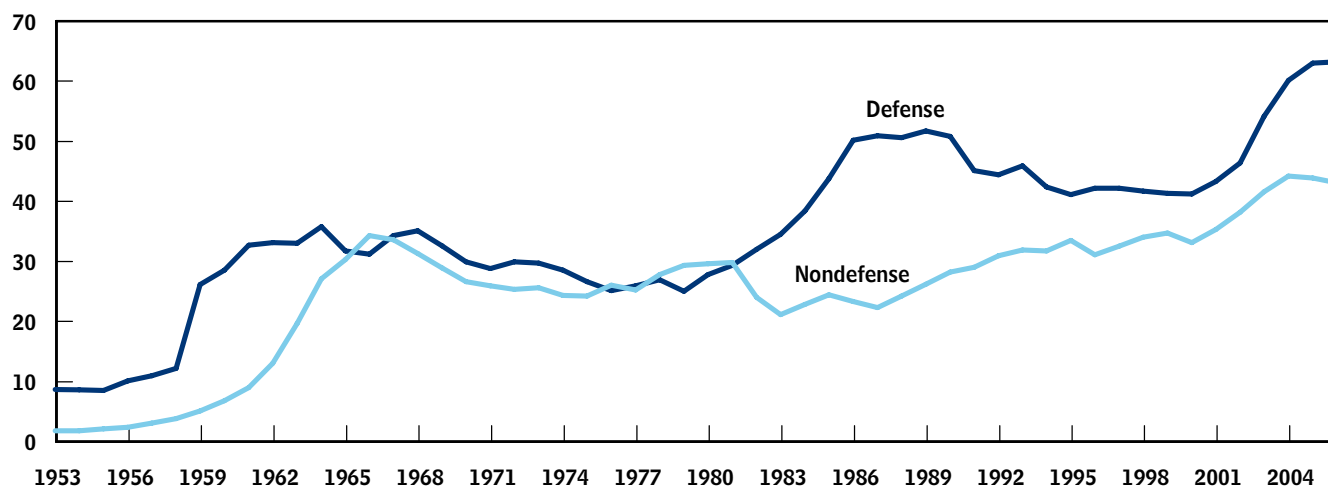
Trends in Federal Support for Research and Development

From 1953 to 2004, real (inflation-adjusted) spending for R&D in the United States rose at an average annual rate of 4.7 percent, faster than the 3.3 percent average growth of GDP. As a result, overall R&D expenditures—including public and private spending—climbed from less than 1.5 percent of GDP in the early 1950s to more than 2.5 percent in 2004 (see Summary Figure 1).

Summary Figure 2.

Federal Outlays for Research and Development, by Discretionary Spending Category

(Billions of 2000 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2008*.

The federal government and industry are the primary sources of funding for research and development in the United States—in 2004 providing \$93 billion and \$199 billion, respectively. As those figures indicate, industry's share of total R&D funding is the larger; although the federal government's share rose rapidly during the 1950s and early 1960s, it has declined significantly since then. Universities and colleges, nonprofit institutions, and state and local governments account for a small share of R&D spending (about \$20 billion in 2004, or roughly 6 percent of the national total).

Federal funding for defense and nondefense research and development show different trends. Real federal R&D spending for national defense purposes doubled in the 1980s and then declined in the 1990s following the end of the Cold War (see Summary Figure 2). From 2000 to 2006, defense-related research and development grew at a real average annual rate of 7.4 percent. Nondefense R&D has increased less rapidly, growing at a real average annual rate of 4.5 percent.

In its appropriated funding of R&D activities, the federal government has expanded its support of basic research more rapidly than its support of applied research (which aims to link scientific knowledge to some practical purpose) or development (which aims to create marketable

products). Between 1953 and 2004, federal funding for basic research grew at a real average annual rate of 6.3 percent, compared with rates of 3.5 percent for applied research and 2.2 percent for development. Federal spending for development has had some large swings, mainly because of increased expenditures at various times for space and defense programs (see Summary Figure 3).

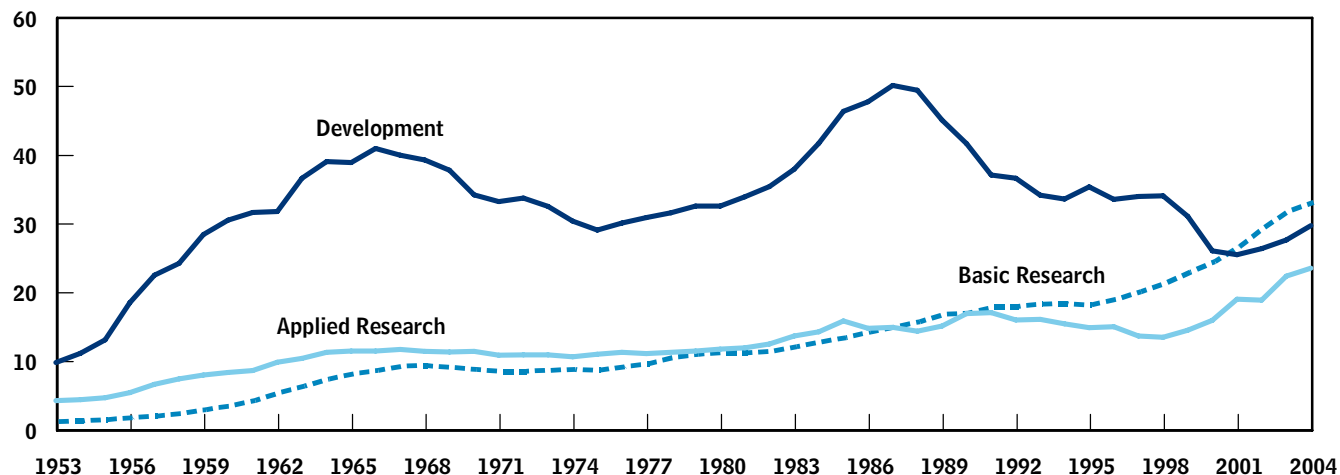
Those federal funds tend to go to different entities depending on whether the work involved is research or development. In 2004, universities performed 42 percent of federally funded research but less than 2 percent of development; industry performed 13 percent of federally funded research but 49 percent of development; and the federal government itself performed 22 percent of its own research and 36 percent of its own development.

Federally supported R&D activities are spread across a number of different fields and agencies. The two agencies with the largest R&D programs—the Department of Defense and the National Institutes of Health—together accounted for 73 percent of federal R&D outlays in 2004 (see Summary Figure 4). The agencies that focus on the physical sciences and engineering—the National Science Foundation, the National Aeronautics and Space Administration (NASA), and the Department of Energy—accounted for 19 percent of outlays.

Summary Figure 3.

Federal Spending for Research and Development, by Type of R&D

(Billions of 2000 dollars)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

Note: Basic research is meant to expand scientific knowledge without regard to commercial applications. Applied research seeks to connect scientific knowledge to some practical end. Development applies scientific knowledge to the creation of specific marketable products.

The federal research portfolio covers a broad range of scientific fields. The fields emphasized by lawmakers have changed over time, with the life sciences accounting for an increasing share of federal research spending since the 1990s (see Summary Figure 5). Federal obligations (the government's legally binding commitments that will result in spending) for life sciences research increased at a real average annual rate of 8.2 percent from 1994 to 2004, more than triple the rate of growth of the rest of the federal research portfolio. The rapid rise in federal spending for life sciences research apparently has not discouraged private-sector spending for such activities: R&D spending by pharmaceutical firms also grew rapidly during the 1994–2004 period.¹

In addition to supporting research and development directly through appropriated spending, the federal government provides a tax credit for R&D activities that firms undertake. First introduced in the United States in 1981, the R&E tax credit lowers the tax bill of firms that increase their spending for research and development. In general, the credit is designed to apply to incremental

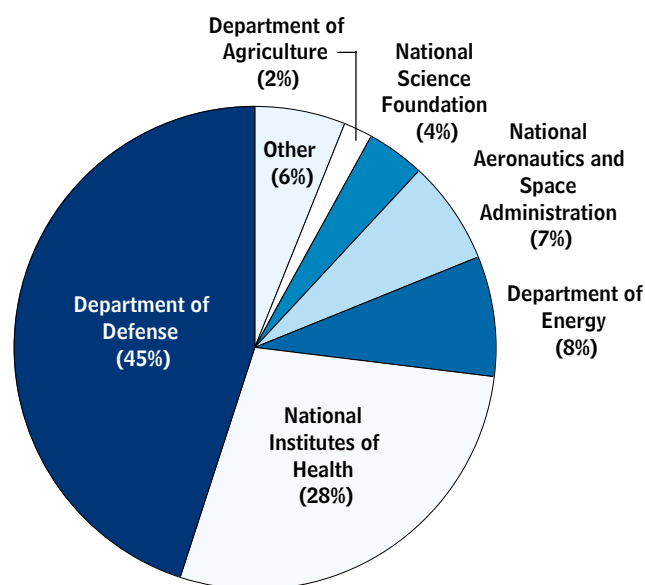
spending—that is, only the R&D funds spent above a base amount are eligible for the credit, which has three variants, each with a different base. The base amounts are meant to approximate what firms would have spent on research in the absence of the credit.

Since 1994, businesses have claimed credits (expressed in 2000 dollars) totaling as little as \$1.5 billion (in 1995) and as much as \$7.0 billion (in 2000). Manufacturing firms have claimed the largest share of those credits; however, over time, other sectors, including health care and construction, have accounted for increasing amounts.

Analysis

Empirical studies of past federal support for research, as opposed to all research and development, suggest that the economic returns to that spending have been positive, and on average, similar returns may be expected from more such spending. Even so, measuring the returns from research in general, and from any project in particular, is complicated by several factors: the difficulty of identifying and valuing all the potential uses of research results, the long periods likely between the decision to fund a project and the eventual uses of its findings to create products, and uncertainty about whether useful findings

1. See Congressional Budget Office, *Research and Development in the Pharmaceutical Industry* (October 2006).

Summary Figure 4.**Federal R&D Outlays, by Agency, 2004**

Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* (Arlington, Va.).

will arise in a specific field at a specific point in time or from any individual project.

Federal Funding of Research and Development

Federally funded R&D may be separated into two broad categories—mission-oriented activities and work that aims to advance the state of scientific and technical knowledge. That distinction may prove useful to policymakers charged with setting funding levels for R&D programs.

A large portion of federal support for research and development is undertaken in the service of a governmental mission—such as the development of NASA's space shuttle or of weapons for the Department of Defense. Spending for those purposes for the most part is included in the federally funded development work carried out by industry. A number of studies have found no economic return associated with such spending. Thus, decisions about undertaking those projects may be best guided by considering how the projects' anticipated results might be expected to contribute to the mission at hand, rather than how big their economic returns might be.

Other federal spending for R&D, and especially for research, is often directed at creating new knowledge and finding new applications for technology. That research includes work in a variety of scientific fields and may also cut across disciplines. This second category of support has tended to be the focus of after-the-fact empirical estimates of the rate of return to research—estimates that have been positive despite the difficulties involved in putting a value on the new knowledge.

The Research and Experimentation Tax Credit

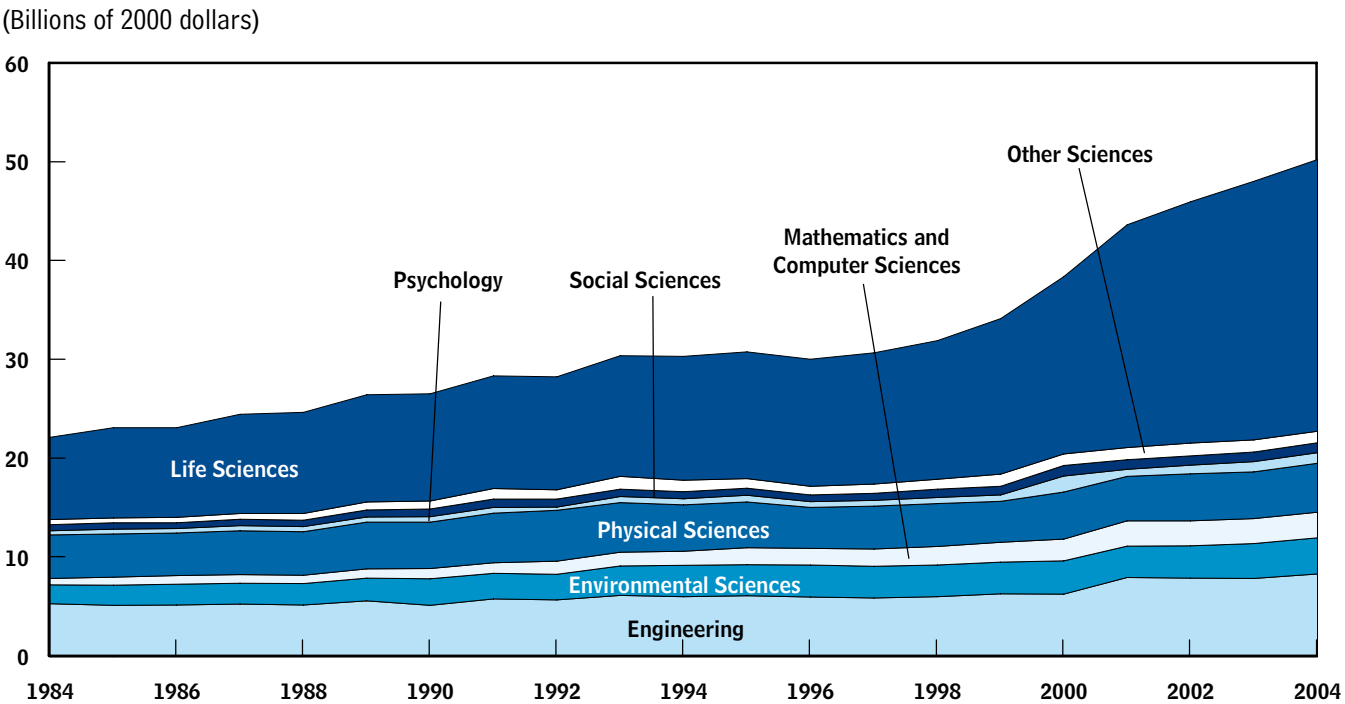
Studies of the effectiveness of the United States' R&E tax credit (and of similar policies in other countries) have focused on estimating the additional research and development that the credit stimulates.² Those studies have produced a variety of results, many of which have clustered around the finding that a dollar of an R&D tax credit leads firms to spend an additional dollar of their own on research and development. Some studies of the credit in the United States suggest that its effect in inducing R&D spending may be growing over time. One group of researchers found that the tax credit had a less than one-to-one effect on R&D spending in the early 1980s but that after a change in the way the base amount was calculated—a change enacted in the Omnibus Budget Reconciliation Act of 1989—firms spent an additional \$2.10 on R&D for each dollar of the credit. The same researchers also found that after 1989, fewer firms were eligible for the credit, but among those that were, a larger share were high-tech firms.

A cautionary note is warranted about those findings, however, because the data may suffer from a relabeling problem that could, over time, lead the credit's effect to be overstated. Firms have an incentive to classify as many expenses as possible as R&D spending to take advantage of the favorable tax treatment, and that incentive grows with the size of the credit. Even if those expenses were related to activities that were not new R&D efforts—just work that was newly classified that way—the activities would be included in the increase in R&D that was apparently spurred by the tax credit, thus overstating the credit's impact.

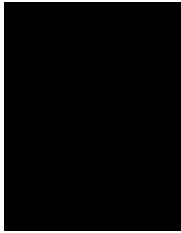
2. The U.S. credit is referred to as the research and experimentation tax credit because to qualify for it, activities must be experimental in nature. The credit is usually understood to apply to R&D activities, although some development work related to the design of a product may not qualify. In other countries, the experimentation distinction may not be explicit, and the class of tax credits that includes the United States' R&E credit is generally referred to as R&D tax credits.

Summary Figure 5.

Federal Obligations for Research, by Field



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* and *Science and Engineering Indicators, 2006* (Arlington, Va.).



Federal Support for Research and Development

Investments in research and development (R&D) have increased productivity, boosted economic growth, generated new products and processes, and improved the quality of people's lives.¹ The possibility of profiting from a new product or process frequently leads businesses to invest substantial amounts of money in research and development. However, private investors cannot capture many of the benefits of their R&D spending, as the knowledge it produces may be used by others; consequently, the private sector may not make some investments that have positive social, or economic, returns—gains for society and for the economy as a whole. To address that problem of incentives and encourage more R&D investment, the government uses several policy tools, including appropriated spending for R&D activities, tax preferences for private-sector research and development, and protection of intellectual property through the copyright and patent systems.

Analysts generally regard the government's funding of research and development as a way to partly offset the problems created by the difference between the returns that private parties achieve from their R&D investment—in the form of profits from new products and processes—and the returns that society may derive from those R&D activities. Federal spending has been critical to the funding of basic research (scientific inquiry that has no clear-cut commercial application but is nonetheless valued for the knowledge that results and the potential for future discoveries to grow from it). The tax preferences that policymakers have provided—the treatment of R&D spending as a fully deductible expense that can be

subtracted from profits immediately rather than as an investment to be amortized and deducted over time, and the research and experimentation (R&E) tax credit—lower the cost of research and development, thereby increasing firms' after-tax returns on those activities and strengthening the incentives for firms to invest even more in research and development.

In addition, the U.S. patent and copyright systems have features that encourage the private sector to fund R&D activities. Researchers who make a discovery often find it difficult to control who makes use of their work once it becomes public because the knowledge they produce may “spill over” and be used by others. Intellectual property protections, such as patents and copyrights, afford researchers—or, in some cases, the sponsors of research—legal control over the results of their work.² Others wishing to make use of those results must secure permission by paying a licensing fee to the patent or copyright holder.

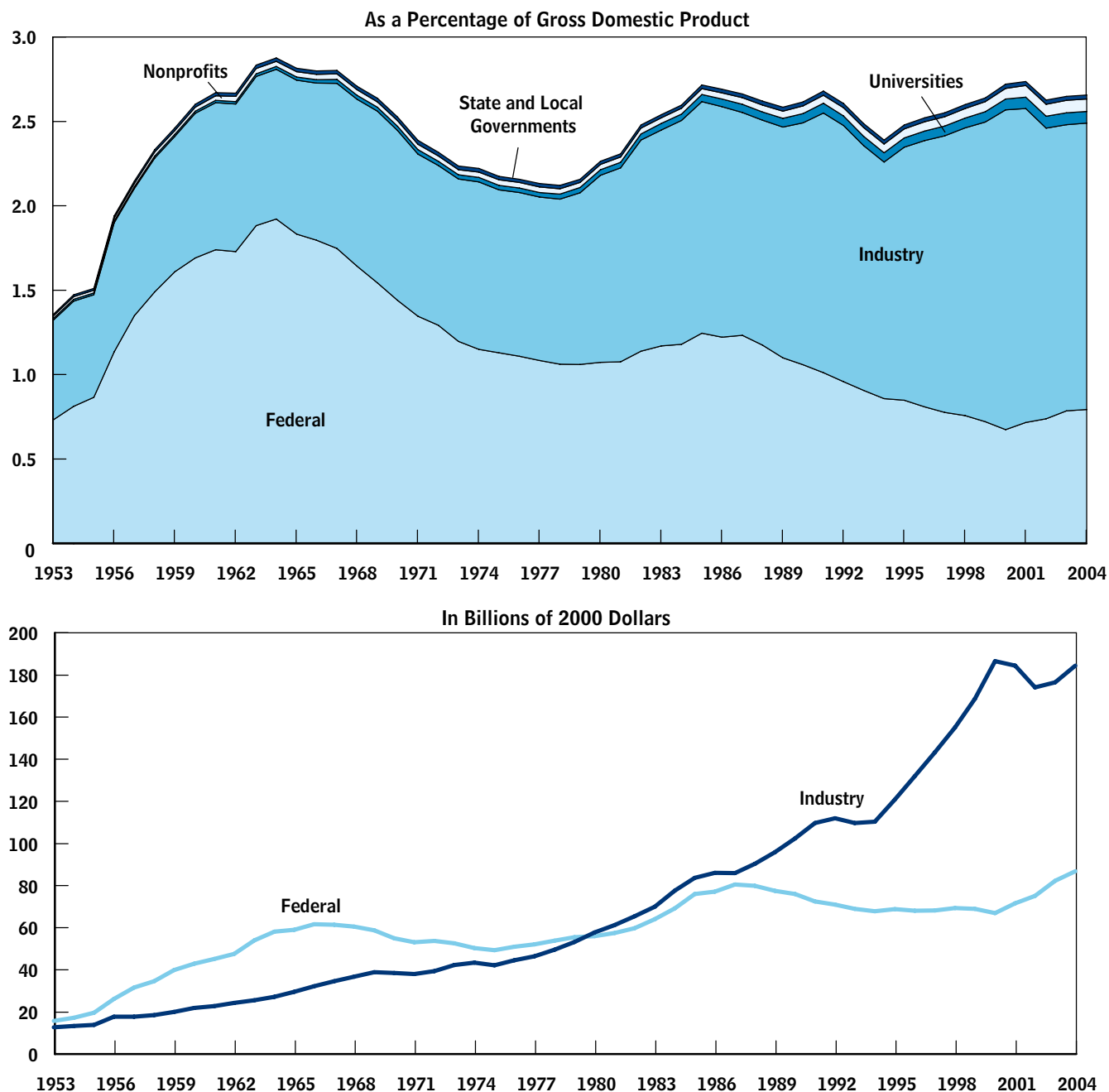
The patent and copyright systems offer some protections against and compensation for others' use of a researcher's results, but they are an imperfect solution to the spillover effects that diminish the incentives for firms to invest in research and development. In some instances, costly delays and court battles over intellectual property protections may ensue, and licensees may not compensate patent holders for the full value of their findings. Moreover, the limitations on the life of a patent may not create strong incentives for firms to invest in research that could have a long path to development. Finally, although patents and copyrights encourage future R&D activities,

1. For a detailed look at the relationship between R&D and productivity as well as a discussion of estimates of the rates of return to private R&D, see Congressional Budget Office, *R&D and Productivity Growth* (June 2005).

2. For a discussion of similar issues as they relate to copyrighted works, see Congressional Budget Office, *Copyright Issues in Digital Media* (August 2004).

Figure 1.

U.S. Spending for Research and Development, by Funding Source



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

they also have a cost: deferral of the social benefits that might result from the more immediate and widespread application of currently protected innovations.

This Congressional Budget Office (CBO) study focuses on government-funded research and development—activities carried out in government laboratories or by academic researchers or private firms funded through federal grants or contracts—and tax incentives that encourage firms to perform research. For fiscal year 2007, federal budget authority (the legal authority to incur financial obligations resulting in outlays by the government) for research and development totals \$137 billion.³ Tax incentives for R&D activities are estimated to have cost \$9.9 billion in forgone revenues in fiscal year 2006. CBO's analysis discusses trends in those expenditures and examines the recent economics literature that has attempted to evaluate the economic effects of federal R&D programs.

Trends in Funding Research and Development

Since the late 1950s, the United States has consistently spent more than 2 percent of its gross domestic product (GDP) for research and development (see the top panel of Figure 1). From 1953 to 2004, real spending for R&D in the United States (that is, spending after an adjustment for the effects of inflation) grew at an average annual rate of 4.7 percent. The federal government and private-sector firms have been the primary sources of that funding. Spending by industry for R&D activities has grown more quickly than spending by the federal government (an average annual rate of 5.4 percent versus 3.5 percent) and has exceeded federal funding since 1980 (see the bottom panel of Figure 1). In 2004, industry's R&D spending reached \$199 billion (in current dollars), and the federal government, according to the National Science Founda-

tion (NSF), spent more than \$93 billion. Other sources of R&D funding are small by comparison.⁴

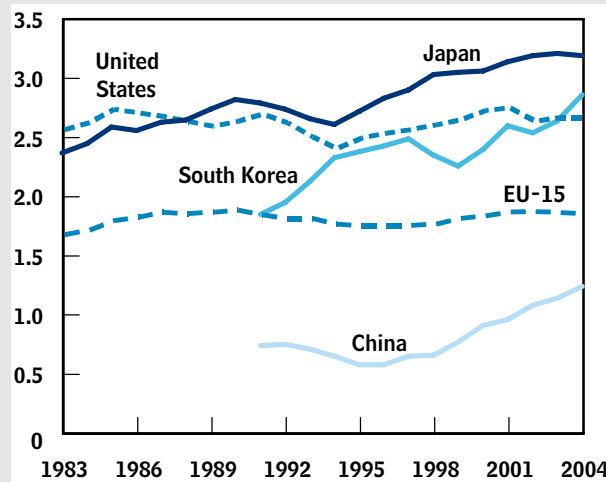
The divergence between federal and industrial research and development was particularly stark in the 1990s, when real federal spending for R&D declined by an average of 1.3 percent per year while industry-sponsored R&D expanded by an average of 6.2 percent annually. Other countries have also expanded their R&D activities in recent years (see Box 1).

Historically, a large part of federal R&D spending has been devoted to agencies that have uniquely public missions, in particular national defense. Although the private sector performs much of that work under contract, the government directs such mission-oriented R&D because it, rather than private customers, is the ultimate consumer of any new technologies that might result.

Federal spending for research and development has at times accounted for a substantial portion of the government's discretionary spending (spending controlled by appropriations). Following the Soviet Union's launch of Sputnik in 1957, the United States' focus on its space program and the sciences in general led to a boost in non-defense R&D activities. As a result, by the mid-1960s, those activities accounted for 25 percent of nondefense discretionary outlays, a share that tapered off through the

3. Intersociety Working Group, *AAAS Report XXXII: Research and Development FY2008* (American Association for the Advancement of Science, Washington, D.C., April 2007), p. 53.

4. Together, the federal government and industry provide well over 90 percent of R&D funding, a share that has fallen from 98 percent in the 1950s and 1960s to 94 percent since 2000. Accordingly, funding from other groups has accounted for a growing share. By 2004, universities and nonprofit organizations each provided just under 3 percent of funds (\$8.2 billion and \$8.6 billion, respectively), and state and local governments provided approximately 1 percent (\$2.9 billion). For additional information, see National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series). Although universities, nonprofits, and state and local governments have increased their R&D funding, the level of support they provide is unlikely to be large enough to offset the industrial R&D that is forgone because of the difference between private and social returns to R&D.

Box 1.**International Research and Development Activity****R&D as a Percentage of Gross Domestic Product**

Source: Except where otherwise noted, the data presented in this figure and in the rest of the box are taken from Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators*, vol. 26, release 2 (Paris, 2007), accessed through the SourceOECD database.

Note: EU-15 = the 15 European Union member countries in 1996.

As scientific papers are published, patents are approved, and products emerge from development, the knowledge embodied in them is made available to scientific and research communities worldwide. U.S. researchers, firms, and consumers benefit from research and development (R&D) performed elsewhere in the world, and people abroad benefit from R&D activities in this country. That global diffusion of new knowledge increases the potential, both here and abroad, for substantial social returns—greater economic growth, new products and processes, improvements in the quality of people's lives—from investments in research and development.

The global context in which the U.S. government and industry provide support for R&D projects may have implications for how much the government should be spending on R&D, for how that spending

is allocated between research and development, and for the mix of scientific disciplines that it is appropriate to fund.

In 2004, R&D spending worldwide totaled roughly \$900 billion. More than one-third of the activities supported by those funds took place in the United States, more than one-eighth were performed in Japan, and more than one-tenth occurred in China.¹ R&D activity is expanding rapidly in Asia: From 1998 to 2004, spending for research and development in China grew at a real (inflation-adjusted) annual rate of 21 percent while R&D expenditures in South Korea rose at a real annual rate of 10 percent. An April 2006 press release by the Organisation for Economic Co-operation and Development recently predicted that in PPP terms, China in 2006 would overtake Japan in R&D expenditures. Using the official exchange rate, the Chinese government in its own press release (in January 2007) claimed a smaller amount of spending.

Although the expansion of R&D in China and South Korea partly reflects the overall growth that the two economies are experiencing, it is also a sign of the increasing importance of science and technology in those nations: Spending for R&D during the 1998–2004 period rose at a faster rate than income in both countries (see the figure to the left). Some analysts have questioned whether the United States can

1. In purchasing power parity, or PPP, terms (a PPP exchange rate is calculated by comparing the purchase price of a given basket of goods in each country's currency), the \$900 billion consists of spending of \$726 billion in countries that are members of the Organisation for Economic Co-operation and Development (OECD); \$143 billion in China and seven other non-OECD countries that the OECD tracks; \$24 billion in India (according to OECD's *Science, Technology, and Industry Outlook 2006*, Paris, 2006, p. 42); and roughly \$30 billion in other countries, based on spending in earlier years reported by the UNESCO Institute for Statistics (see "Statistics on Research and Development," May 2006, available at <http://stats.uis.unesco.org/ReportFolders/reportfolders.aspx>).

Box 1.**Continued****Composition of Research and Development**

Country	Government-Financed Share of R&D, 2004	Defense Share of Government-Financed R&D, 2005	Basic Research Share of Total R&D, 2004 ^a
United States	31.0	57.1	19
EU-15	35.1 (2003)	13.5	n.a.
Japan	18.1	4.0	12
South Korea	23.1	13.3	15
China	26.6	n.a.	6

Note: EU-15 = the 15 European Union member countries in 1996; n.a. = not available.

a. Data on basic research for the EU-15 as a whole were not available. However, as an example of those nations' investment, in 2004, basic research accounted for 24 percent of all R&D in France.

maintain the size and quality of its scientific and engineering workforce in the future if recent trends in the growth of overseas R&D investment continue. A large portion of the U.S. workforce is foreign born, and as more R&D opportunities open up in their home countries, fewer such workers may choose to immigrate to the United States, and those already here may decide to return home.²

The source of R&D funding and the composition of such expenditures vary among countries. In the United States and Europe, governments fund a relatively larger share of research and development than they do in Asia, where industry-financed R&D is more prevalent (it accounts for 75 percent of all R&D in Japan and South Korea; see the table above). Compared with other nations, the United States directs a far larger portion of its government R&D expenditures toward defense-related projects—nearly double the amount of the second largest share (the United Kingdom's 31 percent). Basic research is emphasized more in the United States and Europe than in Asia, perhaps reflecting the government's larger role in financing R&D in those regions.

As other countries expand their R&D activities, the knowledge flowing into the United States from those projects may increase. The number of foreign scientific publications has climbed rapidly: Between 1996 and 2003, scientific articles arising from U.S.-based researchers increased by 5 percent, those from researchers in the EU-15 (the 15 European Union member countries in 1996) increased by 14 percent, and those from the rest of the world increased by 24 percent.³ In addition, improvements in communications technologies make it easier for researchers of all nations to use findings from that research to advance their own work and may open up new possibilities for cross-border collaborations. U.S.-based researchers, for example, have increased their international collaborations: In 2003, 25 percent of articles with at least one U.S.-based author had an international coauthor, compared with only 18 percent in 1996.⁴

2. For a discussion of that issue, see, for example, Richard Freeman, *Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?* NBER Working Paper No. 11457 (Cambridge, Mass.: National Bureau of Economic Research, June 2005).

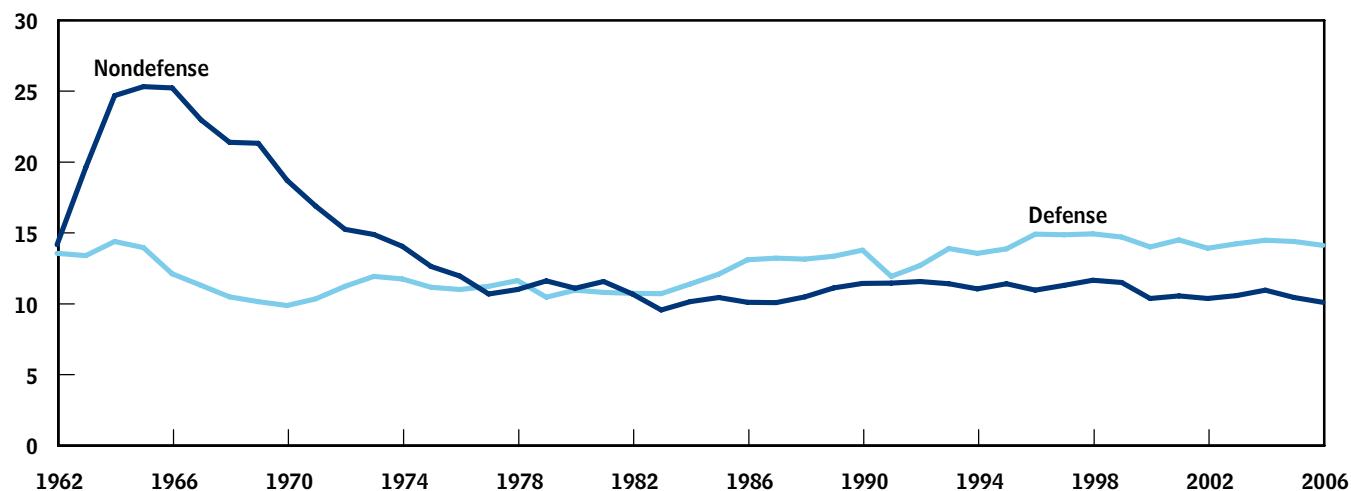
3. National Science Foundation, *Science and Engineering Indicators 2006*, vol. 2 (Arlington, Va., 2006), Appendix Tables 5-44 and 5-45. Those data reflect fractional counts; for example, an article that had two authors, one in a U.S. institution and one in France, would contribute 0.5 articles to the U.S. count and 0.5 articles to the EU count.

4. Ibid., Appendix Tables 5-48 and 5-49.

Figure 2.

Federal Spending for Defense and Nondefense Research and Development as a Percentage of Corresponding Discretionary Outlays

(Percent)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2008: Historical Tables* (2007).

Note: Discretionary outlays constitute spending controlled by appropriations.

1970s to remain at 10 percent to 11 percent (see Figure 2).⁵ In terms of defense spending, R&D activities accounted for an increasing share in the 1980s; since then, though, their share of total defense outlays has held steady at about 14 percent.⁶

In many cases, the entity that actually carries out an R&D project differs from the entity that provides the project's funding. Federal laboratories, universities, other nonprofit organizations, and industry all perform research and development that is funded by the federal government. And the R&D activities funded by the private sector may be outsourced to many of those same entities. Of the research and development performed in

the United States, industry accounts for the vast majority—about 70 percent—a share that has been maintained with some consistency over the past 50 years (see Figure 3). However, firms now fund a much more substantial share—89 percent—of that R&D themselves.⁷ Nonprofit organizations and federally funded research and development centers (FFRDCs) have seen little change in the share of total R&D they perform.⁸

Over the past 50 years, there has been a gradual shift in where research and development is performed outside of industry, with activities moving from the federal government's intramural programs (work performed at government labs by government employees) to universities. In 2004, the federal government conducted 8 percent of the

5. For example, NSF, which was created in 1950, saw its budget more than double from 1956 to 1957 and again from 1958 to 1959. In other years in the 1950s and most of the 1960s, the rate of growth of NSF's budget from one year to the next was in the double digits. See National Science Foundation, Budget Division, "NSF by Account (FY Actuals—FY2006, Constant Dollars in Millions)" (Arlington, Va., 2006), available at http://dellweb.bfa.nsf.gov/NSFHist_constant.htm.

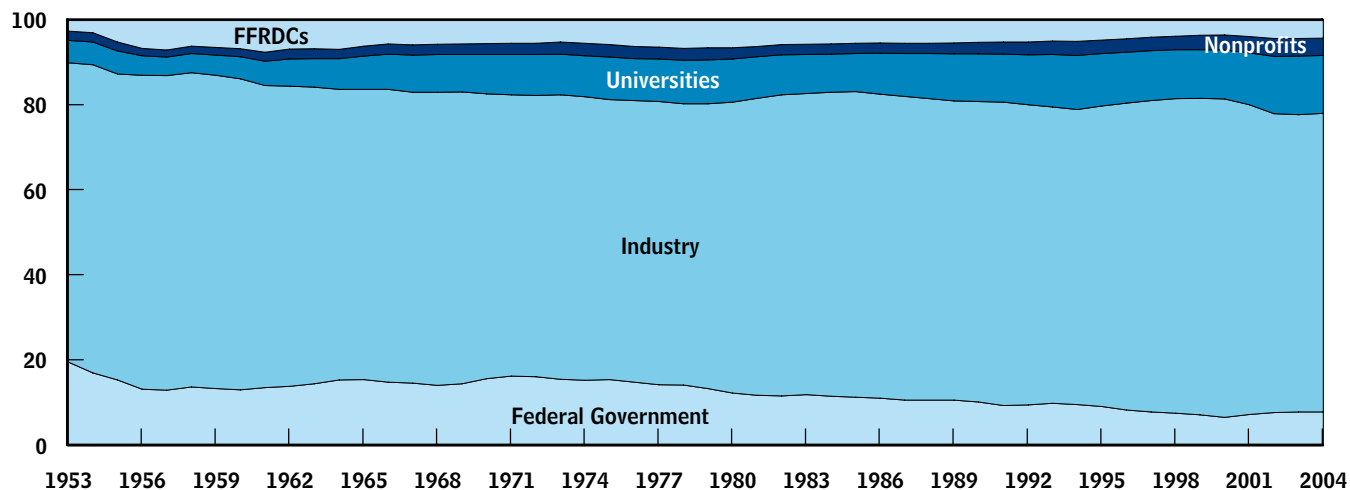
6. For a more detailed history of federal R&D funding, see Richard Rowberg, *Federal R&D Funding: A Concise History*, CRS Report 95-1209 (Congressional Research Service, updated August 14, 1998).

7. National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources: 2004 Data Update* (Arlington, Va., September 2006).

8. FFRDCs often host especially capital-intensive R&D projects. In May 2006, the National Science Foundation counted 37 FFRDCs under the auspices of a variety of federal agencies. Although federally funded, FFRDCs may be administered by industrial firms, universities, or other nonprofit institutions. For details of such centers, see National Science Foundation, Division of Science Resources Statistics, *Master Government List of Federally Funded R&D Centers* (Arlington, Va., May 2006).

Figure 3.**U.S. Research and Development, by Performer**

(As a share of total R&D performed)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

Note: FFRDC = federally funded research and development center.

research and development that took place in the United States, less than half the share it performed in the early 1950s. In contrast, universities and colleges have steadily increased their share of R&D activities, boosting it from 5 percent in the 1950s to 14 percent in 2004.

The sources of funding for industrial, intramural, and academic R&D have also changed over that period. In 2004, the government funded about 10 percent of industrial R&D; by contrast, in the late 1950s and early 1960s, that share peaked at more than 50 percent (see the top panel of Figure 4). Federal funding for intramural and university R&D has continued to increase in real terms over the same period (see the middle and bottom panels of Figure 4). From 1954 to 2004, federal funding for university-performed research and development grew more rapidly than did federal funding for R&D performed by others, rising at a real annual rate of 6.8 percent (compared with 3 percent for intramural government research and development) and now accounting for about 60 percent of university R&D.

NSF's estimates of government spending for research and development do not include the revenues forgone as a result of the tax incentives provided to encourage the private sector to perform more research. In 2004, firms claimed a total of nearly \$5.6 billion under the R&E tax

credit.⁹ Unlike appropriated federal spending for R&D, which has generally trended upward, claims for the R&E tax credit have varied, probably in response to revisions in tax law governing the credit and changes in economic conditions.

Assessing the Federal Government's Role in Research and Development

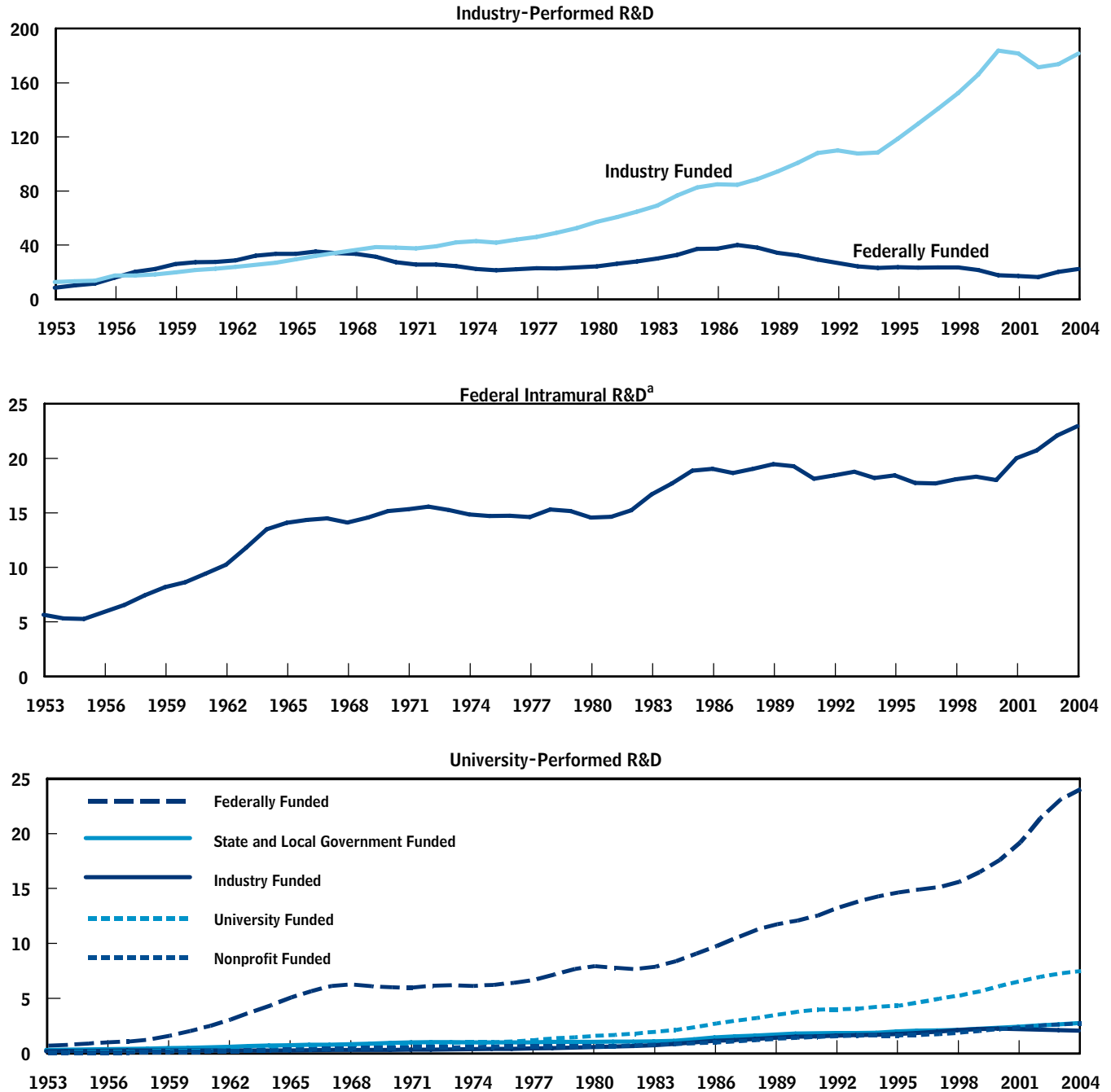
The difference between private financial returns to R&D activities and the social benefits that arise from such work is often used to justify federal support for research and development. Firms undertake R&D that promises the largest likely profit, which is not necessarily the work that produces the greatest benefit to society. As a result, neither the scope nor the amount of R&D initiated by the private sector—even the projects of consortia formed by private-sector firms to conduct collective research—is likely to provide the maximum benefits to society. Governments thus fund research and development activities directly to supplement those private-sector activities but face the challenge of making investments that will produce the most socially beneficial outcomes.

9. Internal Revenue Service, *Statistics of Income: Corporation Complete Report* (2004), Table 21.

Figure 4.

U.S. Spending for Research and Development, by Performer and Funding Source

(Billions of 2000 dollars)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

a. Funded entirely by the federal government and performed in federal facilities by federal employees.

For both types of federal support for R&D—appropriated spending and tax incentives—determining the “right” amount is difficult. Perhaps the biggest hurdle is measuring the returns to R&D because it can be difficult to trace the path that an R&D discovery takes over time, to gauge the value added at each step along the way to a final product, and to consider what might have occurred in the absence of that discovery. In addition, policymakers must decide not only how much to spend on R&D in total (and therefore what they will not be spending to support other governmental priorities) but also how to allocate that funding among fields of scientific study, agencies, constituencies, and missions.

Investment in Research and Development by the Private Sector

Private firms may invest less in R&D activities than is socially desirable because they recognize that they will be unable to keep the full financial benefit of their research investment for themselves.¹⁰ Studies have documented that private firms face difficulties in making exclusive use of their R&D and especially of their research results.¹¹ To reap the rewards from its investment in R&D, a

private firm might have to keep its results closely guarded for some time until it was ready to put them to use in a product. Once a product is marketed, the knowledge that emerged from the firm’s earlier research and development work is likely to become clear to others, often through disclosures in patents or reverse engineering, potentially allowing others who did not invest in the research to benefit from it.

For society as a whole, however, the cost to share the knowledge generated by a firm’s R&D, and in particular by its research (for example, through publication of the results), is usually less than the potential social benefits to be gained from sharing that information. Society can often benefit if new information is shared immediately because other firms with a more immediate use for the knowledge will have access to it and can then avoid costly duplicative research and development. Further, because knowledge persists even after it has been put to use, its utilization by one party does nothing to prevent another from also using it. One set of research findings could thus be used simultaneously by a variety of firms and other researchers.

In recognition of the value of R&D activities in general and the limited incentive for individual firms to conduct research in particular, industry and governments have tried to increase investment in research.¹² Private firms may initiate research joint ventures or similar collaborative research arrangements, in which they coordinate their efforts and share the results. A theoretical model has shown that if such coordinated arrangements maximize the total profits of all firms and avoid duplicating R&D activities, they can benefit the firms and produce substantial social benefits.¹³ Coordination of R&D activities may improve firms’ ability to secure the returns to their efforts, increase R&D spending, and reduce the risk of the investment for each participating firm, all of which would improve efficiency (that is, produce even better

10. Some analyses examine the potential for overinvestment in R&D, which may result from duplicative efforts among firms that are racing to patent findings, deter the entry of new firms or products, or develop small innovations that destroy the market for existing products. See, for example, Kalyan Chatterjee and Robert Evans, “Rivals’ Search for Buried Treasure: Competition and Duplication in R&D,” *RAND Journal of Economics*, vol. 35, no. 1 (Spring 2004), pp. 160–183; Charles I. Jones and John C. Williams, “Measuring the Social Return to R&D,” *Quarterly Journal of Economics*, vol. 113, no. 4 (November 1998), pp. 1119–1135; and A. Michael Spence, “Entry, Capacity, Investment, and Oligopolistic Pricing,” *Bell Journal of Economics*, vol. 8, no. 2 (Autumn 1977), pp. 534–544.

11. Two early papers frequently cited in the literature are Kenneth J. Arrow, “Economic Welfare and the Allocation of Resources for Invention,” in Richard R. Nelson, ed., *The Rate and Direction of Inventive Activity* (Princeton, N.J.: Princeton University Press, 1962), pp. 609–626; and Richard R. Nelson, “The Simple Economics of Basic Scientific Research,” *Journal of Political Economy*, vol. 67, no. 3 (1959), pp. 297–306. Later studies that have revisited the issues include Zvi Griliches, “The Search for R&D Spillovers,” *Scandinavian Journal of Economics*, vol. 94, supplement (1992), pp. S29–S47; and Bronwyn H. Hall, “The Private and Social Returns to Research and Development,” in Bruce L.R. Smith and Claude E. Barfield, eds., *Technology, R&D, and the Economy* (Washington, D.C.: Brookings Institution and American Enterprise Institute for Public Policy Research, 1996), pp. 140–162.

12. The private sector has turned to prizes to stimulate research to solve specific problems. For a discussion of research prizes, see Congressional Budget Office, *Evaluating the Role of Prizes and R&D in Reducing Carbon Dioxide Emissions* (September 2006), pp. 12–13.

13. Morton I. Kamien, Eitan Muller, and Israel Zang, “Research Joint Ventures and R&D Cartels,” *American Economic Review*, vol. 82, no. 5 (December 1992), pp. 1293–1306.

results from the resources that are being used).¹⁴ However, if firms coordinate their R&D activities, they may also reduce competition by giving participants in such ventures more power in the marketplace, erecting substantial barriers to new firms that wish to enter the market, or promoting other types of anticompetitive coordination among member firms.

Research Versus Development

Research—especially basic research—generally produces larger external effects, or spillovers, than development does, suggesting that the government’s involvement in such research may lead to more spillovers than those generated by its support of development activities. The purpose of *basic research* (for example, physics research on the properties of elementary particles) is to make discoveries that expand scientific knowledge, even though commercial applications of that knowledge may be far in the future and not readily identifiable. *Applied research* (for example, the discovery of new materials for drug delivery) is a step closer to commercialization because it seeks to connect scientific knowledge to some practical purpose. *Development* applies scientific knowledge to the creation of specific marketable products.

The private sector has more of an incentive to invest in development activities than in basic or applied research, for several reasons: the uncertainty surrounding the results of research, the long time horizon needed to commercialize research findings, the lack of connection of research in many instances to the current demand for products, or some combination of those factors.¹⁵ And even if all of those problems could be addressed, underinvestment in research by the private sector might still occur, because the returns to research for private firms, unlike the social returns, do not encompass the benefits that research might bring to others who could also put that knowledge to use.

Whether financed by the public or private sector, research and development are characterized by the same set of external effects. But in contrast to private-sector firms, which are motivated primarily by profits, the government

may take into account a number of factors, including the potential for spillovers, in choosing which research projects to support. The different objectives of the public and private sectors are evident in their patterns of spending for R&D (see Figure 5). Development activities accounted for 77 percent of industry’s total R&D budget in 2004, more than twice the share of development in the federal government’s R&D budget. If the Department of Defense’s (DoD’s) R&D spending was excluded, federal obligations—the government’s legally binding commitments to spend money—for development in 2004 would account for only 11 percent of total nondefense R&D obligations, whereas the share of basic research would rise to 46 percent and that of applied research to 43 percent (see Figure 6). In contrast, the vast majority of DoD’s R&D spending occurs in the development phase of projects.¹⁶

Questions about the relative emphasis on research and development in the federal government’s spending prompted a committee of the National Academy of Sciences, in a 1995 report, to suggest the concept of a federal science and technology (FS&T) budget that would reflect the extent of the federal government’s funding for investments that increased the stock of knowledge and led to new technologies and applications. The committee’s report described the FS&T budget as total federal R&D spending minus funding for advanced systems development in the Department of Defense, the Department of Energy, and the National Aeronautics and Space Administration (NASA).¹⁷ The Office of Management and Budget (OMB) reported the first FS&T budget in fiscal

14. Kathryn L. Combs and Albert N. Link, “Innovation Policy in Search of an Economic Foundation: The Case of Research Partnerships in the United States,” *Technology Analysis and Strategic Management*, vol. 15, no. 2 (2003), pp. 177–187.

15. “Out of the Dusty Labs: The Rise and Fall of Corporate R&D,” *The Economist* (March 1, 2007).

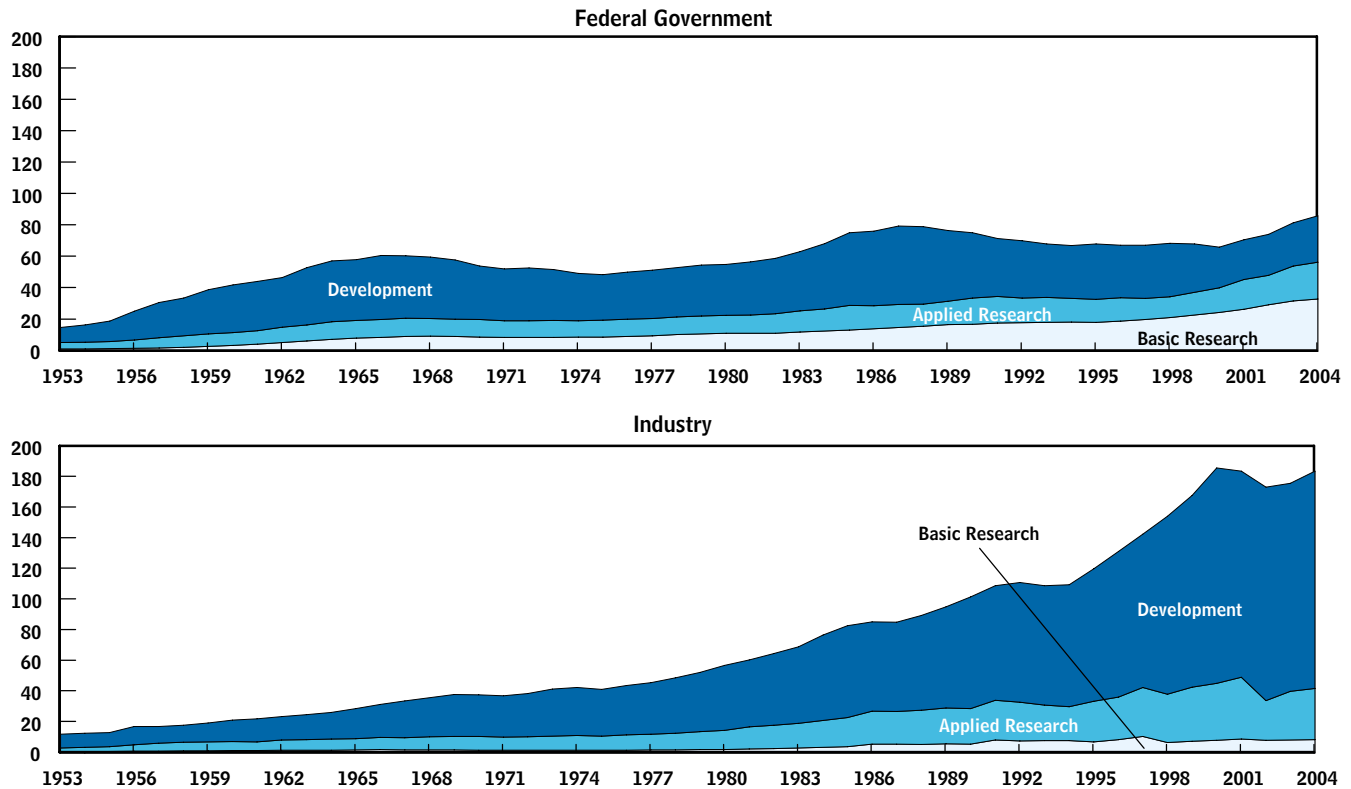
16. There is a difference between so-called performer-reported federal R&D (which appears in NSF’s *National Patterns of R&D Resources*) and the R&D obligations reported by federal agencies (which are the foundation for NSF’s *Federal Funds for Research and Development*). According to the National Science Board, which oversees NSF and offers advice to policymakers on issues involving science and engineering research and education, the problem is not unique to the United States. The discrepancy is due at least in part to differences in timing and accounting. For example, although a federal agency has obligated R&D funds, the organization or individual performing the research may not yet have spent those funds and done the work. For a discussion of the problem, see National Science Board, *Science and Engineering Indicators 2006*, vol. 1 (Arlington, Va.: National Science Foundation, 2006), pp. 4–25.

17. National Academy of Sciences, Committee on Criteria for Federal Support of Research and Development, *Allocating Federal Funds for Science and Technology* (Washington, D.C.: National Academy Press, 1995), p. 56.

Figure 5.

U.S. Spending for Research and Development, by Funding Source and Type of R&D

(Billions of 2000 dollars)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

Note: Basic research is meant to expand scientific knowledge without regard to commercial applications. Applied research seeks to connect scientific knowledge to some practical end. Development applies scientific knowledge to the creation of specific marketable products.

year 2000 (\$42 billion); in 2006, the FS&T budget totaled \$60 billion. According to OMB, it includes “nearly all of Federal basic research, over 80 percent of Federal applied research, and about half of Federal non-defense development.”¹⁸ Given that development accounts for only a small portion of R&D funds outside of defense-related agencies, the FS&T budget closely tracks the sum of federally funded basic and applied research (see Figure 7).

The distribution of patents among the private sector, academia, and the government further reveals their differing roles in the United States’ R&D arena.¹⁹ Universities are

granted a small portion of the patents issued by the U.S. Patent and Trademark Office (PTO) to people and organizations in this country, which reflects those institutions’ focus on basic research (see Figure 8). (The Bayh-Dole Act of 1980 granted universities intellectual property control over innovations that developed out of federally funded research.) The number of such domestically owned patents that are granted annually to universities has been increasing, however, rising from fewer than

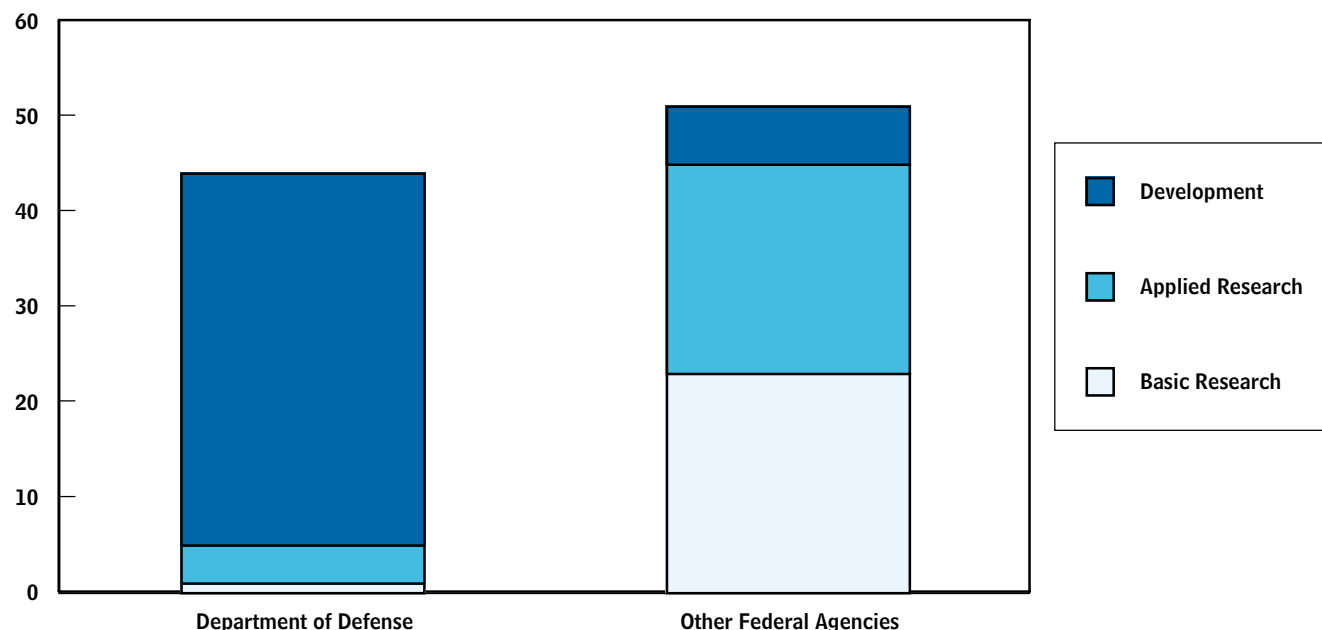
18. *Budget of the United States Government, Fiscal Year 2002: Analytical Perspectives* (2001), p. 135.

19. The patents referred to here and in Figures 8 and 9 are utility patents, which, according to the U.S. Patent and Trademark Office, are granted for new or improved products or processes. There are also two other types of patents—design patents, for the external design of a product, and plant patents, for new varieties. For further information, see www.uspto.gov/web/offices/pac/doc/general/index.html.

Figure 6.

Federal Obligations for Research and Development in the Department of Defense and Other Federal Agencies, by Type of R&D, 2004

(Billions of 2000 dollars)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *Survey of Federal Funds for Research and Development: FY2003, 2004, and 2005*.

Notes: Obligations are legally binding commitments by the federal government that result in outlays.

Basic research is meant to expand scientific knowledge without regard to commercial applications. Applied research seeks to connect scientific knowledge to some practical end. Development applies scientific knowledge to the creation of specific marketable products.

2,000 in the early 1990s to more than 3,000 since 1998.²⁰

The growth of patenting and licensing by universities has raised concerns that academic research is moving away from pure science and toward work that has potential commercial applications, yet few empirical studies have investigated that issue. One study found that researchers who published reports of their work in basic-science

journals were more likely to disclose their inventions than were those who published in journals that did not emphasize basic research.²¹ Another study found that the growing importance of biomedical research has been a driving force in the growth of the number of patents and licenses granted to universities.²²

The bulk of the domestically owned U.S. patents granted each year go to “non-federal, non-university” organizations, according to the Patent and Trademark Office.

20. According to the PTO, the large jump from 1997 to 1998 in the number of total patents granted is largely the result of a significant expansion in the staff of patent examiners (personal communication to the Congressional Budget Office from Jim Hirabayashi, Electronic Information Products Division, U.S. Patent and Trademark Office, March 8, 2007). The PTO’s 1999 annual report states that more than 800 new examiners were hired in fiscal year 1999 and more than 700 in 1998 (U.S. Patent and Trademark Office, *Century of American Innovation, A Patent and Trademark Office Review, Fiscal Year 1999*, p. 7).

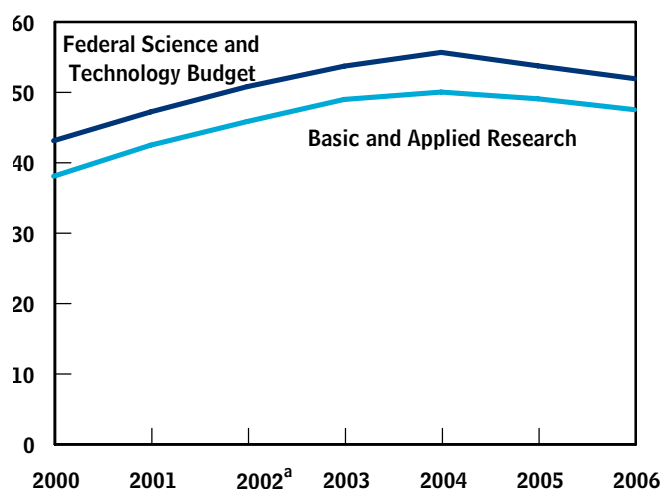
21. Jerry G. Thursby and Marie C. Thursby, “Patterns of Research and Licensing Activity of Science and Engineering Faculty” (working paper, Georgia Institute of Technology, Technological Innovation: Generating Economic Results program, April 2003), available at http://tiger.gatech.edu/files/gt_tiger_patterns.pdf.

22. David C. Mowery and others, “The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980,” *Research Policy*, vol. 30, no. 1 (2001), pp. 99–119.

Figure 7.

The Federal Science and Technology Budget

(Billions of 2000 dollars of budget authority)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Years 2003, 2004, 2005, 2006, 2007, and 2008: Analytical Perspectives*.

Notes: According to the Office of Management and Budget, the federal science and technology budget covers budget authority for nearly all federally supported basic research, more than 80 percent of applied research, and about half of nondefense development.

Because this figure reflects budget authority (the authority provided in law to incur financial obligations that will result in government outlays), data points may differ from the expenditures reported elsewhere in the study.

Basic research is meant to expand scientific knowledge without regard to commercial applications. Applied research seeks to connect scientific knowledge to some practical end.

- a. The amounts reported for 2002 appear as estimates in the President's budget request for 2004. For all other years, amounts are the budget authority reported in the corresponding budget requests.

Those organizations, which include industrial firms, non-profit institutions, and state and local governments, accounted for approximately 63,000 to 72,000 patents annually between 1998 and 2003, or more than 75 percent of the domestically owned U.S. patents granted each year since 1998.²³ Patenting activity related to the federal government's R&D efforts occurs largely through DoD, which conducts most federally funded development (see Figure 9).²⁴

Government Action

In its selection of public research and development projects, the federal government faces at least two types of potential shortcomings when it tries to efficiently address differences between the private and social returns to research and development. One problem arises from the possibility that federal agencies may not design their R&D programs in the same way that private firms would have designed theirs if private returns matched social returns. The other set of potential problems centers on the criteria that are used to choose which R&D projects the government will fund.

Much of the justification for the federal government's R&D spending rests on the notion that the government, in its decisionmaking, can take into account the total social return that might be generated by a specific research project but a private firm will invest only in research that adds to its profitability. In the pursuit of profits, firms will tend to design even their most basic research projects with a future product in mind. In contrast, federally funded government and academic scientists might be motivated by factors other than profit, such as opportunities for academic publications based on their research findings. Correspondingly, those scientists might not design their research so that their findings can be easily adopted by the private sector for its purposes, which in some cases might require firms to carry out duplicative work to develop commercial products.

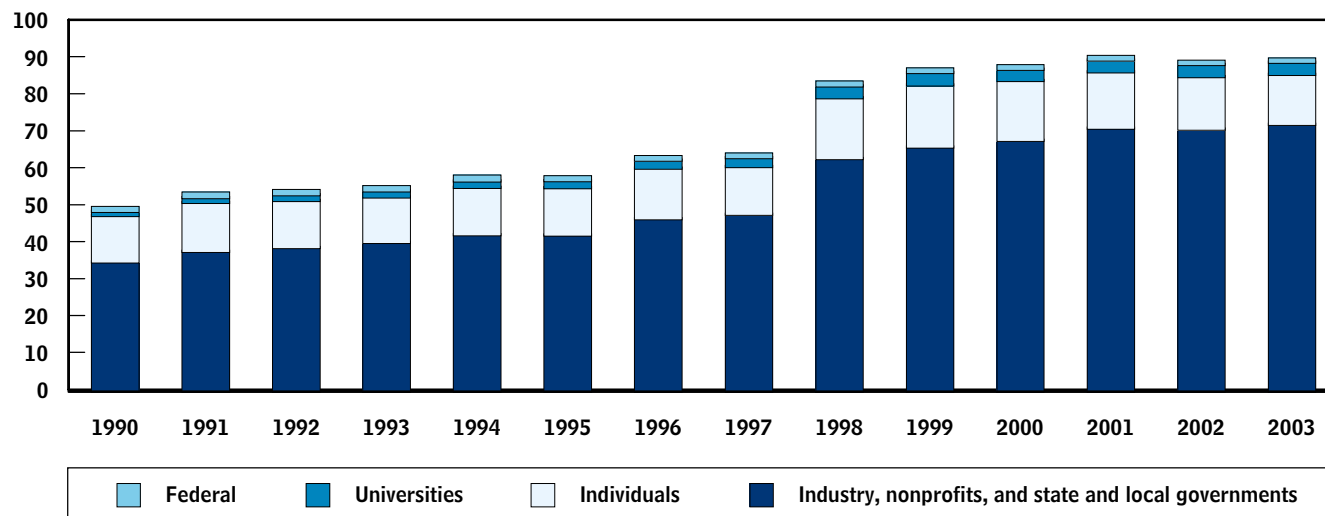
A peer-review selection process for public research, although not perfect, is often held up as the best way to

23. Domestically owned patents represent more than half the utility patents granted each year by the PTO. The federal government and individuals account for a larger share of domestically owned patents than the share of foreign-owned U.S. patents accounted for by their foreign counterparts. However, no similar comparison may be made for universities, businesses, and other nongovernmental organizations because the data on foreign-owned patents are not broken down by those categories. See U.S. Patent and Trademark Office, "Historic Data, All Technologies (Utility Patents) Report," Table A1-1b, available at www.uspto.gov/go/taf/h_at.htm.

24. According to the Department of Commerce (*Summary Report on Federal Laboratory Technology Transfer: Activity Metrics and Outcomes FY 2003*, December 2004, p. 37), the federal government in 2003 collected \$97 million in licensing income, most of which was channeled through the Department of Health and Human Services (\$55 million), which is home to the National Institutes of Health, and the Department of Energy (\$26 million).

Figure 8.**Domestically Owned U.S. Utility Patent Grants**

(Thousands)



Source: Congressional Budget Office based on data from the U.S. Patent and Trademark Office, Patent Technology Monitoring Division.

Note: Utility patents are those granted for new or improved products or processes.

ensure that scientific merit is the basis for deciding whether to fund a research proposal.²⁵ Such a system is used to select a substantial amount of public research for funding (including much of the research funded by NSF and the National Institutes of Health, or NIH); it seems to offer the best chance for choosing an efficient set of projects that are most likely to advance scientific knowledge.²⁶ However, some observers argue that relying on peer review may favor conservative projects (providing only incremental progress in expanding existing knowledge) over pioneering or interdisciplinary work.²⁷ Others have noted that slow-growing funding for some scientific fields, the constraints some agencies place on the length

of time research may take, and the high risk of failure are all factors in the federal government's funding of fewer highly uncertain but potentially groundbreaking research projects.²⁸

Equity or distributional concerns may also influence decisions about funding. Concerns about geographic fairness in allocating federal funds may motivate some awards for R&D projects, either through programs like the Experimental Program to Stimulate Competitive Research (EPSCoR) at NSF or as directed by legislation.²⁹ In addition, projects that attract national attention may receive funding regardless of their scientific merit.³⁰ In other

25. In a peer-review selection process, research proposals are typically evaluated by other scientists in the relevant field who then recommend projects to receive funding on the basis of their scientific merit. See James D. Savage, *Funding Science in America* (New York: Cambridge University Press, 1999), pp. 9–12.

26. Of the projects rated excellent by NSF reviewers in fiscal year 2005, 74 percent were awarded funding. The percentage of projects funded decreased with the rating: very good to excellent, 43 percent funded; good to very good, 11 percent funded; and good or lower, 0.5 percent funded. See National Science Foundation, *Report to the National Science Board on the National Science Foundation's Merit Review Process, Fiscal Year 2005*, NSF Report NSB-06-21 (Arlington, Va., March 2006), p. 21.

27. S. Fölster, "The Perils of Peer Review in Economics and Other Sciences," *Journal of Evolutionary Economics*, vol. 5, no. 1 (March 1995), pp. 43–57.

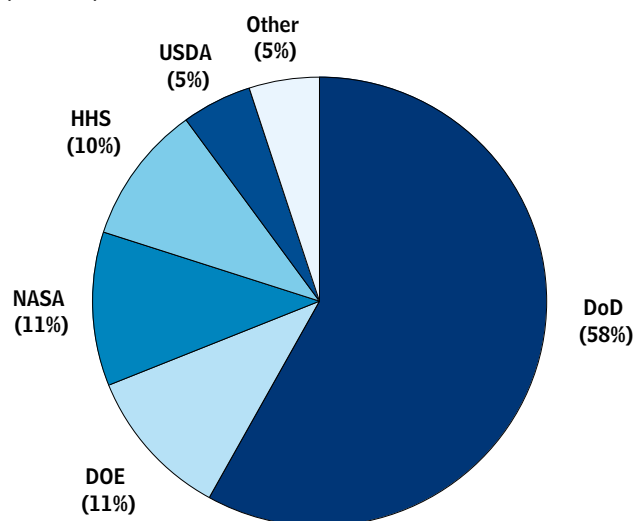
28. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Rising Above the Gathering Storm* (Washington, D.C.: National Academies Press, 2006), pp. 6–12.

29. Under EPSCoR, states that have received less than 0.75 percent of NSF research funding in the three preceding years are eligible for additional grants and assistance in building research institutions and programs.

30. See Linda R. Cohen and Roger G. Noll, *The Technology Pork Barrel* (Washington, D.C.: Brookings Institution, 1991).

Figure 9.
Federally Owned U.S. Utility Patent
Grants, 1990 to 2003

(Percent)



Source: Congressional Budget Office based on information from the U.S. Patent and Trademark Office, Patent Technology Monitoring Division.

Notes: During the 1990–2003 period, a total of 14,388 patents were issued to the federal government.

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

Utility patents are those granted for new or improved products or processes.

instances, spending for R&D projects may become self-perpetuating, creating constituencies that expect continued financial support and that are willing to devote resources to secure that support outside of a peer-review process.

Evaluating the Results of Federal Funding for Research and Development

Two rationales are typically offered in support of the federal government's involvement in the nation's R&D activity. One is that some federal spending for research and development is essential to support a uniquely governmental undertaking (such as national defense). The other arises from the consideration that firms in the private

sector have insufficient incentives to finance all of the R&D that is socially beneficial.

Yet in the end, what result is the \$137 billion in federal R&D spending for fiscal year 2007 likely to produce? No single answer stands out, but the following generalizations can be made from the economics literature that has considered public support for research and development:

- In the case of unambiguously public missions, such as national defense or space exploration, the returns to public R&D spending come as contributions to the fulfillment of that mission. Although mission-oriented projects may also produce spin-off technologies that are not linked to a project's original goals, such by-products are inherently difficult to anticipate for any given R&D activity.
- Federal spending in support of basic research over the years has, on average, had a significantly positive return, according to the best available research. That outcome is indicated in studies of the social rate of return to academic research, studies of the increasingly important role of academic research in businesses' patenting and research activity, and studies of patent and scientific journal citations, all of which suggest that academic research in primary scientific disciplines (for example, chemistry or physics) has broad and sometimes unpredictable effects across a wide variety of commercial applications.
- Returns to the federal government's support of life sciences research are generally estimated to be substantial. However, those calculations are based on a somewhat different metric than that used to estimate the return to all federally supported applied and basic research, making comparisons with other disciplines difficult.³¹ Spending for life sciences research is currently the largest and, since the mid-1990s, the fastest-growing area of federally supported research. That emphasis has altered the balance of scientific fields in the federal research portfolio.

31. At times, the returns to medical research have been measured in terms of the value of the statistical lives saved as a result of an innovation. Statistical lives saved are the "reduction of some mortal hazard to some part of the population." See Thomas C. Schelling, "Value of Life," in John Eatwell, Murray Milgate, and Peter Newman, eds., *The New Palgrave Dictionary of Economics*, vol. 4 (New York: Stockton Press, 1987), p. 793.

Those gross generalizations are difficult to apply as guidance for spending and policy decisions across budget functions, agencies' budgets, and appropriations subcommittee jurisdictions. Any individual research undertaking or particular set of projects may produce a wide range of outcomes and returns, even though, on average, the economic returns to federal research are expected to exceed their costs. Measurement problems present another obstacle: It can be difficult to trace the path of a research finding over time and to consider what might have occurred in the absence of that finding. In addition, much of federal spending for R&D is mission oriented, and those resources are included in measures of the share of GDP that federally funded R&D accounts for and the aggregate dollar value of those activities. Thus, those measures are not indicative of the federal resource commitment to projects with the potential to produce returns that are substantial for society as a whole but that a private firm would not undertake because it could not capture enough of the returns generated by the project.

Mission-Oriented R&D

Whether a particular public-sector R&D program should be considered mission oriented and thereby justified because of its support of a uniquely governmental undertaking is not always easy to determine. R&D activities are clearly mission oriented in cases in which federal agencies are the sole customer for particular goods and services and in which those agencies tend to support R&D activities to develop and improve those goods and services. For defense R&D, as an example, the funding of development falls primarily to the government, because it is the government that produces and "consumes" the final good—national defense. Beyond national defense, however, less agreement exists about where to draw the line between R&D that is mission oriented and R&D that addresses the difference between social and private returns and the weak incentives that firms have to finance R&D.

Some research and development related to space exploration and health care might be included in a more expansive definition of mission-oriented R&D. NASA, for example, might pursue R&D activities to accomplish scientific and exploration objectives for its space missions. Disease-specific research and development supported by NIH is another such example.

With the government as the primary consumer, spending for mission-oriented R&D (such as national defense) has

a different pattern from other federal R&D spending. Defense R&D spending is heavily concentrated on the development end, accounting for more than 87 percent of DoD's total R&D obligations in 2004.³² That emphasis stands in contrast to the research and development funded by nondefense government agencies: They direct only a small portion of their spending for R&D to development and instead concentrate on basic and applied research, leaving development work to the private sector, which will ultimately produce and sell the final goods.

Despite the questions that may arise about whether certain federal R&D activities are mission oriented, methods are available to inform decisions about those undertakings. Such choices are best rooted in a consideration of how the R&D project and its expected results contribute to the overall objective that an agency is pursuing. Although mission-oriented R&D can and does produce development-worthy spin-off technologies, those by-products are unknown at the start of an endeavor and, for the purposes of decisionmaking, difficult to anticipate.³³ Studies of all federally funded R&D—including its large mission-oriented component—have not found evidence of economic returns associated with that spending.³⁴

Basic and Applied Research

Federal spending for nondefense R&D does not generally have the same unambiguously governmental mission behind it that defense R&D does (despite the fact that the "mission" of some agencies—for example, the National Science Foundation—is research itself). Instead, the non-mission-oriented R&D activities that the government supports address the lack—or insufficiency—of private-sector investment. Basic and applied research are more likely than development to fall into that category.

32. National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003–05*, NSF 06-313 (Arlington, Va., 2006), Table 6.

33. For a review of the problems in assessing the benefits of spin-offs, see John A. Alic and others, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Cambridge, Mass.: Harvard University Press, 1992), pp. 60–64.

34. See Office of Technology Assessment, *Research Funding as an Investment: Can We Measure the Returns? A Technical Memorandum*, OTA-TM-SET-36 (April 1986); and Paul A. David, Bronwyn H. Hall, and Andrew A. Toole, "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence," *Research Policy*, vol. 29, no. 4–5 (April 2000), pp. 497–529.

Accordingly, the federal science and technology budget may be a good indicator of the extent of non-mission-oriented research and development, given that basic and applied research account for the bulk of the spending that the budget reports. However, the information offers little help in assessing the returns from R&D, which may vary widely from project to project.

In addition to distinguishing between research and development, it may be important for policymakers setting funding priorities and analysts studying the impact of that funding to be able to differentiate between basic and applied research. Although NSF and the Organisation for Economic Co-operation and Development (OECD) have published consistent definitions of the two kinds of research, a study has shown that neither scientists nor policymakers have a uniform understanding of the concept of basic research.³⁵ Yet despite their lack of agreement on definitions, many of those scientists note that funders of R&D are paying increasing attention to the applicability of research.³⁶ An earlier study warns that such an emphasis on applied work at the expense of research in pursuit of new knowledge and concepts could slow the pace of both scientific advancement and its application.³⁷ That blurring of the line between basic and applied research might present another obstacle to obtaining estimates of the returns to federal spending for research.

Academic Research as a Proxy for the Use of Federally Funded Research. Universities perform a substantial share of federally funded research—in 2004, 57 percent of basic and 20 percent of applied research (see Figure 10).³⁸ Analysts who focus on federally funded

research often rely on the returns to academic research as a proxy for federally funded research returns. Reports of research findings in scientific publications are typically attributed to the author or investigator and his or her institution rather than to a study's funding source. Tracking citations to those publications can provide insight into how those research findings are put to use.

Nevertheless, measuring the rate of return to public research is a difficult endeavor. Although such returns are held to be positive by a broad consensus of analysts, their effects cannot be clearly traced through the economy. Thus, economists have devised other ways to assess the value of public research.

Survey-Based Studies. One segment of the economics literature that studies public research has relied on surveys of the private sector that inquire about how industry uses academic research. A 1985 survey of 76 firms served as the basis for one study that estimated an average rate of return to academic research of 28 percent.³⁹ That finding was based on firms' reports that without the previous 15 years of academic research, they would have faced delays of at least a year in their introduction of 11 percent of new products or their implementation of 9 percent of new production processes. To arrive at the estimated 28 percent average rate of return, researchers compared the value of the sales of new products and the process cost savings that would have been lost without the earlier spending on academic research.⁴⁰ The study emphasized that the 28 percent figure is an average rate of return on

35. Jane Calvert and Ben R. Martin, "Changing Conceptions of Basic Research?" (SPRU [Science and Technology Policy Research], University of Sussex, prepared as a background document for the OECD/Norwegian Workshop on Policy Relevance and Measurement of Basic Research, Oslo, October 29–30, 2001).

36. A recent example is the claim in 2005 by computer scientists that the Defense Advanced Research Projects Agency had sharply cut support for basic research in favor of short-term, narrowly focused projects (see John Markoff, "Pentagon Redirects Its Research Dollars," *New York Times*, April 2, 2005). The House Science Committee held a hearing on the matter on May 12, 2005.

37. Richard R. Nelson and Paul M. Romer, "Science, Economic Growth, and Public Policy," in Smith and Barfield, eds., *Technology, R&D, and the Economy*, p. 70.

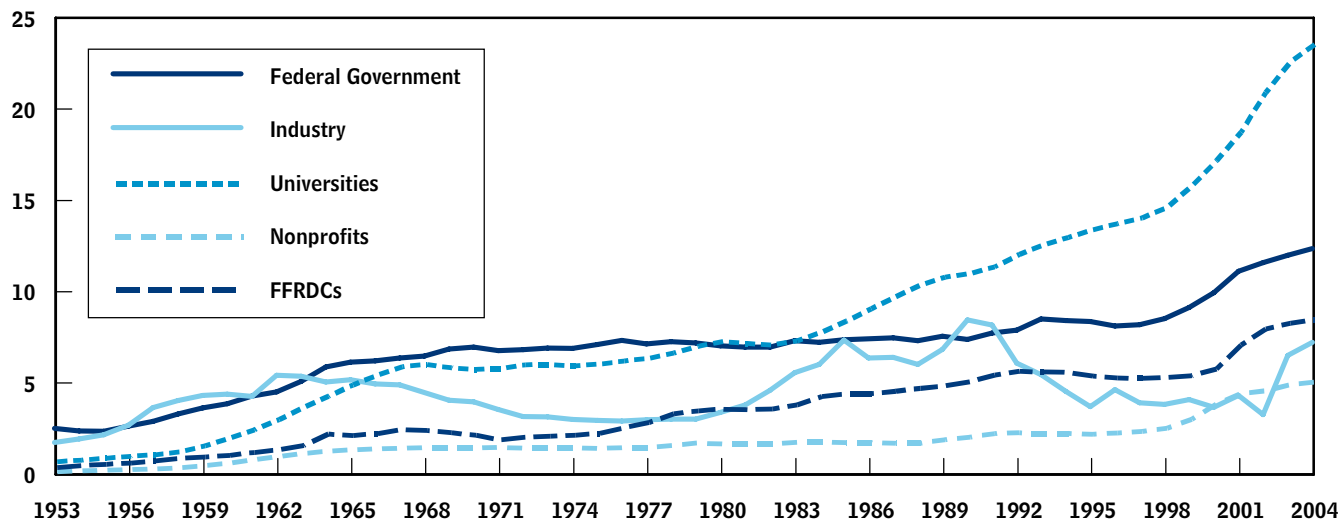
38. Together, universities account for about 42 percent of all federally funded research. However, academic research is supported by a number of other funding sources as well, such as state and local governments, nonprofit agencies, industry, and the universities themselves (see the bottom panel of Figure 4 on page 8). Of those sources, industry-funded research is likely to be the only one whose character differs substantially from government-funded research, because a private-sector research sponsor may seek to prevent or delay the publication of research findings. According to NSF, industry has consistently been the smallest source of funds for university-conducted R&D, never accounting for more than 9 percent of funding.

39. Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy*, vol. 20, no. 1 (1991), pp. 1–12.

40. Mansfield suggests that 28 percent is a conservative estimate because the survey's methodology limited the period over which firms make use of academic research and excluded spillover effects.

Figure 10.**Federal Spending for Research, by Performer**

(Billions of 2000 dollars)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

Note: FFRDC = federally funded research and development center.

the total amount spent on academic research in the past and avoided predicting the return that would result from any increase in funding for academic research.⁴¹

A later study is based on a broader 1994 survey of U.S.-owned firms.⁴² It offers no estimate of returns to public research but instead recounts how industry R&D makes use of public research, which in the study includes that performed at both universities and government laboratories. The sample of more than 1,200 manufacturing firms revealed that firms did not find public research to be an important source of new ideas for their R&D projects. However, more than a third of the firms reported using

public research results—research findings, prototypes, and new instruments—in their own R&D activities. In addition, the study found that firms in different industries vary in their reliance on public research. The pharmaceutical industry, for example, reported much more intensive use of public research than is the average among other industries.

Citations to Academic Research. Other studies have used patents and the scientific literature to track how industry uses the results of academic science. A recent paper compares the effects of publications by academic and industrial researchers on the scientific output of industrial firms—that is, the published papers of industry scientists.⁴³ When weighted by each sector's accumulated spending for research, academic research was found to have a larger influence than industrial research on the scientific output of researchers in industry. In addition, the study, which was limited to the impact of basic research, found that academic research had larger spillover effects than industrial research had—which suggests that firms

41. A 1993 CBO publication (Congressional Budget Office, *A Review of Edwin Mansfield's Estimate of the Rate of Return from Academic Research and Its Relevance to the Federal Budget Process*, April 1993) also cautions against relying on the 28 percent figure as an estimate of the returns to federal R&D. CBO's skepticism was based on the assumptions the researchers made to arrive at that result and its exclusion of several factors, including the benefits to be derived from training students to conduct academic R&D and the research performed at federally funded research and development centers.

42. Wesley M. Cohen, Richard R. Nelson, and John P. Walsh, "Links and Impacts: The Influence of Public Research on Industrial R&D," *Management Science*, vol. 48, no. 1 (2002), pp. 1–23.

43. James D. Adams and J. Roger Clemmons, *Science and Industry: Tracing the Flow of Basic Research Through Manufacturing and Trade*, NBER Working Paper No. 12459 (Cambridge, Mass.: National Bureau of Economic Research, August 2006).

may perform more narrowly focused basic research than university researchers conduct, leading to fewer spillovers.

The study does not discuss the relationship between published industrial research and firms' product development. In the case of R&D that relates more directly to the products and processes being generated, firms may require researchers to keep the results of such activities confidential. If that is so, the published work of industrial researchers may be a poor proxy for estimating the value of academic research to industry.

Patent citations to the academic literature are another way of assessing the use of academic research by industry. Studies have noted a sharp increase from the mid-1980s to the 1990s in the rate at which patents cite the academic science literature, an increase that outstrips growth in the number of patents granted, in real expenditures on R&D, and in the output of scientific papers. One study considers a number of possible explanations for the increase in the citation rate;⁴⁴ one important impetus appears to be the relatively strong growth of patenting in the biomedical fields, with their traditionally strong links between academic research and industrial activity. The study also finds evidence of a change in the way firms invent new products and processes, suggesting that knowledge spillovers from academic research grew stronger in the 1990s.

Does Public R&D Crowd Out Private R&D? One concern about governmental support for research and development is that public R&D may crowd out R&D by the private sector. However, statistical data suggest that overall, firms' spending for private R&D increases in response to federal R&D spending.⁴⁵ In specific cases, the government may have funded some R&D activities that the private sector would otherwise have financed, but identifying the instances in which such crowding out has occurred is difficult. It is probably more likely to happen in areas in which potentially valuable commercial applications of government-funded research and development can be identified.

44. Lee Branstetter and Yoshiaki Ogura, *Is Academic Science Driving a Surge in Industrial Innovation? Evidence from Patent Citations*, NBER Working Paper No. 11561 (Cambridge, Mass.: National Bureau of Economic Research, August 2005).

45. David, Hall, and Toole, "Is Public R&D a Complement or Substitute for Private R&D?"

An indirect form of crowding out may occur if increases in federal R&D spending cause the demand for workers in a particular field of scientific inquiry to rise. Greater demand for research scientists could lead to an increase in salaries—and thus in firms' labor costs.⁴⁶ Salaries may be more likely to rise when federal funding is growing at a fast pace. Between 1997 and 2003, when NIH's funding climbed rapidly, the rate of employment for holders of doctorates in the biological, health, and life sciences declined slightly, just as it did for doctoral-level scientists overall. Meanwhile, the median salary for such workers in the life sciences grew at a real average annual rate of 2.2 percent, faster than the 1.9 percent rate for similar workers in the physical sciences but slower than the growth of salaries for those with doctorates in engineering, computer science, and math.⁴⁷

One recent study examines the effects of different types of government funding of R&D on the amount that firms themselves spend on such activities.⁴⁸ In a sample of 17 OECD countries between 1981 and 1996, the study found that when firms received federal R&D funds, they were induced to spend, on average, 70 cents of their own money on R&D for each dollar of government funding. The study also found that if the government-funded R&D was more oriented toward defense, that complementary effect diminished, probably because defense-related R&D may lead to fewer spillover effects or because security concerns may make it difficult to use the work in civilian applications.

Other findings from the same study include the following:

- Government-funded university R&D had a positive effect on industrial R&D spending after analysts controlled for defense R&D activities.

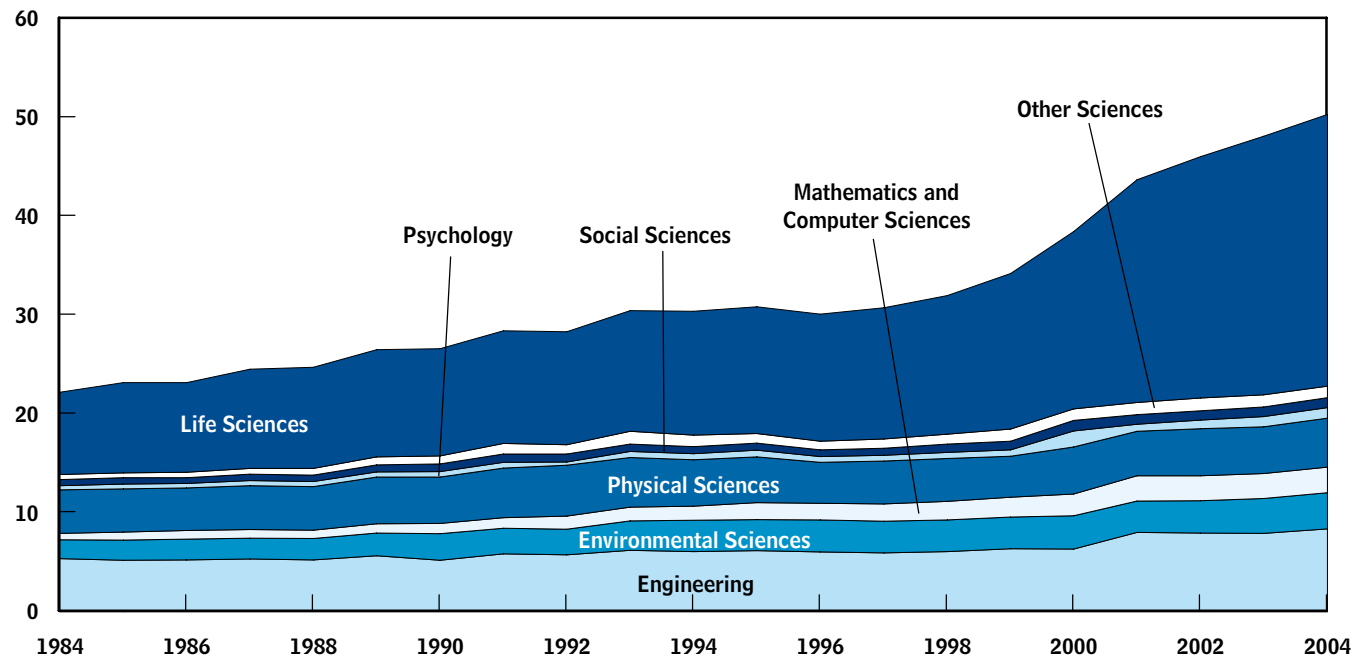
46. Austan Goolsbee, "Does Government R&D Policy Mainly Benefit Scientists and Engineers?," *American Economic Review*, vol. 88, no. 2 (May 1998), pp. 298–302.

47. National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States: 2003 and Characteristics of Doctoral Scientists and Engineers in the United States: 1997* (Arlington, Va., June 2006 and November 1999).

48. Dominique Guellec and Bruno van Pottelsberghe de la Potterie, "The Impact of Public R&D Expenditure on Business R&D," *Economics of Innovation and New Technology*, vol. 12, no. 3 (June 2003), pp. 225–243.

Figure 11.**Federal Obligations for Research, by Field**

(Billions of 2000 dollars)



Source: Congressional Budget Office based on National Science Foundation, Division of Science Resources Statistics, *Federal Funds for Research and Development: Fiscal Years 2003, 2004, and 2005* and *Science and Engineering Indicators, 2006* (Arlington, Va.).

■ Intramural government research was not clearly found either to stimulate or crowd out industrial R&D spending. One explanation for that result is that businesses may have needed more time than the study allowed to adapt findings from government-supported R&D activities to their own endeavors.

The Shift in the Federal Research Portfolio. The mix of research supported by the federal government has changed in recent years. Starting in the late 1990s, policymakers doubled funding to the National Institutes of Health, which left the government's research portfolio much more concentrated in the life sciences.⁴⁹ From 1984 to 2004, the life sciences saw their share of federal research obligations increase from 38 percent to 55 percent (see Figure 11). Between 1997 and 2004, real federal

research obligations for the life sciences grew at an average annual rate of 11 percent, compared with 3.9 percent for all other research areas.⁵⁰ Funding for research in engineering and the physical sciences (including astronomy, chemistry, and physics) grew slowly, rising at annual rates of 5 percent and 2 percent, respectively.

That trend has prompted calls for a renewed emphasis on engineering and the physical sciences in federal research spending. Under recent proposals, increases in federal funding for research in the physical sciences and engineering would be accelerated, much like the growth that occurred in NIH's budget. Under President Bush's American Competitiveness Initiative, the research budget of the National Science Foundation and other agencies that focus on the physical sciences and engineering would

49. Since 2003, those increases have slowed sharply, which leaves NIH's budget declining in real terms when the biomedical research and development price index is used as a deflator. (For additional information, see officeofbudget.od.nih.gov/UI/GDP_FromGenBudget.htm.)

50. Obligations for applied research in the life sciences increased at an average annual rate of 12.7 percent over the 1997–2004 period, and obligations for basic research grew at an average annual rate of 9.6 percent.

double by 2016.⁵¹ Similar action, with a particular emphasis on basic research, was recommended in a report from the National Academies of Sciences and Engineering and the Institute of Medicine.⁵²

The shift to increased funding for the life sciences highlights another question that arises in decisionmaking about federal funding for R&D: not just how much to spend but on what types of research. The increasing emphasis on the life sciences in the federal research portfolio finds some support in the high returns to medical research that some economists have found.

In the literature on the effects of medical research, some recent studies have attempted to estimate the value of improvements in health and in life expectancy that result from the new treatments and knowledge that such research has produced.⁵³ One study suggests that the value of improvements in life expectancy is large.⁵⁴ Another agrees that the amounts spent on medical research are small in comparison with the value of the longer lives and improved quality of life that results, but it suggests that determining the returns to medical research is not simply a matter of comparing the benefits with the cost of the actual research performed.⁵⁵ If a particular piece of medical research leads to large enough increases in health care costs, the study cautions, there may in fact be a negative return to that research, especially in a health care system dominated by third-party payers.⁵⁶

A substantial related literature examines the social benefits (including direct and indirect cost savings and improvements in people's health and life expectancy) that follow the implementation of break-through treatments for particular diseases.⁵⁷ (Such benefits would include direct savings in the cost of health care, indirect savings resulting from a healthier workforce, and any commercial developments that followed the medical research.) The focus in those studies on a specific medical condition may make the problem of estimating returns to research more tractable, but the studies' narrow scope limits the ability to generalize their results.

A 2001 report by the National Research Council (NRC) offers a detailed picture of trends in federal research support, by scientific field, in the 1990s, when the growing role of the life sciences first emerged.⁵⁸ The NRC recommends that the government pay close attention to the weight it gives to different fields of science in its research efforts. The most important problems for science to solve, the NRC suggests, are interdisciplinary, and the uncertainty surrounding the results of research makes it difficult to know where new advances are likely to emerge.⁵⁹ The NRC also notes that current trends in research funding may influence future scientific advances because of the close association between federal research funding and enrollment in graduate schools.⁶⁰ More than one-fifth of science and engineering graduate students rely on federal funding to support their graduate studies (see Box 2).

Some of the literature that examines how the private sector uses public research offers evidence to support the idea that scientific research has results that affect multiple disciplines—basic biology research, for example, may be able to proceed because of new instruments derived from work by engineers or physicists. The scientific papers published by industry researchers cite both academic and

51. President Bush announced the initiative in his 2006 State of the Union address. Details of the original proposal may be found at www.ostp.gov/html/ACIBooklet.pdf.

52. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Rising Above the Gathering Storm*, p. 6-2. The report also recommended a number of other actions, including providing grants for researchers in the early stages of their career, promoting energy and high-risk research, and improving science, mathematics, and engineering education.

53. Kevin M. Murphy and Robert H. Topel, eds., *Measuring the Gains from Medical Research* (Chicago: University of Chicago Press, 2003).

54. William Nordhaus, "The Health of Nations: The Contribution of Improved Health to Living Standards," in Murphy and Topel, eds., *Measuring the Gains from Medical Research*, pp. 9–40.

55. Kevin M. Murphy and Robert H. Topel, "The Economic Value of Medical Research," in Murphy and Topel, eds., *Measuring the Gains from Medical Research*, pp. 41–73.

56. *Ibid.*, p. 71.

57. For a review of a number of those papers, see Martin Buxton, Steve Hanney, and Teri Jones, "Estimating the Economic Value to Societies of the Impact of Health Research: A Critical Review," *Bulletin of the World Health Organization*, vol. 82, no. 10 (October 2004), pp. 733–739.

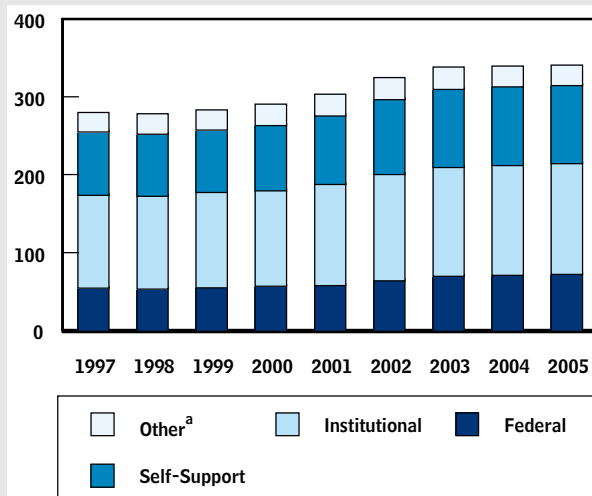
58. National Research Council, Board on Science, Technology, and Economic Policy, *Trends in Federal Support of Research and Graduate Education* (Washington, D.C.: National Academy Press, 2001).

59. *Ibid.*, pp. 87–88.

60. *Ibid.*, p. 50.

Box 2.**Federal Support for Graduate Students in Science and Engineering****Science and Engineering Graduate Students, by Primary Source of Funding**

(Thousands of students)



Source: National Science Foundation, Division of Science Resources Statistics, *Graduate Students and Postdoctorates in Science and Engineering: Fall 2004* (August 2006) and *Fall 2005* (May 2007).

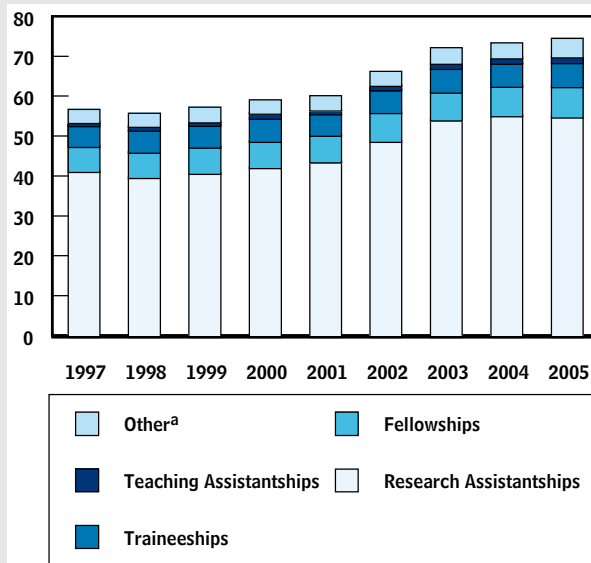
b. Other sources of funding include industry, nonprofit organizations, and foreign governments.

Graduate studies in science and engineering in this country are supported through a variety of means, including funding from the federal government. Institutional support, provided by students' own universities, is the largest source of funding; in 2005, 42 percent of science and engineering graduate students received such support. Just under 30 percent of students (the next largest share) provided their own funding in that year, which included loans and family and personal support. For 22 percent of U.S. graduate students in scientific and engineering fields, however, the federal government is the primary source of financial support, providing funding in 2005 to more than 74,600 students (see the figure above). Two federal agencies—the National Institutes of Health and the National Science Foundation—provided support for more than half of those students.

Research assistantships are the most common mechanism by which science and engineering graduate students receive federal support—more than 55,000 students received them in 2005 (see the figure below). Such assistantships are frequently part of the research grants awarded by government agencies to faculty researchers at a university—who in addition to graduate students often employ undergraduate students and young postdoctoral researchers in their laboratories. As a result, federal grants for research and development support science and engineering students by allowing them to gain experience in performing research during their graduate training.

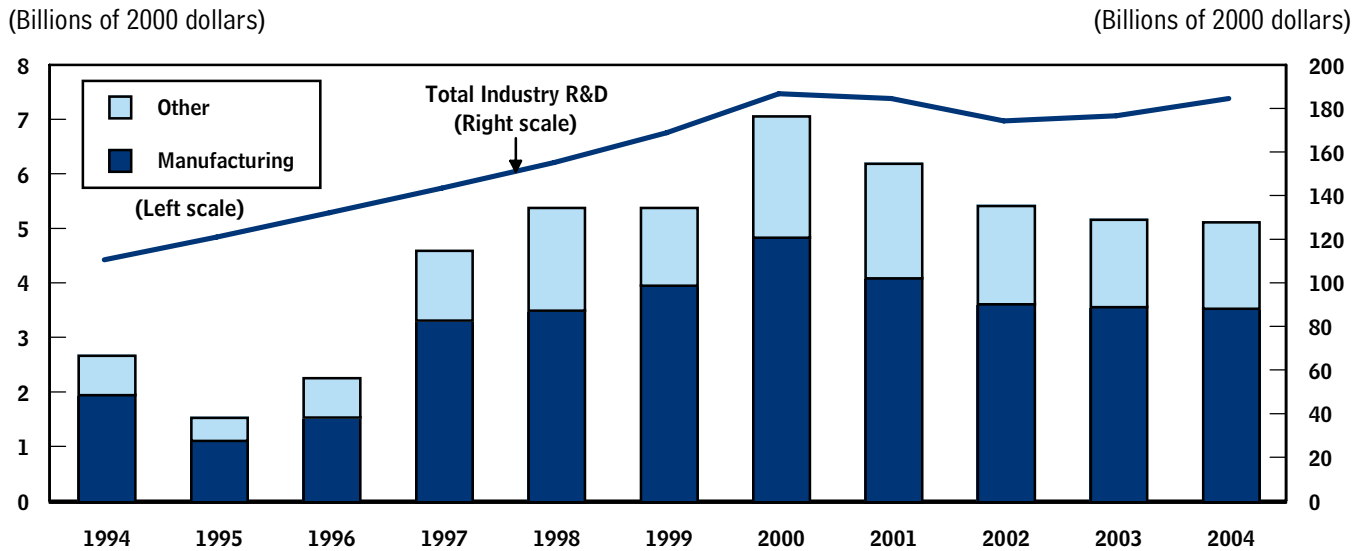
Federally Supported Science and Engineering Graduate Students, by Type of Funding

(Thousands of students)



Source: National Science Foundation, Division of Science Resources Statistics, *Graduate Students and Postdoctorates in Science and Engineering: Fall 2004* (August 2006) and *Fall 2005* (May 2007).

a. Examples of other types of support include that provided for veterans under the GI Bill and tuition paid by the Department of Defense for members of the armed forces.

Figure 12.**R&E Tax Credit Claims and R&D Spending by Industry**

Source: Congressional Budget Office based on Internal Revenue Service, *Statistics of Income, Corporation Complete Report* (annual series), and National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources* (Arlington, Va., annual series).

Note: R&E = research and experimentation; R&D = research and development.

industry research from other fields, with computer sciences having the largest spillover effects outside its own field.⁶¹ Surveys of R&D managers also reveal that they make use of research from outside their primary field.⁶²

Tax Preferences for Research and Development

The government also uses the tax system to encourage the private sector to invest in research and development. The research and experimentation tax credit provides an incentive to undertake new research by giving firms a credit for expenses related to those new activities against the taxes they owe. In addition, R&D expenses that are not covered by the credit can be fully deducted from income as a business expense when incurred, a treatment that contrasts with the more usual method of amortizing and deducting investments over a number of years. The cost of those tax incentives in 2006, in the form of foregone revenues, is estimated to have been \$9.9 billion, much less than the same year's spending authority for R&D of \$131 billion.⁶³

61. Adams and Clemmons, *Science and Industry*.

62. Cohen, Nelson, and Walsh, *Links and Impacts*.

The Research and Experimentation Tax Credit

The R&E tax credit, which was introduced in the Economic Recovery Tax Act of 1981, is designed to encourage firms to increase their investment in research and development through a tax credit based on growth in that spending. In short, the R&E credit allows companies to reduce their tax liability in exchange for increasing certain of their qualifying expenditures on R&D above their past levels. Policymakers have renewed and restructured the credit a number of times; it is currently slated to expire at the end of 2007.

Claims for the R&E tax credit are much smaller than firms' total R&D spending, which is in keeping with the credit's incremental nature. In 2004, the \$5.1 billion in tax credit claims (2000 dollars) amounted to only 2.8 percent of the \$184 billion that industry spent on research and development that year (see Figure 12).⁶⁴ When compared only with industry-sponsored research—the sum of firms' basic and applied research spending

63. *Budget of the United States Government, Fiscal Year 2008: Analytical Perspectives* (2007), pp. 51 and 291.

64. As discussed later, firms do not actually receive all of the R&E tax credit they claim in a given year.

but excluding their expenditures for development—the tax credit claims are somewhat more significant. In 2004, such claims represented just over 12 percent of basic and applied research funded by firms.

Comparisons over time of the amount of the R&E tax credit that firms have claimed are complicated by the numerous revisions to the credit and by the introduction on several occasions of associated research tax credits. The incremental research tax credit is the longest-standing part of the incentive. It offers firms three alternative calculation methods: the standard research credit; the alternative incremental credit; and, for tax years ending after December 31, 2006, the alternative simplified credit (see Box 3). Payments to universities and other tax-exempt research organizations to conduct basic research are eligible for a similar incremental tax credit. If those payments are for energy research, larger tax credits are now available following enactment of the Energy Policy Act of 2005, which introduced a flat credit for spending on energy research.

In all other cases, the credit is incremental—that is, it applies only to R&D spending above a base amount. The incremental design follows from the aim of the tax credit: to encourage firms to do more R&D than they otherwise would. The base amounts for each type of credit are intended to approximate the amount that would be spent on research and development in the credit's absence.

Effectiveness of the Credit in Stimulating R&D. The rationale behind the R&E tax credit is that if the credit makes research and development less costly, firms will realize larger expected returns to that investment, thus encouraging them to undertake projects that would not have been funded in the credit's absence. Studies suggest that the tax credit does stimulate additional R&D activity; however, no basis exists for judging whether such additional expenditures provide a high value to society relative to their value to private enterprises.

Economists who have studied the effectiveness of the R&E tax credit in the United States and similar incentives in other countries generally conclude that each additional dollar of forgone revenue attributable to the R&D-promoting tax credit causes companies to spend another dollar on R&D projects. Such studies have tended to focus on estimating the additional research and development that occurs as a result of the tax credit, usually through a two-part process: first, a calculation of how the

tax credit and other tax preferences alter the cost of R&D; and second, an estimation of the price elasticity of R&D—or how much spending for R&D would change in response to a change in the cost of performing those activities. Combining those two numbers provides an estimate of how much research and development the tax credit stimulates. Studies have produced a variety of results, but many have clustered around the finding that a dollar claimed under an R&D tax credit leads firms to spend an additional dollar on R&D.⁶⁵

Some studies suggest that the effect of the tax credit may be growing over time. The credit had a less than one-to-one effect on industrial R&D spending in the early 1980s, when firms were still becoming accustomed to the credit and implementing systems to take advantage of it.⁶⁶ Fewer studies examine the tax credit in the 1990s and beyond; however, one that compares the credit's effects before and after the change in the base calculation enacted in 1989 found that after the change, firms spent an additional \$2.10 on research and development for each dollar of the tax credit they claimed.⁶⁷ The same study also found that after 1989, fewer firms were eligible for the credit but of those that were, a larger share than before 1989 were in high-tech industries.

With few other studies of the credit in the 1990s, it cannot be determined whether the credit's effect has continued to grow. In addition, the data may suffer from a re-labeling problem that could overstate the credit's effect over time. To take advantage of the favorable tax treatment of spending for research and development, firms have an incentive to classify as many expenses as possible as R&D related, an incentive that grows with the credit's generosity. Thus, activities that are not new—merely

65. See Bronwyn H. Hall and John Van Reenen, "How Effective Are Fiscal Incentives for R&D? A Review of the Evidence," *Research Policy*, vol. 29 (2000), pp. 449–469; and Nick Bloom, Rachel Griffith, and John Van Reenen, "Do R&D Tax Credits Work? Evidence from a Panel of Countries, 1979–1997," *Journal of Public Economics*, vol. 85 (2002), pp. 1–31.

66. Hall and Van Reenen, "How Effective Are Fiscal Incentives for R&D?," p. 462.

67. Sanjay Gupta, Yuhchang Hwang, and Andrew Schmidt, "An Analysis of the Availability and Incentive Effects of the R&D Tax Credit After the Omnibus Budget Reconciliation Act of 1989" (draft, W.P. Carey School of Business, Arizona State University, August 2006), available at www1.gsb.columbia.edu/mygsb/faculty/research/pubfiles/2366/GHS%20082606%20.pdf.

Box 3.**Calculating the Tax Credit for Research and Experimentation**

Since it was instituted, the research and experimentation (R&E) tax credit has been calculated in different ways. The current formulation sets the *standard credit* at 20 percent of a firm's qualified research expenditures (QREs) above a base amount that is the product of the firm's average annual gross receipts over the four previous tax years and a fixed-base percentage.¹ The fixed-base percentage is derived by using one of two methods, depending on when the firm first conducted research and had taxable receipts. For firms that had both receipts and QREs in tax years 1984 to 1988, the fixed-base percentage is the ratio of total research spending to total gross receipts over that period. For start-up companies (those that had neither receipts nor spending for research in tax years 1984 to 1988), the fixed-base percentage grows steadily. In the first five years that a firm is eligible for the credit, the fixed base is 3 percent; the percentage rises by the 11th year of eligibility to the ratio of total QREs to total receipts over the same five-year period. Two other restrictions apply to both kinds of firms: The fixed-base percentage may not exceed 16 percent, and the base amount must be at least 50 percent of current-year research expenditures.

Two other calculation methods are also available:

- As of January 1, 2007, firms are allowed an *alternative incremental tax credit* equal to the sum of the following: 3 percent of a firm's QREs that are more than 1 percent and less than or equal to 1.5 percent of its average annual gross receipts over the four previous years; 4 percent of its QREs that are between 1.5 percent and 2 percent of those same average gross receipts; and 5 percent of QREs that exceed 2 percent of such receipts.
- The *alternative simplified credit* was added in the latest extension of the tax credit at the end of

2006. Firms that elect this method may take a credit equal to 12 percent of their qualified research expenses that exceed 50 percent of their average QREs in the three preceding tax years. For firms that do not have expenses for research in all three previous tax years, the alternative simplified credit equals 6 percent of their QREs.²

If a firm chooses to calculate the tax credit by using an alternative method, it must continue to use that method in all future tax years.

Two other credits in addition to the main R&E tax credit offer firms an incentive to invest in R&D. Firms can claim the *basic research credit* for payments they make to qualified organizations (usually universities or other tax-exempt institutions) for performing basic research. The credit is equal to 20 percent of the amount a firm pays a qualified organization in excess of a base amount. (Calculation of that base amount is more complicated than the base-amount calculation for the standard credit, but like the latter, it is also a function of a firm's spending for research in previous years.) Any expenses that a firm applies to the basic research credit may not also be applied to the main research credit.

The *energy research credit*, created in the Energy Policy Act of 2005, extends a flat tax credit of 20 percent to firms that fund energy research through a tax-exempt energy research consortium.

1. For more details on this and the other methods of calculating the tax credit, see Gary Guenther, *Research Tax Credit: Current Status and Selected Issues for Congress*, CRS Report RL31181 (Congressional Research Service, April 26, 2007).

2. The method for calculating the alternative simplified credit is similar to the way the standard credit was calculated prior to 1990, when the base amount was the greater of a three-year moving average of research spending or 50 percent of the current year's research expenditures. That method was criticized for diminishing a firm's incentives to increase its current spending: An increase in research would generate a tax credit for the current year, but it would also set a higher base amount for ensuing years, making it more difficult for a firm to claim the credit in the future. The Omnibus Budget Reconciliation Act of 1989 put in place the current method for calculating the standard research credit.

newly classified as R&D—might be counted as part of the increase in R&D activities stimulated by the tax credit, leading to an overstatement of its impact.

Limitations in the available data constrain analysts' ability to draw definitive conclusions about the efficiency of the R&E credit in encouraging new private-sector R&D spending. Most studies use only publicly available data, which leaves analysts to infer the amount of firms' reported R&D that would be eligible for the credit, the amount firms claim for the credit, and the amount of the credit they actually receive. The investment in research and development that firms report in their financial statements is not the same as the "qualified research expenditures" that may be used to calculate the credit.⁶⁸ In some cases, the tax credit's effects are estimated on the basis of the amount of credits that firms claim, which may differ from the amount of credits they actually receive (given that the R&E credit is nonrefundable).

Two factors may contribute to an understatement of the cost of the R&E tax credit in these studies. First, the cost is measured only in terms of forgone revenues, with no mention of those revenues' "opportunity cost"—the benefits that their next-best use would have generated. Second, the studies ignore the cost of administering the credit—both the cost incurred by the Internal Revenue Service (IRS) to design guidelines and audit returns and by the firms to comply with the credit's requirements.⁶⁹

Criticisms of the Credit. Economists, industry analysts, and others have offered numerous criticisms of the R&E tax credit (although few mention the potential other uses of the forgone revenues it generates). Most critiques claim that some aspects of the credit's design limit its effectiveness in stimulating research and development by firms—in particular its temporary status, nonrefundability, incremental formula, and definition of qualified research.

68. According to the General Accounting Office (now the Government Accountability Office), COMPUSTAT data, which are used in many of these studies, are a poor proxy for confidential tax data from the Internal Revenue Service. For a discussion of the issue, see General Accounting Office, *Review of Studies of the Effectiveness of the Research Tax Credit*, GAO/GGD-96-43 (May 1996).

69. A September 1989 GAO report (*The Research Tax Credit Has Stimulated Some Additional Research Spending*, GGD-89-114) estimated that the IRS audited 74 percent of the firms that claimed the credit. It is not known whether that pattern has persisted.

Temporary Status. The credit has been in place with few interruptions since it was introduced in 1981, but it has always been temporary. The credit has been extended 12 times, 9 of those times for a period of two years or less but never for more than five years. For one year—July 1995 through June 1996—the research credit lapsed, and the renewal was not extended back to its most recent expiration.

The effectiveness of the R&E tax credit may be limited by its temporariness, an attribute that does not mesh with the (generally) long time horizon of R&D projects.⁷⁰ In many cases, businesses plan their R&D projects years in advance because it takes time to build labs, acquire the right equipment, design experiments, and test products. An extension of the tax credit by one or two years may not offer enough certainty that the credit will be available over the life of a project to reduce firms' costs. As a result, the temporary credit may offer a limited incentive to firms to undertake new research and development. However, the repeated renewals of the tax credit may lead firms to expect future renewals beyond its currently stated expiration date and to invest in R&D accordingly.

Refunds and Deductions. The effectiveness of the R&E tax credit is limited, some observers say, because it is not refundable and as a result, certain companies, especially firms that are just starting up, cannot realize the value of the credit. The credit's not being refundable means that firms with tax liabilities of less than the value of the credit cannot claim it immediately. (Firms may, however, claim the credit and carry it forward or backward to reduce their tax bill in other years.) The nonrefundability of the credit may make it difficult for new firms to benefit from it: They are likely to incur expenses for research for a number of years before selling any products, and that lag is likely to reduce the credit's value for them and for other firms that must wait to claim it. Moreover, firms that do not survive long enough to apply the credit may lose its value entirely.

For firms that are more established and profitable, claiming the credit limits the deductions that firms may take,

70. For example, President Bush, in his 2006 American Competitiveness Initiative (a description is available at www.ostp.gov/html/ACIBooklet.pdf), called for the R&E tax credit to be made permanent. See also Congressional Budget Office, "Revenue Option 36: Permanently Extend the Research and Experimentation Tax Credit," *Budget Options* (February 2007), p. 305.

which reduces the nominal value that the credit provides. Firms may deduct their expenditures for research and development in the current year. Some of those expenses are also eligible for the R&E tax credit, but firms must reduce their deductions by the amount of the tax credit they claim to avoid applying two tax benefits to the same spending. For a firm that uses the standard R&E tax credit and is taxed at the top corporate rate of 35 percent, the credit of 20 percent for R&D spending above the base amount effectively falls to 13 percent when the firm's deductions are adjusted for the credit.⁷¹ As a result, the value of the effective tax credit is less than the full value of the statutory credit.

Formulas for Calculating the Credit. The formulas that are currently used to calculate the credit may not be the most efficient way to encourage additional R&D activities. The R&E tax credit is intended to give firms an incentive to spend more on research and development than they would otherwise have spent. For that reason, the credit, in all its variations except for the energy research tax credit, has an incremental component: Firms may collect the credit only if they direct a larger portion of their revenues toward research and development than they did during a base period, which since 1989 has been set at the years 1984 to 1988. Over time, however, firms, technologies, and products have changed, and little connection may remain between what firms spent during the mid-1980s and what they would have spent now if there were no tax credit. Those circumstances suggest that it is difficult to know how much additional R&D activity can be attributed to the credit.

For firms that have become eligible for the credit only since 1989, its structure differs from the structure that applies to firms that became eligible before that date (see

Box 3 for details). In their early years of operation, those firms may have had a relatively high ratio of research and development spending to receipts because they were still researching, designing, and introducing new products. If that period has left those firms with a large base percentage, it might set a high hurdle for them to overcome to be able to claim the credit in later years.

What Is Qualified Research? The definition of research that is eligible for the credit may limit the credit's effectiveness because the expenses that are eligible may not be applicable to new activities that would be valuable to the firm or to society. The R&E tax credit is directed toward so-called qualified research expenditures, which do not generally match the R&D figures that firms report to shareholders. Only expenses that would normally be deductible are eligible for the credit; such expenses exclude capital equipment, land, and exploration for oil, gas, and other minerals, all of which might be an important part of the R&D process. In contrast, section 41(d)(1) of the Internal Revenue Code requires that qualified research pursue something "technological in nature" to develop or improve some aspect of the firm's business. In addition, the qualified activity should involve experimentation. The firm's in-house R&D and the R&D that it contracts out to others are both eligible for the credit.

Despite new regulations that were issued in 2003 to clarify the definition, some confusion still exists over the spending that qualifies for the credit.⁷² (For example, the eligibility of spending for development of software to be used only by the firm for internal purposes remains a subject of debate.) In addition, questions remain about whether R&D activity that is directed at reducing costs qualifies.⁷³ A further area of uncertainty is the treatment of research and development by firms in the service industries. The R&D those industries conduct is more likely to be performed on a computer than to take place in a laboratory, making it difficult for such firms to meet the experimentation requirement for the credit.

71. For example, consider a firm that uses the standard method to calculate its tax credit and has \$1 million in R&D expenditures above the base amount. That firm's R&E tax credit would be \$200,000, which would reduce the firm's deductions by \$200,000 and have the effect of increasing its taxable income by the same amount. For a firm in the 35 percent tax bracket, that additional \$200,000 of taxable income would increase the firm's tax liability by \$70,000. In the end, the R&E tax credit would reduce the firm's tax liability by \$130,000, or 13 percent of the firm's R&D expenditures above the base amount. Alternatively, the firm might simplify its accounting and take a tax credit of only 13 percent. Similar adjustments would also be required for firms that opted to use one of the alternative methods for calculating the R&E tax credit (see Box 3).

72. Julian Y. Kim, "The Federal Research Credit—The Definition of Research," presented at the American Enterprise Institute Forum *The Research Tax Credit: Gone Today, Here Tomorrow?*, November 15, 2006.

73. Gary Guenther, *Research Tax Credit: Current Status and Selected Issues for Congress*, CRS Report RL31181 (Congressional Research Service, April 26, 2007).

Deductibility of R&D Expenditures

In addition to the tax preference firms receive by claiming the R&E tax credit, they may also benefit from deducting R&D expenses from corporate income in determining their corporate income taxes. The Office of Management and Budget estimated that the lost revenues from firms' ability to deduct expenses for research activities in the current tax year totaled \$7.8 billion in 2006.⁷⁴ R&D activities are essentially an investment because they are conducted today in anticipation of returns in future periods, once their results can be commercialized. Like other investments, spending for R&D entails risk; those activities may or may not produce a marketable result, just as a new factory or machine may or may not produce cost savings for a firm.

74. *Budget of the United States Government, Fiscal Year 2008: Analytical Perspectives.*

In most instances, the funds that a firm spends today on an investment, such as a new factory, must be amortized and deducted on the firm's tax returns over a number of years. R&D investments are treated differently: The IRS allows firms to deduct R&D expenditures in the year in which they are made; amortize them over at least 60 months, once the work begins to benefit the firm; or write them off over a 10-year period. If a firm opts to take the current-year deduction, its current tax liability will be lower, although its taxes in future years may be higher if the R&D generates a positive return.

Deducting R&D expenses as they are incurred lowers a firm's costs for performing research and development. That factor may stimulate the firm to do more such work because the lower cost may make R&D a more attractive alternative than other investment opportunities that do not have the same favorable tax treatment.