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CBO

Federal Policies and Innovation

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Note

Numbers in the text and figures may not add up to totals because of rounding.

Contents

Summary

Innovation is a central driver of economic growth in the United States. Workers become more productive when they can make use of improved equipment and processes, and consumers benefit when new goods and services become available or when existing ones become better or cheaper—although the transition can be disruptive to established firms and workers as new products and processes supersede old ones. Looking ahead, innovation will continue to be important for economic growth, in part because the supply of workers to the economy is expected to increase at a much slower rate in the future.

Innovation produces some benefits for society from which individual innovators are not able to profit, and, as a result, those innovators tend to underinvest in such activity. Policymakers endeavor to promote innovation to compensate for that underinvestment. The federal government influences innovation through two broad channels: spending and tax policies, and the legal and regulatory systems. In this report, the Congressional Budget Office (CBO) examines the effects on innovation of existing policies and systems and the possible effects of a variety of proposals for changing those policies and systems (see Summary Table 1).

How Might Changes in Federal Spending and Tax Policies Promote Innovation?

Policymakers have a number of options for expanding the federal government's contribution to innovation. CBO examined several:

- Increase funding for federal programs that support research and development (R&D);
- Increase federal spending on education (both efforts to raise the general educational level of the workforce and efforts to support education that focuses on science, technology, engineering, and mathematics, or "STEM" fields);
- Implement tax policies that provide more incentives for private spending for R&D or other sources of innovation; and
- Increase loans or loan guarantees for firms that bring innovative technologies to market.

Using more federal resources to spur innovation, however, would entail redirecting money from other federal programs, raising taxes, increasing budget deficits, or some combination thereof. Furthermore, the federal government is not the central actor in many areas crucial to innovation. Private firms and state and local governments spend significantly more than the federal government does for many areas of R&D and for education, respectively.

Research and Development

Economic studies have shown that federal support for R&D—particularly early-stage research—has long been very important in promoting innovation. Federal spending for R&D reached $132 billion in 2013, more than doubling its 1962 value after adjusting for inflation. As a share of gross domestic product, federal spending for R&D declined by roughly half over that period (although spending for early-stage research increased slightly). The decline in the federal share of total spending for R&D during that period is largely attributable to the expansion of private R&D and to the contraction of federal R&D associated with the end of the Cold War and the space race. Increases in federal R&D spending would be expected to boost innovation by increasing total spending for R&D, although the prospects for federal support for new products that are closer to commercialization are at best mixed. Devoting additional resources to efforts to transfer government technology to the private sector would help private innovators better utilize the specialized equipment and expertise available at federal laboratories.

Summary Table 1.

Potential Federal Policy Changes to Promote Innovation That Are Considered in This Report

Policy Area and Potential Policy Change	What That Change Would Entail
Using Federal Resources	
Research and Development (R&D)	
Increase federal spending for R&D . . .	. . . by spending more on nondefense R&D and more on defense R&D that is relevant to science and technology (see page 13).
Provide more support to the private sector for the commercialization of new technologies . . .	. . . by allocating more nondefense R&D funding to commercial technology development (see page 15).
Use the federal government's purchasing power to promote technology development . . .	. . . by basing procurement decisions on the innovativeness and commercial potential of a product's or service's underlying technology (see page 16).
Education	
Increase spending on academic R&D . . .	. . . by providing more funding for research conducted at universities (see page 20).
Provide financial incentives for students to specialize in science, technology, engineering, and mathematics (STEM) fields . . .	. . . by funding more university research grants (which provide jobs for STEM graduates) and by providing subsidized grants and loans to STEM students (see page 20).
Make STEM instruction more effective . . .	. . . by increasing funding for programs that provide training to teachers of mathematics and science and that develop ways to improve the teaching of STEM (see page 20).
Improve educational attainment generally . . .	. . . by spending more to support elementary, middle, and high schools; by increasing Pell grants, lowering interest rates for postsecondary student loans, or both; or by improving school performance in other ways (see page 21).
Tax Policy	
Reinstate and enhance the R&D tax credit . . .	. . . by making it permanent, simplifying it, decreasing the potential for so-called windfalls, or making it more relevant to the current state of technology (see page 24).
Increase tax incentives for domestic manufacturing . . .	. . . by reducing the after-tax cost of investment and other activities related to innovation (see page 24).
Loan and Loan Guarantee Programs	
Increase federal credit for young, innovative firms . . .	. . . by promoting loans and loan guarantees to firms that commercialize new technologies with social benefits that are not fully captured by the market (see page 27).

Continued

Education

A more educated workforce could spur innovation in the economy in two ways: by developing more innovative ideas and by implementing those ideas more readily. In 2013, federal spending for education, not counting student loans, totaled $126 billion, amounting to roughly 15 percent of total spending on education nationally. The effect on innovation of increased federal spending for education generally is uncertain. Over the past 40 years, per-student spending (from all sources) at the elementary and secondary levels has more than doubled in real (inflation-adjusted) terms, but student achievement has remained flat. Additional spending for STEM education might contribute to innovation. However, federal spending on STEM education programs, totaling roughly

Summary Table 1. **Continued**

Potential Federal Policy Changes to Promote Innovation That Are Considered in This Report

Policy Area and Potential Policy Change	What That Change Would Entail
Legal and Regulatory Environment	
Immigration Policy	
Increase the supply of foreign-born workers in the United States who have STEM training . . .	. . . by issuing more H-1B visas (for work on a short-term basis) and immigrant visas (see page 32).
Allow more foreign-born students specializing in STEM fields to remain in the United States after they graduate from a college or university . . .	. . . by offering them a nonimmigrant or immigrant visa (see page 32).
The Patent System	
Increase the resources available to the U.S. Patent and Trademark Office (USPTO) and to federal courts . . .	. . . by making funding for the USPTO independent of Congressional appropriations, using general revenues to supplement user-based funding for the USPTO, or providing more funding to the federal courts that adjudicate patent lawsuits (see page 35).
Reduce low-quality patents . . .	. . . by changing the ways in which the USPTO administers patent law—making patent examination, and the requirements for patent applications and renewals, more demanding (see page 36).
Reduce the costs defendants incur as a result of patent litigation and, in particular, the frequency of nuisance lawsuits . . .	. . . by changing patent law—reducing the potential payoff from engaging in patent litigation, making it harder for plaintiffs to prevail in patent infringement lawsuits, and limiting the scenarios in which patent infringement can be asserted (see page 36).
Regulatory Policies and Tools	
Modify regulatory goals to favor more innovation . . .	. . . by placing greater weight on innovation than federal regulations do today relative to other goals (such as ensuring public safety) (see page 38).
Adopt flexible regulatory tools . . .	. . . by drawing on price signals and market forces to reduce the cost of regulation to innovators and by revisiting existing regulations (see page 39).
Restrict state and local laws and regulations that impede innovation . . .	. . . by forestalling regulations (for example, on product liability) that could impede innovation (see page 40).

Source: Congressional Budget Office.

Note: The inclusion or exclusion of any particular option does not imply an endorsement or lack thereof by CBO, and the report makes no recommendations.

$3 billion, currently constitutes a small fraction of federal spending for education overall and is spread across many agencies and grade levels. The most significant federal contribution to the education of new scientists comes from the federal spending for university R&D, which often pays for the training of graduate students and newly minted Ph.D.s working in the laboratories of established scientists.

Tax Policy

The tax code can provide financial incentives to individuals and businesses to pursue innovation through the R&D tax credit and other tax preferences. In 2012, the R&D tax credit resulted in tax expenditures totaling $6 billion. However, the R&D credit expired in December 2013, raising the question of its extension or modification. Some analysts argue that the R&D credit stimulates some additional private R&D, whereas others contend that much, if not most, of the forgone revenues go to firms for performing R&D that they intended to perform anyway, regardless of the credit. Increasing federal support for manufacturing through increased tax deductions for investment in plant and equipment would be a very indirect way to increase innovation because only a modest share of such investment is made by manufacturing firms and a large share of manufacturing is not very R&D-intensive.

Loan and Loan Guarantee Programs

The federal government can also attempt to promote innovation by providing more loans or loan guarantees to private firms that commercialize new technologies with social benefits that are not fully reflected in the market, such as some sorts of renewable energy. Because private investors already devote substantial resources to commercializing innovative products and services, increasing financial support for such federal credit programs may be difficult without funding projects that could obtain private funding anyway or funding projects whose social costs outweigh their benefits.

How Might Changes in the Federal Legal and Regulatory Environment Promote Innovation?

To further encourage innovative activity, policymakers could also make changes to immigration policies, the patent system, and the regulatory regime. Modifying laws and regulatory policies would involve less of a commitment of federal resources than increasing federal spending.

Immigration Policy

Foreign-born workers—and particularly highly skilled immigrants—contribute significantly to innovation in the United States, partially because many are highly educated and disproportionately employed at high-tech firms, universities, and other institutions that foster innovation. However, U.S. immigration policy is more oriented toward family reunification than admitting workers who would be likely to contribute to innovation. Policymakers could modify immigration law to increase the number of highly skilled noncitizens that are allowed to enter and work in the United States and so promote innovation. Analysts disagree about whether increasing the immigration of such highly skilled workers would negatively affect the employment and wages of highly skilled native-born workers.

The Patent System

The patent system promotes innovation by helping inventors recoup the costs of their efforts in exchange for making their inventions public. The Congress is currently faced with calls to address a number of perceived shortcomings of the patent system, including the recent proliferation of supposedly low-quality patents, pronounced delays in processing patent applications, and the cost of infringement litigation (in particular, the frequency of "nuisance" lawsuits). Because modifications to the patent system could have both positive and negative effects on the incentives to innovate, and because research on important issues of concern today remains limited, estimating the net impact of specific proposals for patent reform is generally difficult.

Regulatory Policies and Tools

Policymakers could alter how federal regulations affect the pace of innovation in several ways. First, they could change the emphasis on innovation when there are trade-offs between innovation and other federal goals, such as public safety. Separately, policymakers could rely more on regulatory tools that draw on prices and market forces to reduce some of the costs resulting from regulation. Finally, federal policymakers could address the ways in which liability laws and other regulations promulgated by state and local governments affect the balance of innovation and other policy goals.

CHAPTER

1

Effects of Innovation on the Economy

Innovation is a key determinant of long-term economic growth: The development of new products and processes makes businesses more productive, and consumers benefit as new goods and services become available or as existing ones become more affordable. In addition to benefiting firms (in the form of higher profits) and consumers (in the form of lower prices for goods and services), innovation often makes a contribution to society's welfare that is not easy to measure economically, improving the quality of life in ways that are not reflected by increases in individuals' income. However, because innovation can also be disruptive to established firms and workers, the gains from such activity may be unevenly distributed.

Innovation and Economic Growth

Innovation can take many forms, and innovators are found throughout the economy. Broadly speaking, an innovation is a new or significantly improved product or process—for example, a breakthrough device, such as the integrated circuits that are at the heart of modern computing, or a better way of operating a business, such as a more advanced inventory management system. Both the quality of an innovation and the extent to which it is used determine the impact it will have on the economy.

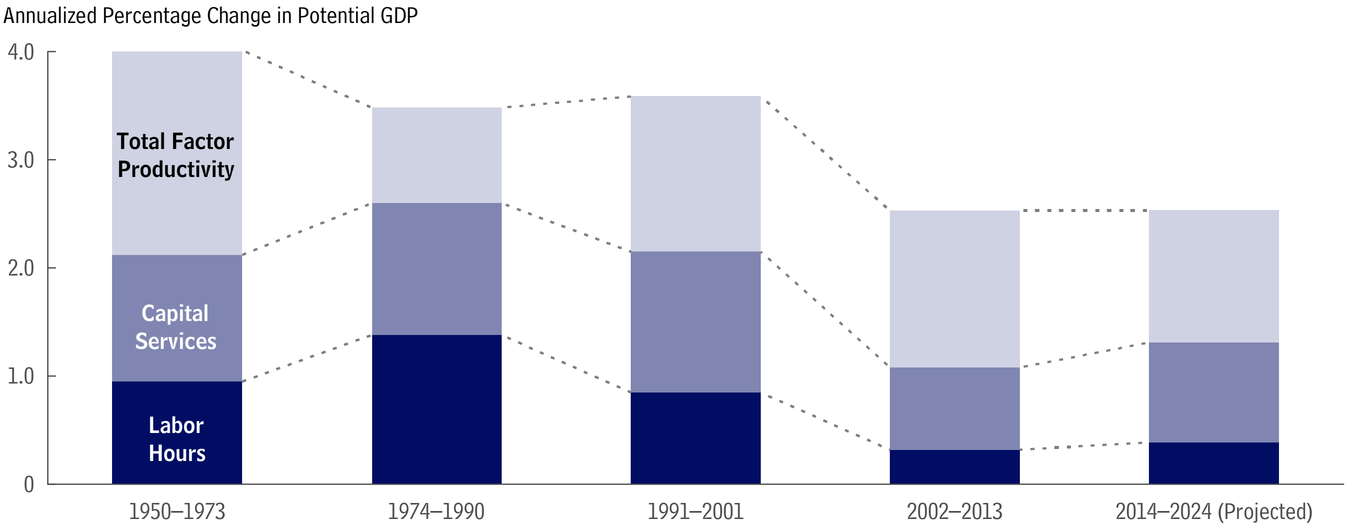
Although the technological advances that have occurred in the manufacture of computer and communications equipment are prominent examples of innovative activity today, other sectors of the economy also generate important innovations. In retailing, for example, new methods of marketing and distributing products—both over the Internet and through traditional retail stores—have resulted in lower prices (and in the case of the Internet, added convenience) for consumers. Some of the benefits of innovation may not be readily measured in economic terms. For example, innovative pharmaceuticals and improved medical equipment and procedures continue to improve the quality of life and to extend life expectancy.

Because the effects of innovation on the economy can be difficult to measure, economists typically use the growth in total factor productivity (TFP) as a proxy. Growth in TFP is defined as the growth of real output that is not explained by increases in the amount of labor and capital—typically physical structures and equipment used in production, along with intangible capital such as computer software and research and development (R&D). For example, innovation can result in improvements in the quality of capital that are not reflected in the measured amount of capital used. Innovation can also allow production or distribution to be reorganized so that it becomes less expensive to supply goods and services to consumers using the same amounts of capital and labor. The increase in economic output associated with such improvements will show up as an increase in TFP and growth in the economy.[1]

1. With its latest comprehensive revision to the national income and product accounts (released in July 2013), the Bureau of Economic Analysis (BEA) began classifying as investment R&D spending by government, businesses, and nonprofit organizations that serve households (together with business spending on some other types of intellectual property, such as music, movies, and other original artistic and literary works). BEA also revised its historical estimates of the capital stock to incorporate that reclassification (back to 1959 for business spending on R&D and even earlier for works of entertainment, such as music and books). A comparison of the sources of economic growth before and after that reclassification shows little qualitative change in the contribution of TFP. Some researchers suggest that spending by firms on certain other activities also results in innovation and influences TFP; examples include spending on industrial design, worker training, and firm branding and marketing. See Carol A. Corrado and Charles R. Hulten, "How Do You Measure a 'Technological Revolution'?" *American Economic Review*, vol.100, no. 2 (May 2010), pp. 99–104, http://tinyurl.com/nb6vs7z.

Figure 1-1.

Contributions to the Growth of Potential GDP, 1950 to 2024



Source: Congressional Budget Office.

Notes: Potential GDP is the maximum sustainable output of the economy. This figure depicts growth in the nonfarm business sector (which excludes the economic activities of general government, private households, nonprofit organizations serving individuals, and farms).

Total factor productivity is the growth in output that remains after removing the contributions from growth in labor hours and capital services. Capital services are a measure of the flow of services available for production from the real (inflation-adjusted) stock of capital (typically, the physical structures and equipment used in production, along with intangible capital, such as computer software and knowledge gained from spending for research and development).

GDP = gross domestic product.

The contribution of TFP to economic growth has varied over the years, as have the contributions of other factors (see Figure 1-1). From 1950 to 1973, the growth in TFP added nearly 2 percentage points each year to the growth of potential gross domestic product (potential GDP is the maximum sustainable level of output). The contribution of TFP to potential GDP was only about half as large between 1974 and 1990, although an increase in the contribution of labor hours (the number of hours worked) partially offset that decline. Over roughly the past 20 years, the contribution of TFP to potential GDP has risen to about 1½ percentage points each year; the contributions from labor hours and capital declined over the 2002–2013 period. The Congressional Budget Office projects that the rate of growth in TFP will be slightly smaller between 2014 and 2024 than it was in the preceding two decades. The growth in the supply of workers in the economy is expected to be about as slow during the next 10 years as it was in the past decade, owing both to the retirement of baby boomers and to a relatively stable labor force participation rate among working-age women after sharp increases in some previous decades. For that reason, innovation that makes those workers more productive—for instance, by improving the equipment they use and by enabling their work to be organized more efficiently—will continue to be important.

The Impact of Innovation on Firms and Workers

Although innovation leads to economic growth, it can also lead to changes that adversely affect established firms and workers. For example, in the travel industry, the wide availability of the Internet brought with it the ability for consumers to search for information, to compare prices, and to book travel and hotel accommodations quickly, thereby making many travel agencies redundant. Many bookstores, record shops, and video rental services eventually met a similar fate. Even large firms that have become leaders in an existing technology may be unable to transfer their success to a new one such as occurred in the film manufacturing and processing industry after digital photography replaced celluloid film.

Innovation can also affect the labor force and, in particular, the distribution of income among workers in different sectors or with different skill sets. Workers in firms that go out of business as a result of a new technology have to find new jobs, which may pay less than they earned previously. In contrast, the availability of new technologies may increase the demand for workers who have the skills to use them. As a result, employment and income may rise for individuals whose training or ability enables them to make use of innovations but fall—at least as a share of the workforce and of total worker income, if not in an absolute sense—for those individuals who are less well positioned to do so.

The spread of information technology throughout the economy during the past few decades illustrates the ways in which innovation can shift the distribution of employment and income among workers. New information technologies have complemented nonroutine cognitive work (such as analysis, evaluation, and decisionmaking) and have increased the demand for the highly skilled, more educated workers who perform those tasks. As a result, both the share of employment in that kind of work and the real (inflation-adjusted) median wage earned by the most educated workers have risen over the past few decades. Beginning in the 1990s, the use of information technology not only made highly skilled workers more productive, it also increasingly substituted for workers who perform routine jobs requiring average skills (such as typing and filing). As a result, information technology led to a decline in the share of employment in occupations in which workers perform more routine cognitive tasks. In real terms, the median wage of workers with less than a bachelor's degree has displayed little or no growth.[2] Technology-driven developments in labor markets will almost certainly continue as innovation allows additional tasks—such as those required in many stages of manufacturing—to be automated.

2. Congressional Budget Office, *Changes in the Distribution of Workers' Hourly Wages Between 1979 and 2009* (February 2011), pp. 6–10, www.cbo.gov/publication/22010.

CHAPTER

2

Using Additional Federal Resources to Spur Innovation

The federal government promotes innovation directly by funding research and development and education, and indirectly by encouraging private investment in R&D and other innovative activity through tax preferences and loans and loan guarantees. However, federal agencies are no longer making the largest investments in some fields. The federal share of total R&D in the United States has decreased over the past several decades—both because of the expansion of private R&D and because of the diminution of federal R&D associated with the end of the Cold War and the space race. And, although the federal government provides a substantial portion of funding for academic R&D, which is used to train graduate and postdoctoral students specializing in science and related fields, most funding for education is provided by state and local governments.

Using more federal resources to spur innovation would mean either diverting money from other federal programs or activities—which would entail compromising on or reassessing national priorities—raising taxes, increasing deficits, or some combination thereof.

Funding for Research and Development

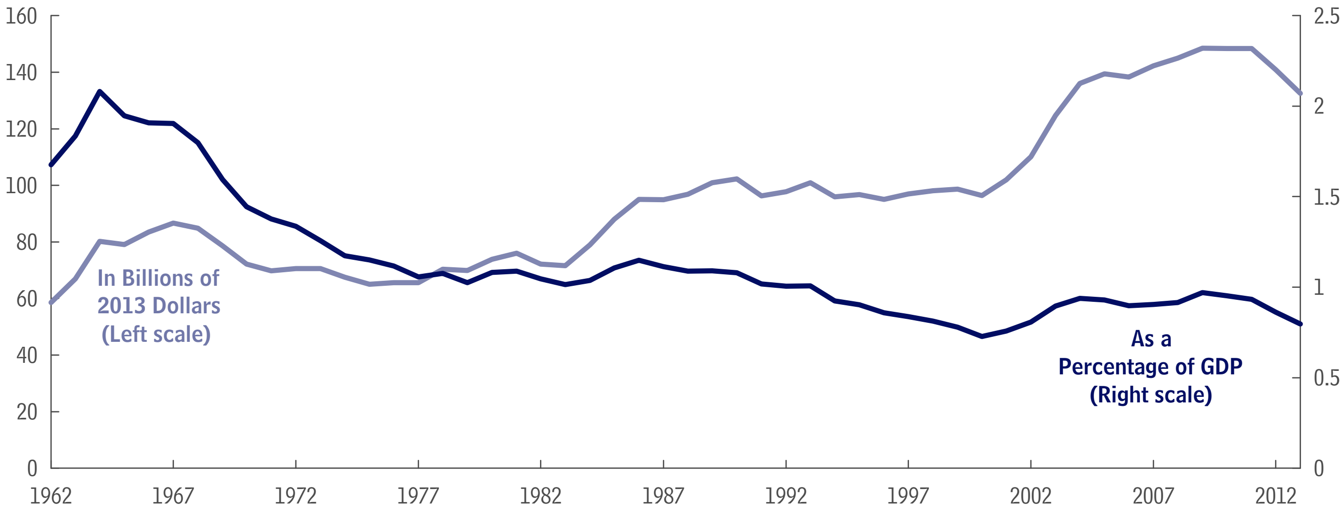
The process of R&D contributes to economic productivity by generating knowledge that leads to the development of new goods and services or to improvements in existing goods and services. (The performance of R&D also produces trained scientists, which is discussed later in this report.) For example, modern computers grew out of research into integrated circuits, and many of today's innovative services and business processes, such as Internet retailing and advanced inventory management systems, rely on advanced computer technology. The R&D process encompasses three stages:

- Development or improvement of products and services—which accounted for almost two-thirds of the R&D expenditures in the economy in 2012;
- Applied research—research designed to link scientific knowledge to some practical purpose, ultimately leading to the development of a marketable product or service—which accounted for a fifth of the national R&D; and
- Basic research—scientific inquiry that has no clear-cut commercial application but is nonetheless valued for the knowledge it produces and its potential for leading to future discoveries—which accounted for a sixth of such expenditures.

Economic analysis suggests that the benefits from R&D would justify higher spending on R&D than would be undertaken by the private sector alone. As mentioned above, the benefits that flow from R&D typically extend beyond the profits gained by the firm or person producing the knowledge, reducing the incentive to invest in the production of such knowledge relative to the amount of social benefit. That difference in incentives, particularly in basic research, has long provided a rationale for federal involvement. In addition, federal agencies—most notably the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA), but others as well—often need to develop specialized technology and equipment in order to fulfill their assigned missions.

Figure 2-1.

Federal Outlays for the Conduct of Research and Development



Source: Congressional Budget Office based on data from the Bureau of Economic Analysis and from the Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2015: Historical Tables* (March 2014), Table 9.8, http://go.usa.gov/7DWB.

Notes: Outlays do not include spending for research facilities.

GDP = gross domestic product.

Federal Spending for R&D

Federal outlays for R&D more than doubled between 1962 and 2013 in real terms, driven mostly by an increase in spending for R&D related to defense during the defense buildup of the early 1980s and by an increase in spending for health research from 1998 to 2004.[1] In 1962, federal outlays for R&D totaled about $59 billion (in 2013 dollars). By 2013, federal agencies were spending $132 billion for R&D (see Figure 2-1), averaging a 1.6 percent real annual rate of growth between 1962 and 2013. However, growth has been intermittent. For example, since 2009, real federal R&D spending has declined by about 10 percent. When measured against the growth of gross domestic product, federal spending for R&D has generally declined since the 1960s (with the notable exceptions of the two periods discussed above).

Although federal R&D spending has been declining as a share of the economy overall, R&D expenditures from all sources reached 2.8 percent of GDP over the past several years, a level that had not been reached since the early 1960s.[2] Since 1962, the share of GDP devoted to basic research expenditures has increased by half, whereas the share of applied research expenditures has declined slightly. The share of development expenditures has fluctuated around its average (see Figure 2-2).

Looking at the different stages of R&D and sources of spending, expenditures by private industry across all stages have grown in the past 50 years. The largest single shift was the increase in industrial development expenditures—up by 150 percent relative to the size of the economy—that almost completely offset the decrease in federal expenditures for development (which were mainly for activities related to defense and space exploration).

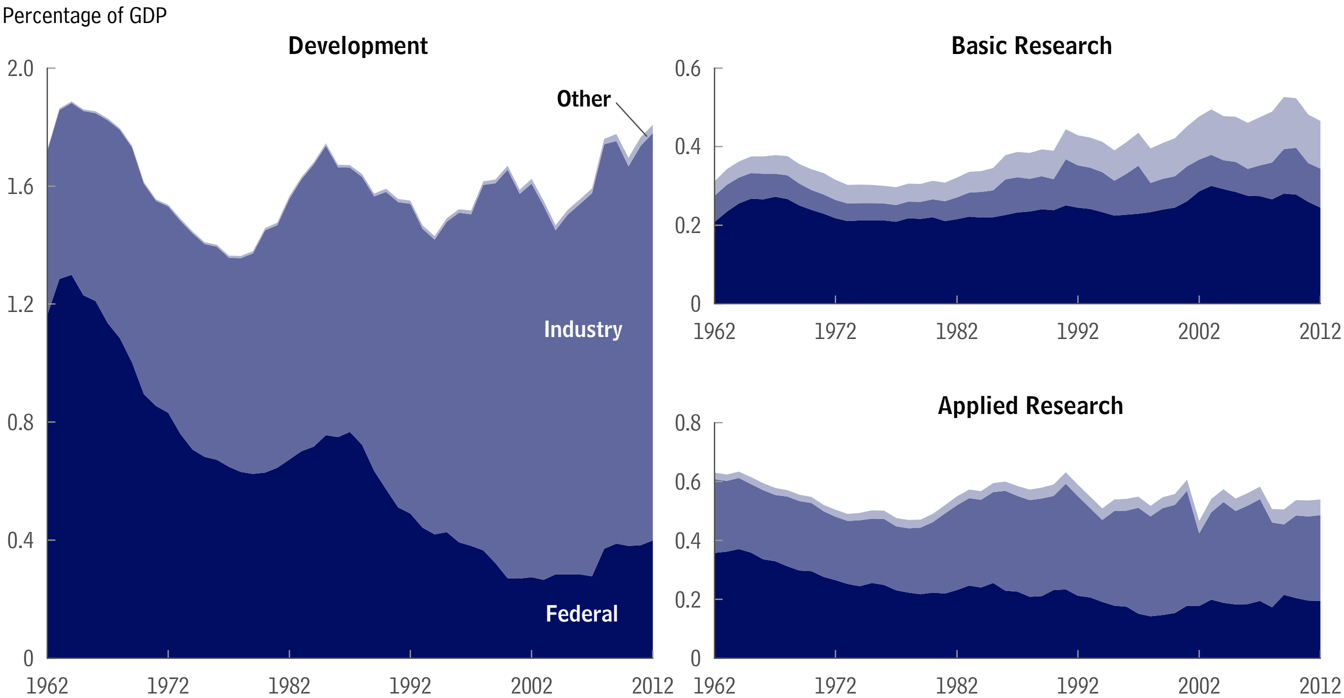
Federal agencies also decreased their expenditures on applied research as a share of GDP by 45 percent, and an increase in spending by industry offset part of that decline. Federal agencies did increase their expenditures on basic research slightly relative to the size of the

1. Most agencies disburse their annual appropriations over more than one fiscal year—consequently, there may be discrepancies between *funding* (appropriations) and *spending* (outlays) in any given year. In addition, the estimates given here are for the conduct of R&D only. Although most federal spending for R&D involves the actual conduct of R&D, federal agencies also spend a small fraction of their R&D funds on equipment and facilities.

2. National Science Foundation, "National Patterns of R&D Resources: 2011–12 Data Update" (December 2013), Table 1, http://go.usa.gov/EWBH.

Figure 2-2.

Expenditures for Research and Development as a Share of GDP, by Source of Funding



Source: Congressional Budget Office based on data from the National Science Foundation, "National Patterns of R&D Resources: 2011–12 Data Update" (December 2013), http://go.usa.gov/EWBH.

Notes: The category "Other" consists of support from universities, colleges, nonprofit organizations, and state and local governments but excludes funding from the federal government or industry.

Basic research is scientific inquiry that has no clear-cut commercial application but is nonetheless valued for the knowledge it produces and its potential for leading to future discoveries. The objective of applied research is to link scientific knowledge to some practical purpose, ultimately leading to the development of a marketable product or service.

Estimates from the National Science Foundation for national expenditures for research and development (R&D) are based on surveys of performers of R&D and thus differ slightly from estimates of outlays that come from federal agencies. Data for 2012 are preliminary.

GDP = gross domestic product.

economy, at the same time that other nonindustrial institutions such as universities, nonprofits, and state and local governments increased their expenditure share by almost twice as much. In the early 1960s, federal expenditures accounted for roughly two-thirds of all spending devoted to R&D. Industry and all other sources combined (universities and colleges, nonprofits, and state and local governments) accounted for roughly one-third of total R&D expenditures. Since 2000, the shares have been reversed: Industry has accounted for roughly two-thirds of national R&D expenditures; the federal government has accounted for between 25 percent and 30 percent; and other sources, collectively, have accounted for 7 percent.

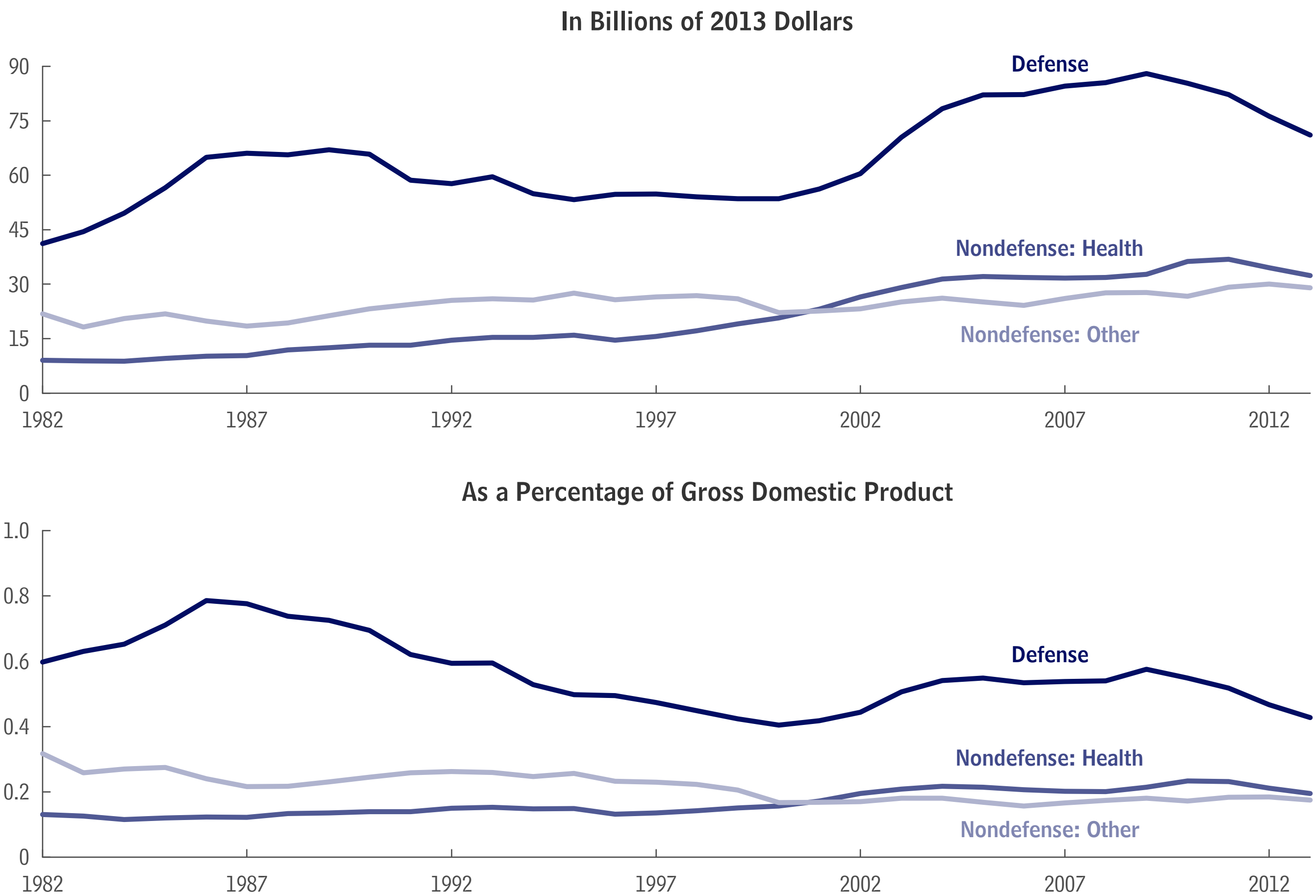
Trends in Federal Spending for R&D by Subject Area

Viewing federal spending for R&D by budget function shows that two areas accounted for roughly 80 percent of federal R&D spending in 2013. Defense-related R&D accounted for 54 percent of all federal R&D outlays, and health R&D accounted for an additional 24 percent. The remaining 22 percent was spread among all other categories of nondefense R&D, such as agriculture, energy, general science, and space exploration. Defense and health have grown the most over the past few decades (see Figure 2-3).

The defense category primarily supports R&D undertaken by DoD to develop weapon systems and to support

Figure 2-3.

Federal Outlays for Research and Development, by Subject Area



Source: Congressional Budget Office based on data from the Bureau of Economic Analysis and from the Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2015: Historical Tables* (March 2014), Table 9.8, http://go.usa.gov/7DWB.

science and technology.[3] In 2013, DoD received $66 billion for R&D, of which 82 percent was for weapons development. Over the past decade, funding for weapons development by DoD has risen dramatically and then fallen, growing from $59 billion (in 2013 dollars) in 2003 to a peak of $73 billion in 2008 and then declining to $54 billion in 2013.[4] By contrast, real funding for DoD's science and technology programs has generally varied by less than 10 percent from its 2004–2013 average of $14 billion. However, in 2013, DoD science and technology R&D fell 18 percent below that average (other federal R&D programs declined as well).

Most growth in spending for nondefense R&D has been in the area of health. Health-related R&D has grown notably in real terms over the past few decades, whereas the growth in spending for R&D in other areas has been limited. Support for health R&D received a very large boost from 1998 to 2004 when the Congress passed legislation to double appropriations for the National Institutes of Health (NIH). Following that surge in funding, NIH's appropriations began to decline in real terms. That decline resulted in substantial disruption among biomedical research institutions that had committed to higher growth in spending for facilities and the training of young scientists, which they then found difficult to maintain.

3. The Department of Energy and the Department of Homeland Security account for a small fraction of defense R&D.

4. American Association for the Advancement of Science, *Trends in Defense R&D, FY 1976-2015* (May 6, 2014), http://tinyurl.com/lh63smp (XLS, 14.6 KB).

The different areas of R&D funded by the federal government can vary in their effects on innovation and productivity growth. The two categories of nondefense R&D—health and other—and the small portion of defense R&D that is directed largely at basic and applied research probably have a positive effect on private-sector productivity.[5] Defense R&D devoted to weapons development is often thought to have less applicability to innovation in commercial or civilian products (notwithstanding some prominent technological advances that have resulted from defense R&D and subsequent procurement of weapons arising from the R&D process).[6]

R&D for national defense and health also produces public benefits that are not fully captured in the accounting of GDP. Economists have long estimated that federal health R&D has had a substantial impact on life expectancy, public health, and society's well-being.[7] However, such social benefits are often only indirectly reflected in the output of workers and calculations of national income and economic growth.

Although federal and industrial spending on health-related R&D continues to yield new medical discoveries and new drugs, the average cost for each new drug or medical discovery is rising. For instance, each extra billion dollars spent on pharmaceutical R&D now results in fewer new drugs than was the case in years past.[8] Potential explanations for this phenomenon range widely—from the likelihood that researchers have exhausted the better understood molecular targets to the effects of corporate mergers among pharmaceutical companies. In response to the decreasing number of new drugs and treatments that result from health-related R&D, NIH has an initiative specifically devoted to addressing that issue.

Policies to Increase Federal Support for R&D

The decline in the federal share of R&D relative both to private efforts and to the size of the economy has led some analysts to suggest that the federal government could increase innovation by increasing its overall R&D budget. Some economic analysis suggests that the benefits from R&D would justify much higher spending on R&D and, in particular, much higher spending on basic research.[9]

However, in an effort to limit overall federal spending, policymakers have placed caps on most discretionary funding, a category of the federal budget that includes appropriations for R&D. Discretionary programs—that is, programs funded though annual appropriation acts—run the gamut from agriculture to youth opportunity grants and include most federal programs other than benefit programs (such as Social Security and Medicare) and interest payments on the national debt. Given the caps on most funding for those programs through 2021 that are in current law, the Congressional Budget Office projects that discretionary spending will shrink markedly as a share of GDP in coming years (see Figure 2-4).

If policymakers choose to maintain spending for R&D at its historical share of total discretionary spending, then federal R&D would be expected to shrink significantly relative to the size of the economy. Thus, given the

5. See Congressional Budget Office, *Federal Investment* (December 2013), www.cbo.gov/publication/44974; and Andrew A. Toole, "Does Public Scientific Research Complement Private Investment in Research and Development in the Pharmaceutical Industry?" *Journal of Law and Economics*, vol. 50, no. 1 (February 2007), pp. 81–104, http://dx.doi.org/10.1086/508314.

6. The development of weapon systems primarily contributes to the national welfare through its role in military policy rather than through increases in economic productivity. Because weapons development is largely devoted to optimizing the operation of specific weapon systems, the results of that work generally have narrower applicability than does research in broader areas of science and technology. Reviews of the literature suggest that such optimization and other product development generally lead to fewer benefits for other parts of the economy than basic and applied research. See Bronwyn H. Hall, Jacques Mairesse, and Pierre Mohnen, *Measuring the Returns to R&D*, Working Paper 15622 (National Bureau of Economic Research, December 2009), pp. 19–20, www.nber.org/papers/w15622.

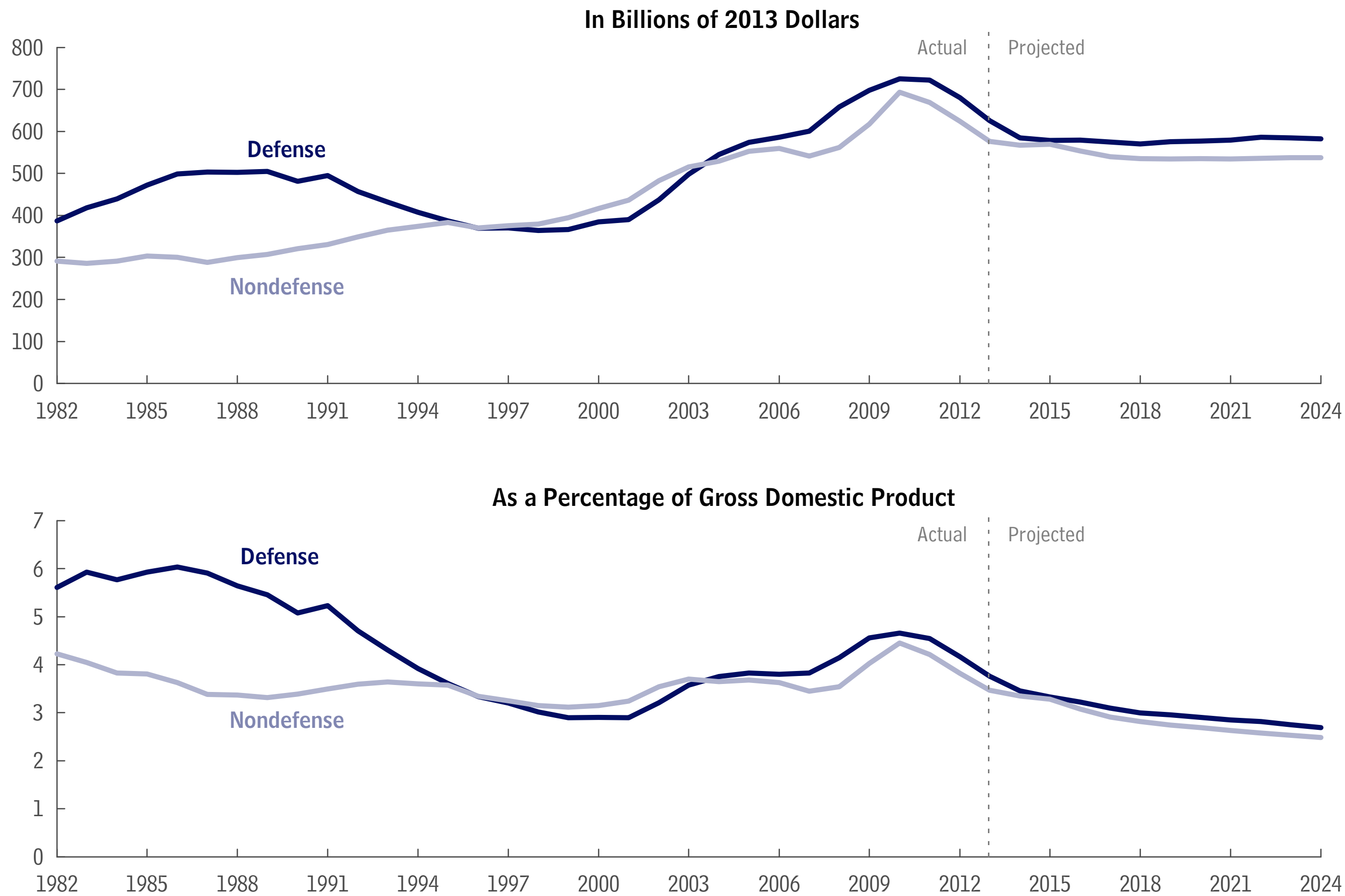
7. Iain M. Cockburn and Rebecca M. Henderson, "Publicly Funded Science and the Productivity of the Pharmaceutical Industry," in Adam B. Jaffe, Josh Lerner, and Scott Stern, eds., vol. 1 of *Innovation Policy and the Economy* (National Bureau of Economic Research, January 2001), pp. 1–34, www.nber.org/chapters/c10775. For more information on life expectancy, see David M. Cutler and Mark McClellan, "Is Technological Change in Medicine Worth It?" *Health Affairs*, vol. 20, no. 5 (September 2001), pp.11–29, http://content.healthaffairs.org/content/20/5/11.full.

8. Jack W. Scannell and others, "Diagnosing the Decline in Pharmaceutical R&D Efficiency," *Nature Reviews Drug Discovery*, vol. 11, no. 3 (March 2012), pp. 191–200, www.nature.com/nrd/journal/v11/n3/full/nrd3681.html.

9. Nicholas Bloom, Mark Schankerman, and John Van Reenen, *Identifying Technology Spillovers and Product Market Rivalry*, Centre for Economic Performance Discussion Paper 675 (London School of Economics and Political Science, December 2012), pp. 3–4, http://tinyurl.com/Kmv4srm (PDF, 1 MB).

Figure 2-4.

Actual and Projected Federal Outlays for Discretionary Programs



Source: Congressional Budget Office based on data from the Bureau of Economic Analysis and from the Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2015: Historical Tables* (March 2014), Table 8.7, http://go.usa.gov/7DWB.

current budgetary caps, policymakers would have to reduce the share of discretionary funding going to other kinds of activities if they decided to increase R&D funding. In the past, federal R&D has accounted for a fairly stable share of discretionary spending. Since 1985, nondefense R&D has typically accounted for between 9 percent and 11 percent of nondefense discretionary outlays, and defense R&D has typically ranged between 12 percent and 15 percent of defense discretionary outlays. CBO projects that in the 2020s DoD will not have the budgetary resources to fund its current plans, so that sustaining or increasing R&D would require disproportionate cuts to other areas.[10] Similarly, about half of the nondefense portion of discretionary spending is for investment of some kind, whether R&D, education (discussed in the next section of the report), or infrastructure.[11] Increasing funding for R&D would put greater budgetary pressure on other categories of federal investment or on nondefense discretionary activities that do not constitute investment.

Policies to Redirect Federal Resources for R&D

Some advocates of a greater federal contribution to innovation propose that the government spend more not on R&D but on programs that would translate the results of research into commercial products. Looking back to earlier generations of successful government technology programs, some analysts further suggest that the federal

10. Congressional Budget Office, *Long-Term Implications of the 2014 Future Years Defense Program* (November 2013), www.cbo.gov/publication/44683.

11. Congressional Budget Office, *Federal Investment* (December 2013), p.12, www.cbo.gov/publication/44974.

government should use its purchasing power to increase the demand for products that might have substantial commercial spinoffs.

Federal Programs to Commercialize Technology. Over the past 30 or more years, the Congress has enacted various laws and funded programs designed to facilitate cooperative R&D between and among government, industry, and academia with the intent of increasing commercial innovation. The goals of the programs are varied: Some target new energy technologies, others are directed at small businesses, and others are geared to specific industries or technologies. Similarly, the programs use a variety of vehicles to accomplish those goals. Overall, federal programs to commercialize technology through product development have had a mixed record. However, programs that focus on developing technology—while leaving industrial partners to handle commercial aspects—generally seem to have enjoyed more success in the past.

Although some federal programs that were designed to commercialize technology have had a measure of success, others have proved to be economically redundant at best and commercial failures at worst. In some areas, such as agriculture and health, government agencies have long assisted industry with the introduction of innovative products, such as new plant varieties, the annual flu vaccine, or the development of drugs for AIDS. Other fields have proved more problematic. For example, in coal-powered electricity and commercial nuclear power, the Department of Energy (DOE) has long sought to introduce new energy production technologies through expensive technology demonstration plants that often have failed to deliver commercially useful products or to attract much private investment.[12]

Efforts to transfer technology out of federal laboratories to private-sector partners seem to have borne some fruit and are more numerous than some observers may realize. Many innovative commercial products incorporate technology developed at federal laboratories or using federal research funding. One survey of award-winning innovative products showed that, over the past 20 years, technologies developed at federal laboratories—often in collaboration with industry—have accounted for roughly a third of such products introduced every year.[13] Nor is such transfer of technology from federal laboratories to industry limited to the award-winners: Every year roughly 7,500 formal cooperative research ventures take place that involve many of the 300 federal laboratories active in technology transfer and either industry or universities active in developing the commercial potential of technology.[14] In addition, those federal laboratories have entered into a rising number of less formal collaborative R&D agreements with outside parties, totaling 25,000 in 2011 (the most recent year for which estimates are available). Similarly, the Small Business Innovation Research and Small Business Technology Transfer programs provide research grants to roughly 6,500 small businesses per year to help with the commercialization of new technologies.[15] In all, federal agencies fund or participate in some 40,000 individual cooperative efforts to commercialize new technologies yearly, independent of federal agencies' researching or funding technology development that might have commercial potential.

At least part of the problem with large federal technology demonstration programs—as opposed to the transfer of individual inventions developed in federal laboratories—is the fact that federal agencies are not usually equipped to oversee the commercial and business aspects of new product introduction. Companies launch new products and services embodying novel technology daily. The

12. Congressional Budget Office, *Federal Climate Change Programs: Funding History and Policy Issues* (March 2010), pp. 16–19, www.cbo.gov/publication/21196. See also Peter Ogden, John Podesta, and John Deutch, "A New Strategy to Spur Energy Innovation," *Issues in Science and Technology*, vol. 24, no. 2 (Winter 2008), http://issues.org/24.2/ogden.html.

13. Each year since 1963, *R&D Magazine* has recognized the 100 best inventions that are incorporated into commercial products. The survey in question tracked the sources of the inventions. Fred Block and Matthew R. Keller, *Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1970–2006* (July 2008), http://tinyurl.com/mzxys7g. Federal laboratories include not just the major DOE weapons laboratories, but those of all agencies.

14. Federal laboratories often have specialized equipment or expertise that help private firms develop technology. National Institute of Standards and Technology, *Federal Laboratory Technology Transfer, Fiscal Year 2011: Summary Report to the President and the Congress* (September 2013), p. 8, http://go.usa.gov/K5Qx. For laboratory count, see Federal Laboratory Consortium, "About the FLC" (accessed November 10, 2014), www.federallabs.org/flc/home/about/.

15. For data on small business awards, see Small Business Innovation Research program, "Awards" (accessed May 15, 2014), www.sbir.gov/past-awards.

commercial success of those products and services often depends less on the novel technologies they incorporate and more on product design and broader business factors—the timing of product introduction, market placement, advertising, cost control, logistics, and product support. In those areas, federal employees generally have no special expertise; indeed, the very mission of many federal agencies often militates against such considerations. Those factors suggest that federal agencies may be ill-suited to participate in expensive demonstration projects; but they may experience more success with smaller, peer-reviewed efforts in basic and applied research where the technological competence predominates.

Use of Federal Procurement to Promote Technology. One approach to commercializing federally sponsored technology would involve using government purchases of new technologies to reduce their cost and help them compete successfully in the open market. In the early 1960s, DoD and NASA purchased large numbers of integrated circuits. Because those government purchases were large enough for firms to achieve economies of scale and reduce per-unit production costs in that industry, those purchases paved the way for the nation's successful integrated circuit industry. In the 1980s, both the Internet and the Global Positioning System made the transition from a military-based technology infrastructure to one primarily serving private demand. Advocates of such policies argue that the federal government could try to accomplish the same thing today in several areas—most notably in the energy sector.

However, recent efforts along those lines have generally not been successful. For example, in trying to reduce carbon emissions produced by coal-fired power plants and other industrial facilities, DOE is sponsoring the construction of power plants that separate carbon dioxide from the exhaust, compress it into a fluid, and then pump it into deep underground geologic formations (a process commonly called carbon capture and storage). DOE hopes that the cost of those plants will fall enough to make them competitive with conventional coal-fired plants. At least one problem with this strategy is that DOE's program is not nearly large enough to reduce the costs of building such plants, given normal patterns of industrial cost reduction.[16]

The federal government would have to spend perhaps tens or hundreds of billions of dollars to make a substantive impact on a number of industries on the basis of procurement alone; that kind of additional discretionary spending is unlikely to be forthcoming. A spending increase of smaller size devoted specifically to procurement would be too small to be useful to spur innovation in most fields in a systematic way. Furthermore, federal procurement increasingly utilizes commercial off-the-shelf technology to help reduce costs. DoD, the largest single federal purchaser of advanced technology goods, has made a policy decision to use commercial off-the-shelf technology where available, including in the computer market.[17] As a result of increases in civilian demand for high-technology goods, technology is now more advanced and costs are often lower in civilian products than in comparable defense products.

Support for Education

A more educated workforce could spur innovation in the economy in two ways: by developing more innovative ideas and by putting those ideas into use more readily. Highly trained individuals are most likely to come up with the insights that will drive innovation, creating new products and services and making existing ones better. For example, the share of people working in corporate research laboratories who have completed graduate or even postgraduate training has increased over time. Research also shows that more educated workers have a comparative advantage at making use of new technologies. At present, governments at all levels and private sources currently spend over $1.1 trillion a year on education.

Federal Spending for Education

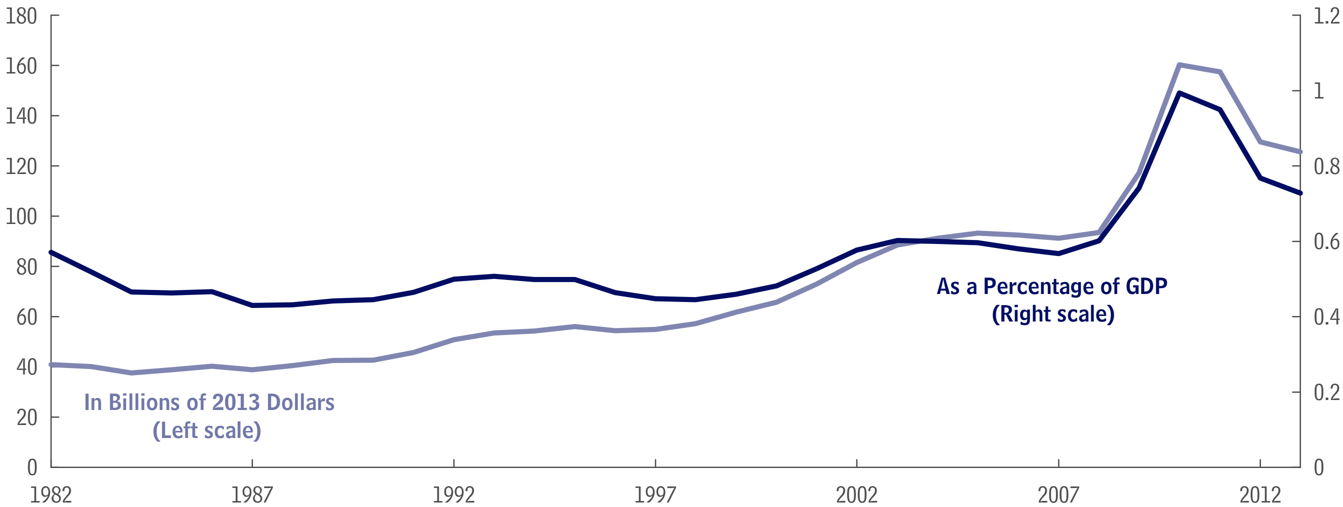
Federal spending for education (at the primary, secondary, and postsecondary levels) and training has risen substantially since 1982, both in real terms and as a share of the economy. In 1982, federal spending for education, excluding student loans, was $41 billion (in 2013 dollars). Under the American Recovery and Reinvestment

16. Congressional Budget Office, *Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide* (June 2012), www.cbo.gov/publication/43357.

17. David J. Carney and Patricia Oberndorf, *A Summary of DOD COTS-Related Policies* (Carnegie Mellon Software Engineering Institute, September 1998), http://tinyurl.com/n4oax7m.

Figure 2-5.

Federal Outlays for Education and Training



Source: Congressional Budget Office based on data from the Bureau of Economic Analysis and from the Office of Management and Budget, *Budget of the U.S. Government, Fiscal Year 2015: Historical Tables* (March 2014), Table 9.9, http://go.usa.gov/7DWB and *Budget of the U.S. Government, Fiscal Year 2014: Supplemental Materials* (April 2013), "Public Budget Database, Outlays," http://go.usa.gov/Wwy9 (XLS, 2.84 MB).

Notes: This figure does not reflect outlays for college student loans or for federal contracts or grants for university research and development.

GDP = gross domestic product.

Act of 2009, funding for the Federal Pell Grant Program and for education in general increased substantially. However, that additional spending has ended, and policymakers have tightened eligibility for Pell grants and eliminated grants for summer students; as a result, federal spending on education has fallen from its peak of $160 billion in 2010 to $126 billion in 2013 (see Figure 2-5).[18] More recently, lawmakers also made several changes to federal student financial aid programs that, on net, led to relatively small changes in federal education spending.

Most funding for primary and secondary education in the United States occurs at the state and local government levels. For the 2009–2010 school year, the most recent year for which data are available, revenues devoted to public primary and secondary schools totaled $606 billion (in 2013 dollars). Federal agencies provided only 13 percent of those funds ($77 billion); by contrast, 87 percent came from state and local governments and other sources (see the first chart in Figure 2-6).[19] Federal assistance at the K–12 level occurs primarily through grants for education of the disadvantaged and the disabled and for school-lunch programs.

Similarly, at the postsecondary level, most funding for education comes from sources other than federal grants. Of the $524 billion in total funding for postsecondary education during the 2009–2010 school year (in 2013 dollars), federal grants and contracts provided about 17 percent or roughly $90 billion (see the second chart in Figure 2-6). Many of the grants and contracts were for academic research, but about $32 billion was for Pell grants to help low- and lower-middle-income students attend college.

In addition to grants and contracts, the federal government issued about $100 billion in federal student loans

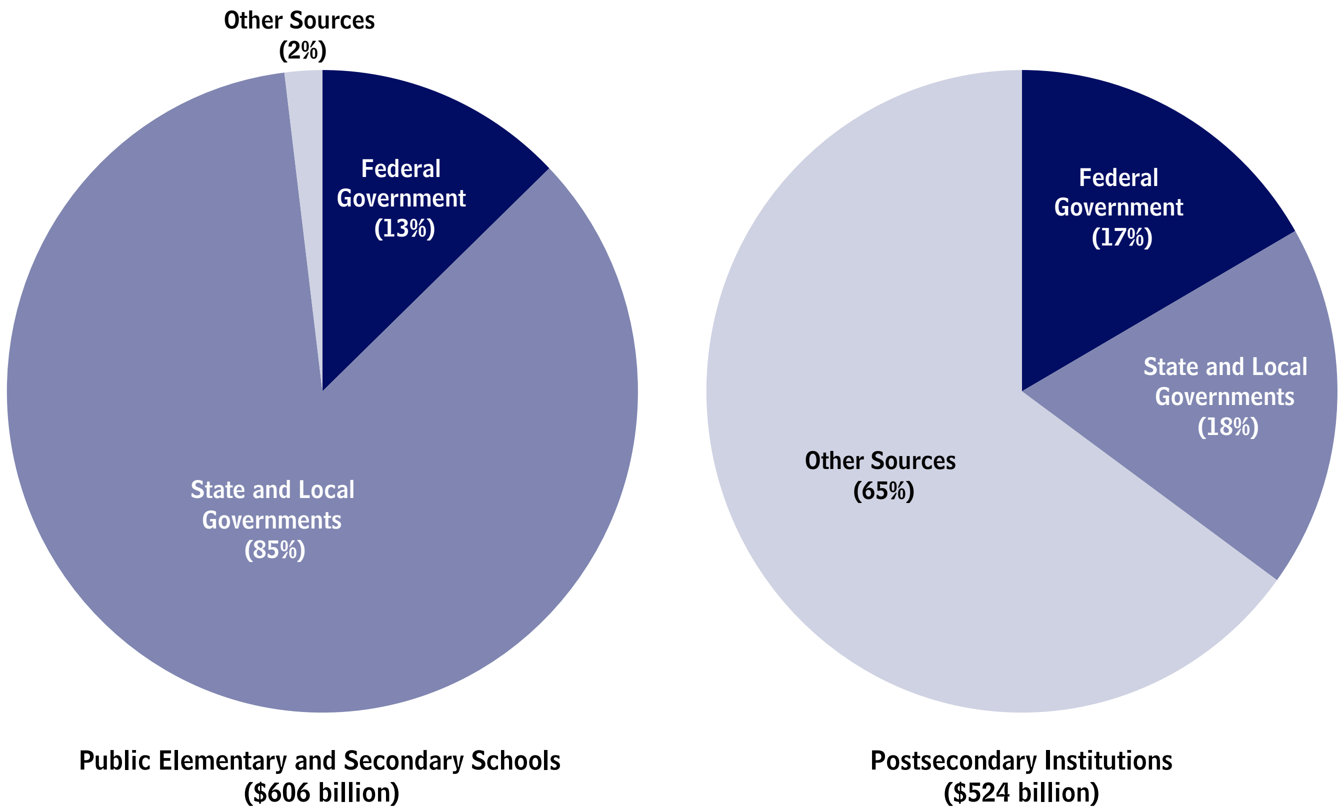
18. See Congressional Budget Office, *The Pell Grant Program: Recent Growth and Policy Options* (September 2013), www.cbo.gov/publication/44448.

19. National Center for Education Statistics, *Digest of Education Statistics 2012* (January 2013), Table 202, http://go.usa.gov/7DDA. The federal share might have been exceptionally high in the year displayed because of spending authorized by the American Recovery and Reinvestment Act of 2009.

Figure 2-6.

Revenues for Educational Institutions During the 2009–2010 Academic Year, by Source

2013 Dollars



Source: Congressional Budget Office based on data from the Department of Education, National Center for Education Statistics, *Digest of Education Statistics: 2012* (December 2013), http://go.usa.gov/WVkw; Office of Postsecondary Education, *2009–2010 Federal Pell Grant End-of-Year Report* (last modified August 11, 2011), http://go.usa.gov/ZaGY; and National Center for Education Statistics, *2007–08 National Postsecondary Student Aid Study* (April 2009), http://go.usa.gov/7rSe (PDF, 475 KB).

Notes: The 2009–2010 academic year covers the period from July 1, 2009, through June 30, 2010.

Data were not available for private elementary and secondary schools, which account for 10 percent of total enrollment in elementary and secondary schools. The numbers shown for postsecondary institutions, however, do include private schools (both nonprofit and for-profit) as well as public ones. The postsecondary institutions' revenues include support for research and development. The postsecondary institutions' "other sources" of revenues include tuition and fees (financed in part by student loans), income from assets, revenues of hospitals operated by the institutions (including amounts appropriated by governments for the hospitals), payments for services provided by the institutions (such as food services and intercollegiate athletics), and contributions from private donors.

for the 2009–2010 academic year. Those loans have to be repaid by students and their families. Borrowers generally receive more favorable terms on those loans than they would receive from a private lender and, in some cases, federal loans may be their only means of paying for their postsecondary education. Yet despite those benefits to borrowers, student loans are recorded as producing budgetary savings for the government: For example, the Department of Education attributed approximately $20 billion in budgetary savings to loans made in fiscal year 2010, the year that most closely corresponds to the 2009–2010 academic year.[20] Those budgetary savings are estimated using the procedures specified by the Federal Credit Reform Act of 1990 (FCRA). If the budgetary costs or savings associated with federal student loans were estimated on a fair-value basis—an accounting method

20. Department of Education, *FY 2014 Department of Education Justifications of Appropriation Estimates to the Congress*, vol. 1, "Student Loans Overview," p. S-12, http://go.usa.gov/7SZR.

that provides a more comprehensive estimate of the cost of those loans, in CBO's view—those loans would be reported as having either costs or considerably smaller savings.[21] Consequently, a complete accounting of the federal share of financing for postsecondary education is difficult.

Federal support for adult education, which is included in Figure 2-5 on page 17, consists primarily of funding for training and employment programs ($2 billion in 2013) and for veterans' education, training, and rehabilitation ($13 billion in 2013). Other spending for adult education, as when a worker takes courses at a community college to qualify for a better job, is already captured in the statistics of postsecondary education presented above.

Federal policy also supports educational investments through tax preferences. In 2014, such education-related preferences cost the Treasury $46 billion, most of which was associated with postsecondary education.[22] Tax credits for tuition for postsecondary education alone resulted in $23 billion in forgone revenue.

Federal Spending for Education in the Fields of Science, Technology, Engineering, and Mathematics (STEM)

The federal spending that is specifically identified as supporting STEM education accounts for only a small fraction of overall federal spending for education—about $3 billion—although additional amounts are scattered among federal programs not explicitly targeting STEM education.[23] About one-third of federal STEM spending is targeted at the elementary and secondary levels and two-thirds at the postsecondary level. Federal spending for STEM education currently is channeled through more than 200 small programs.[24]

The unique federal contribution to the training of the workforce in STEM fields mainly occurs through R&D grants to universities and other research institutions; that funding is not included in the $3 billion referenced above. Graduate and postgraduate training, especially at universities that grant doctorates, includes work on faculty research projects, which is funded more often than not by the National Science Foundation (NSF), NIH, or another federal agency.[25] That work is analogous to an apprenticeship, wherein the students learn the skills necessary to engage in scientific pursuits in their chosen field. In this way, the NSF, NIH, and other agencies funding academic science contribute significantly to STEM education. Since 2000, research grants from federal agencies have paid for 61 percent of all academic R&D; consequently, federal funding underlies many of the apprenticeships that train young scientists.[26]

Policies to Increase Federal Support for Education in STEM-Related Fields

Additional targeted support for education in fields especially relevant to innovation, such as STEM, might have a direct impact on innovation, and many advocates have proposed new initiatives in those areas. However, as with R&D, most federal spending for education is funded

21. Under procedures established by FCRA, the cost of a student loan is estimated in the federal budget by taking into account the amount of the loan, expected payments to the government over the life of the loan, and other cash flows—all discounted to a present value using interest rates on Treasury securities. See Congressional Budget Office, *Options to Change Interest Rates and Other Terms on Student Loans* (June 2013), www.cbo.gov/publication/44318. In contrast, the fair-value approach uses an estimate of the discount rates that private investors would use to discount the risky cash flows from student loans. The difference between the private discount rates and the rates paid on Treasury securities reflects the cost of market risk associated with those loans. (Market risk is the component of risk that remains even after a portfolio has been diversified as much as possible.) For additional discussion, see testimony of Douglas W. Elmendorf, Director, Congressional Budget Office, before the House Committee on Financial Services, *Estimates of the Cost of the Credit Programs of the Export-Import Bank* (June 2014), www.cbo.gov/publication/45468.

22. Joint Committee on Taxation, *Estimates of Federal Tax Expenditures for Fiscal Years 2014–2018*, JCX-97-14 (August 2014), pp. 29–30, www.jct.gov/publications.html?func=select&id=5.

23. Heather B. Gonzalez and Jeffrey J. Kuenzi, *Science, Technology, Engineering, and Mathematics (STEM) Education: A Primer*, Report for Congress R42642 (Congressional Research Service, January 2014).

24. See Government Accountability Office, *Strategic Planning Needed to Better Manage Overlapping Programs Across Multiple Agencies* (January 2012), www.gao.gov/products/GAO-12-108; and National Technology and Science Council, *The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio* (December 2011), p. xi, http://go.usa.gov/7v5H (PDF, 1.34 MB).

25. Some undergraduates also work on such grants, but it is not generally a central component of their education.

26. National Science Foundation, *Science and Engineering Indicators 2014* (February 2014), Appendix Table 5-2, www.nsf.gov/statistics/seind14/index.cfm/appendix.

through annual appropriation acts, so efforts to increase federal support for education in STEM-related fields would encounter the same budgetary pressures that apply to spending for R&D.

Among the specific approaches to increase federal support for STEM education are proposals to:

- Increase federal funding for academic R&D,
- Provide more scholarships and financial aid for STEM graduate students,
- Focus more STEM resources on community colleges and technical schools,
- Increase the number of mathematics and science teachers in elementary and secondary schools and improve their effectiveness through additional training, and
- Develop innovative approaches to teaching mathematics and science at elementary and secondary schools.

Additional federal funding for academic R&D may expand the size of the technically trained workforce. One recent study found that increased funding for R&D conducted by NIH led to a rise in the number of students who wanted to attend graduate school in biomedical fields. In addition, demand for such students as graduate assistants increased.[27]

An alternative to additional funding for academic R&D would be to increase funding for STEM graduate students in particular. A smaller share of people with baccalaureates in science currently receives direct federal support for graduate studies in scientific fields than was the case from the 1950s through the 1970s.[28] Furthermore, providing additional financial support for graduate students specializing in science—either by increasing the number of grants awarded or by increasing their value—has been shown to boost the number of U.S. citizens interested in entering those fields. At the same time, some analysts argue that the U.S. educational system produces more STEM-educated workers than can find employment in those fields.[29] Roughly half of STEM degree holders at all levels and a third of people with STEM graduate degrees do not work in a STEM-related occupation.[30] Other analysts identify a wage premium paid to workers with STEM credentials, relative to wages paid for jobs with similar educational requirements, and cite it as evidence of a need for a larger STEM workforce.[31] Those wage premiums (for similar levels of educational attainment) vary substantially within STEM fields—for instance, jobs in life sciences command less of a wage premium, whereas jobs in engineering and computer fields get more.

Another alternative would be to reallocate resources within current STEM programs. At present, only 7 percent of NSF spending on STEM education focuses on community colleges and technical schools.[32] Such workers have the potential to account for half of the STEM workforce in the United States. Increasing the quality of their STEM education may increase their ability to implement innovations in the workplace. Furthermore, many community college students transfer to four-year institutions, and increasing the quality of their STEM education during the community college period is likely to result in greater academic success after the transfer.

Although some advocates of increased spending for K–12 STEM education maintain that the nation needs more

27. Margaret E. Blume-Kohout and John W. Clack, "Are Graduate Students Rational? Evidence From the Market for Biomedical Scientists," *PLOS ONE,* vol. 8, no. 12 (December 2013), http://dx.doi.org/10.1371/journal.pone.0082759.

28. Richard B. Freeman, Tanwin Chang, and Hanley Chiang, "Supporting 'The Best and Brightest' in Science and Engineering: NSF Graduate Research Fellowships," in Richard B. Freeman and Daniel Goroff, eds., *Science and Engineering Careers in the United States: An Analysis of Markets and Employment* (University of Chicago Press, 2009), pp. 19–57, http://papers.nber.org/books/free09-1.

29. B. Lindsay Lowell and Harold Salzman, *Into the Eye of the Storm: Assessing the Evidence on Science and Engineering Education, Quality, and Workforce Demand* (Urban Institute, October 2007), p. 30, www.urban.org/publications/411562.html. Other analysts dispute those assertions. See Robert D. Atkinson and Luke A. Stewart, *The Real Story on Guestworkers in the High-Skill U.S. Labor Market* (Information Technology and Innovation Foundation, May 2013), http://tinyurl.com/q7db28p.

30. National Science Foundation, *Science and Engineering Indicators 2014* (February 2014), Appendix Table 3-3, www.nsf.gov/statistics/seind14/index.cfm/appendix.

31. Jonathan Rothwell, *The Hidden STEM Economy* (Brookings Institution, June 2013), p. 7, http://tinyurl.com/nvvhrq5.

32. Ibid., p. 19.

teachers specializing in STEM fields, surveys of the market find that the shortages are limited to schools with high levels of student discipline problems and low levels of teacher autonomy.[33] Teachers at those schools leave more frequently than teachers at other schools. A more direct solution might be to decrease the turnover of teachers in the problem schools, for instance, by changing the financial rewards of teaching science, technology, engineering, and mathematics in those schools; however, pay and tenure policies are mainly local decisions.

Some policymakers advocate increasing the quality of the corps of STEM teachers as a way of improving the quality of STEM education. Performance by U.S. students on international tests has lagged behind the performance of students in other countries—as shown most recently by the results of the 2012 Programme for International Student Assessment.[34] Many analysts feel that the weak performance is further evidence of the need for better teachers. However, increasing the quality of the U.S. teacher corps is not straightforward: The majority of public school science teachers are already credentialed in the field, either because they majored in the field in college or received postgraduate certification.[35] Furthermore, researchers have not found evidence that the level of teachers' educational credentials is associated with gains in the educational achievement of their students. Some policymakers advocate increasing the amount of clinical experience that prospective teachers get while obtaining their education because research shows that beginning teachers are less effective than those with just a few years of experience. That evidence notwithstanding, the nation already spends much more money on education per student than other countries with higher student assessment scores.

Reform of U.S. science curricula is currently under way as part of the Administration's Race to the Top initiative, a $4 billion effort to spur innovation and improvements in K–12 education at the state and local levels. Independently, many states are already acting to improve their STEM curricula, although implementation of new educational standards may require additional time and resources.

Policies to Increase Federal Support for Education

Additional support for education could foster innovation by enhancing individuals' ability to learn and apply knowledge generally. However, it is not clear what the best approach is for adding such support. Among the potential approaches to increasing federal support for education overall are proposals to lower interest rates on student loans and to provide more generous Pell grants for lower-income students. However, federal funding for education represented 15 percent of spending for education nationwide in the 2009–2010 academic year. Consequently, even large percentage increases in federal support for education would not represent a large boost in total educational resources. In addition, over the past 40 years, spending per student at the elementary and secondary levels has more than doubled in real terms, whereas achievement among elementary and secondary students has remained flat—a result that raises questions about how effective additional spending would be in boosting achievement.

Changing the financial incentives that federal programs offer state and local educational authorities in an attempt to increase the effectiveness of federal support would be an alternative to providing more federal resources. The No Child Left Behind Act of 2001 gave states more flexibility in how they used federal funds in return for being accountable for showing progress in students' educational achievement. However, the standards used to measure that progress may have been too high, and 42 states and the District of Columbia have asked the Department of Education for waivers from the consequences of not meeting those progress standards. The Department of Education's Race to the Top program provides additional funds to states through a competitive process that also encourages states to make such reforms. To date, the evidence regarding the effectiveness of such incentives in raising students' achievement is inconclusive.

33. Richard M. Ingersoll and David Perda, "Is the Supply of Mathematics and Science Teachers Sufficient?" *American Educational Research Journal,* vol. 43, no. 3 (September 2010), pp. 563–594, http://dx.doi.org/10.3102/0002831210370711.

34. Organisation for Economic Co-operation and Development, Programme for International Student Assessment, "Country Note: United States" (2012), www.oecd.org/pisa/keyfindings/pisa-2012-results.htm.

35. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), Public School Teacher Data File, 2007–2008, http://go.usa.gov/7SnC.

Tax Treatment of Private Investment Related to Innovation

Discussions of federal tax policy related to innovation generally focus on two major areas: using tax credits to encourage increased R&D expenditures by the private sector and using tax preferences to foster more manufacturing in the United States. Although providing a tax credit for increasing R&D expenditures has been generally correlated with increases in private R&D, many analyses find that the forgone revenues often rewarded firms for undertaking R&D that they would have performed anyway. Manufacturing accounts for a disproportionate share of private R&D, but only a small share of manufacturing is R&D-intensive, and some service-sector activity is as well, so increasing support for manufacturing generally would be less effective than increasing support for innovation directly. The sections that follow first discuss current policy in those two areas and then present options for changing those policies. (The focus on R&D and closely related investments in this section does not mean that such investments are the only private activities promoting innovation. As noted above, firms also innovate in many ways other than through R&D and closely related investments.)

Tax Credits for Increasing R&D Expenditures

Since 1981, the tax code has usually included tax credits for firms and individuals for increasing their investment in R&D.[36] However, the R&D credit has not been a permanent part of the tax code. Since it was first temporarily enacted in 1981, the credit has expired and been temporarily reauthorized multiple times (sometimes retroactively after expiring).[37] Most recently, the tax credit expired in December 2013. While in effect, the credit could be claimed for increases in spending for salaries of research personnel and supplies; it excluded expenditures for equipment and structures used for R&D as well as for fringe benefits and overhead.

In 2012, the forgone tax revenues related to the R&D tax credit were estimated to be $6 billion (in 2013 dollars).[38] Historically, the value of the R&D credit has equaled between 3 percent and 4 percent of overall spending by business for R&D.[39]

For 2013, taxpayers could calculate their credit in either of two ways:

- Using the regular credit, which was equal to 20 percent of qualified spending that exceeded a 1984–1988 base, or
- Using an alternative, simplified credit, which was equal to 14 percent of qualified spending above 50 percent of the average of three previous years, and which was most useful for younger or merged firms or for firms for which the 1984–1988 base was otherwise irrelevant.[40]

Research-intensive industries, such as electronics and pharmaceuticals, have seen a plethora of mergers, spinoffs, and new firms such that, for the purposes of calculating the credit, the 1984–1988 base years lost relevance for many firms. Consequently, almost 60 percent of the credits for 2011, the most recent year for which data are available, were claimed for the alternative credit. Because of the incremental nature of the credit—it applied to *increases* in qualified R&D spending above a specific base amount—calculating the credit was complicated.

Despite the credit's temporary nature, restrictions, and complexity, its use expanded over the past decade. Generally, credit claims tracked the rise, decline, and subsequent resurgence of private-sector R&D during

36. The tax code also favors R&D by allowing firms to deduct the cost of R&D in the year those expenses are incurred as opposed to depreciating them over time. Changing that permanent feature of the tax code is rarely proposed. For 2014, the Joint Committee on Taxation estimates that the expensing of private R&D cost the Treasury $4.7 billion. See Joint Committee on Taxation, *Estimates of Federal Tax Expenditures for Fiscal Years 2014–2018*, JCX-97-14 (August 2014), www.jct.gov/publications.html?func=select&id=5.

37. Senate Committee on the Budget, *Tax Expenditures: Compendium of Background Material on Individual Provisions,* S. Prt. 112-45 (December 2012), pp. 95–111, http://go.usa.gov/A4dj (PDF, 53 MB).

38. Joint Committee on Taxation, *Estimates of Federal Tax Expenditures for Fiscal Years 2012–2017*, JCS-1-13 (February 2013), http://go.usa.gov/KDKV.

39. Laura Tyson and Greg Linden, *The Corporate R&D Tax Credit and U.S. Innovation and Competitiveness: Gauging the Economic and Fiscal Effectiveness of the Credit* (Center for American Progress, January 2012), Table 7, http://tinyurl.com/pvmd3r3.

40. The credit also had two additional components: a basic research credit of 20 percent for the funding of university or other non-profit research and an energy research credit of 20 percent for research at qualified consortiums. A permanent tax credit also exists for research related to orphan drug development.

that period. Soon after its passage in 1981, economic analyses suggested that private-sector R&D was not very responsive to the credit. More recent analyses have suggested a higher level of responsiveness to the credit by firms conducting R&D.[41] One interpretation of that change is that firms had to learn how to best use the credit. However, it may be difficult to determine whether firms truly increased their R&D efforts or whether firms reclassified existing expenses as related to R&D to improve the tax treatment of such activities.[42] Other research suggests that, even if firms responded to the credit, much—or even most—of the forgone federal revenues resulted from firms' claiming credits for performing R&D that they intended to conduct anyway, regardless of the credit.[43]

Tax Preferences for Domestic Manufacturing

Manufacturing firms account for an outsized share of the nation's private-sector R&D—two-thirds of R&D compared to little more than one-fifth of gross output in 2011. Some analysts associate innovation with a robust manufacturing sector for reasons unassociated with that sector's R&D spending; for example, knowing how to build a product, or having ready access to people who do, can make it easier to improve upon the product.[44] From that perspective, encouraging domestic manufacturing would also foster innovation.

One way that federal policy encourages manufacturing is by lowering the after-tax cost of investment. Manufacturers and other firms are generally allowed to claim accelerated deductions from their taxable income each year for costs associated with the depreciation of plants and equipment located in the United States; that depreciation is defined as resulting from wear and tear, deterioration, and obsolescence. Those accelerated deductions encourage investment by enabling firms to more quickly recover the cost of their spending on physical capital. An additional first-year depreciation (known as bonus depreciation) was allowed in recent years for equipment spending in order to provide an extra incentive for investment. (The most recent provision was in effect from January 1, 2012, to December 31, 2013.) Finally, firms with a sufficiently small amount of investment are allowed to claim that cost as an expense for the year in which the investment took place, rather than over time. Over the past decade, the maximum amount of investment that a firm could claim as a tax-deductible expense in the year the investment occurred has varied from a low of $25,000 (the level in 2003 and also the current level) to as much as $500,000 from 2010 through 2013.

According to the latest available data on how depreciation deductions are distributed across industries, the manufacturing sector accounted for 28 percent of total depreciation and expensing deductions—slightly higher than its share of gross output in the economy, as manufacturing on average uses more physical capital than other industries.[45] Using those data on depreciation and expensing deductions, together with estimates of federal tax expenditures made by the staff of the Joint Committee on Taxation, CBO estimates that the federal revenue loss from offering those accelerated deductions to manufacturing firms in 2012 amounted to about $10 billion.[46]

Policies for Changing the Tax Treatment of Private Investment

Both of the tax policies discussed above have attracted their share of proposals for changes that might promote more innovation. However, the effects of tax preferences on businesses' behavior are difficult to predict. In particular, the interaction of many provisions of the tax code

41. For a recent review of this literature, see Joint Committee on Taxation, *Background and Present Law Relating to Manufacturing Activities Within the United States*, JCX-61-12 (July 2012), pp. 119–121, http://go.usa.gov/KDQQ.

42. For example, before the credit became available, it did not matter whether an employee's salary was for conducting R&D or not. Either way, it was deducted as an ordinary business expense. With the credit, classifying salaries as related to R&D could be of additional value to the firm.

43. Government Accountability Office, *Tax Policy: The Research Tax Credit's Design and Administration Can Be Improved*, GAO-10-136 (November 2009), pp. 16–18, www.gao.gov/products/GAO-10-136.

44. See, for example, Gary P. Pisano and Willy C. Shih, "Restoring American Competitiveness," *Harvard Business Review* (July–August 2009), http://hbr.org/archive-toc/BR0907.

45. Joint Committee on Taxation, *Background and Present Law Relating to Manufacturing Activities Within the United States*, JCX-61-12 (July 2012), pp. 28–43 and 96–98, http://go.usa.gov/KDQQ.

46. Joint Committee on Taxation, *Estimates of Federal Tax Expenditures for Fiscal Years 2012–2017*, JCS-1-13 (February 1, 2013), p. 34, http://go.usa.gov/KDKV. Tax expenditure estimates of accelerated depreciation for equipment investment (which include the effects of bonus depreciation) must be interpreted carefully. For example, because the provisions regarding bonus depreciation were not extended after 2013, the staff of the Joint Committee on Taxation estimates that negative tax expenditures will occur between 2014 and 2016.

makes the effect of a single provision of the tax code on a firm's behavior difficult to discern.

Tax Credit for Increasing R&D Expenditures. Advocates of changing the incremental R&D tax credit to increase innovation have suggested three main types of modifications:

- Renew the credit and make it permanent,
- Make the credit simpler and reduce the potential for so-called windfalls, and
- Make the credit more supportive of new technology.[47]

Renew the Credit and Make It Permanent. The Congress is currently considering several measures to renew the R&D credit, which expired in December 2013, including permanently extending it (unlike previous extensions that were temporary). A permanent renewal would avoid the perennial negotiations over its expiration. However, since it has always been renewed, industry has probably come to treat the credit as effectively permanent anyway and to incorporate it into financial planning.

Simplify and Modify the Credit. One approach would retain the alternative simplified credit and eliminate the regular credit. The Government Accountability Office (GAO) has suggested that, to reduce the potential for firms to receive subsidies for R&D they would have undertaken anyway (so-called windfalls), lawmakers should also consider increasing the base for the alternative simplified credit from the current 50 percent of the average for the three prior years to a minimum of 50 percent of the current year's expenses.[48] Alternatively, some advocates argue that the credit rate should be increased because some other nations offer more generous research tax credits and, in general, provide more generous tax treatment of private-sector R&D overall.[49]

Make the Credit More Relevant to the Current Role of Technology. Many of the rules governing the credit were written decades ago when technology and high-tech firms played a very different role in the economy. For example, the credit is nonrefundable, meaning that only firms with tax liabilities can benefit from it in a given year, although firms can carry it forward in hopes of offsetting tax liabilities in the future. The lack of refundability means that the credit is often unavailable to firms during their start-up period, when they need assistance the most—a situation that is especially common in high-tech industries, given the relatively large number of start-ups in that sector.[50] Some analysts have suggested making the credit refundable by size or allowing start-up firms to sell unused credits. Making the credit refundable, however, would increase the likelihood that revenue losses are attributed to R&D activities that would have occurred without the credit or to activities that do not truly reflect innovative pursuits.

Similarly, R&D for software development for firms' internal use is explicitly *not* covered by the R&D credit.[51] When the law was written, most such software was used for purposes such as internal accounting processes. However, now that companies often provide Internet services using internally developed software, such an exemption may be outmoded.

Encouraging Domestic Manufacturing Through the Tax Code. It is difficult to determine whether providing more federal support for manufacturing would increase innovation. Offering investment incentives for manufacturing overall might have only a modest effect on R&D and innovation if less R&D–intensive manufacturing firms frequently took advantage of them. Although the manufacturing sector spends disproportionately on R&D, almost two-thirds (63 percent) of that R&D is conducted by firms in two manufacturing industries—computers and electronics; and chemicals, including pharmaceuticals—that have much larger ratios of R&D

47. For a more extensive list of possible modifications, see Robert D. Atkinson, "Expanding the R&E Tax Credit to Drive Innovation, Competitiveness and Prosperity," *Journal of Technology Transfer,* vol. 32, no. 6 (December 2007), pp. 617–628, http://dx.doi.org/10.1007/s10961-007-9046-y.

48. Government Accountability Office, *Tax Policy: The Research Tax Credit's Design and Administration Can Be Improved*, GAO-10-136 (November 2009), p. 39, www.gao.gov/products/GAO-10-136.

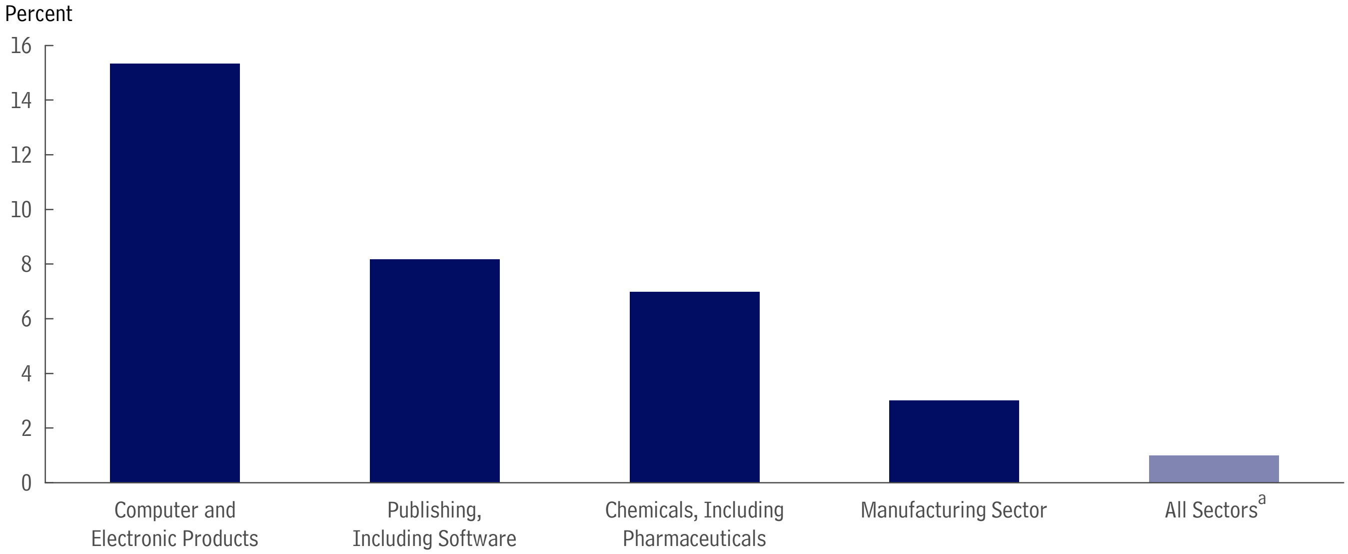
49. Luke A. Stewart, Jacek Warda, and Robert D. Atkinson, *We're #27: The United States Lags Far Behind in R&D Tax Incentive Generosity* (Information Technology and Innovation Foundation, July 2012), http://tinyurl.com/opd5qdz.

50. Gary Guenther, *Research Tax Credit: Current Law and Policy Issues for the 113th Congress*, Report for Congress RL31181 (Congressional Research Service, February 2014), pp. 24–29.

51. Testimony of Annette Nellen, Professor, College of Business, San Jose State University, before the Senate Finance Committee, *Tax Reform Options: Incentives for Innovation* (September 20, 2011), http://go.usa.gov/KDhh (PDF, 365 KB).

Figure 2-7.

Ratio of R&D Expenditures to Output, by Selected Industries and Sectors of the Economy, 2011



Source: Congressional Budget Office based on data from Raymond M. Wolfe, *Business R&D Performance in the United States Increased in 2011*, NSF Info Brief 13-335 (National Science Foundation, September 2013), Table 2, http://go.usa.gov/Be7J (PDF, 148 KB) and from the Bureau of Economic Analysis, *Interactive Access to Industry Economic Accounts Data—GDP by Industry*, "Gross Output by Industry" (January 23, 2014), www.bea.gov/iTable/index_industry_gdpIndy.cfm.

Note: R&D = research and development.

a. The category "All Sectors" does not include the agriculture, forestry, and fishing and hunting sector or the public administration sector.

to output than the sector average (see Figure 2-7). Some service industries, most notably the computer software industry, have also become significant sources of R&D spending.[52]

Similarly, the argument that domestic firms—regardless of the industry they operate within—must have ready access to manufacturing capacity in order to innovate lacks broad evidence. For example, research on firms whose products are manufactured in one location—often a different country—while other parts of the business operate elsewhere, suggests that it may not be necessary to collocate manufacturing with product design and engineering.[53]

Proposals to increase support for manufacturing and innovation through the tax system include offering additional investment subsidies and increasing the value of other tax preferences for innovative activity. Such proposals include the following:

- Encouraging investment in R&D-related assets by expanding accelerated depreciation deductions, or extending bonus depreciation, for investments by firms in research-intensive industries, such as electronics and pharmaceuticals, and

52. A similar pattern of R&D intensity across those industries emerges when comparing R&D spending and the number of workers conducting R&D to industry net sales and employment, respectively; see Raymond M. Wolfe, *Business R&D Performance in the United States Increased in 2011*, NSF Info Brief 13-335 (National Science Foundation, September 2013), http://go.usa.gov/Be7J (PDF, 148 KB). The concentration of R&D spending in certain industries may arise because firms in those industries may be inherently more likely than others to be innovative, given both current technologies and demand for the goods and services they produce. That could explain why firms specializing in computers, electronics, and software are the most R&D–intensive and why the software industry emphasizes R&D whereas other service-sector firms spend comparatively little relative to their gross output.

53. See Andrew B. Bernard and Teresa C. Fort, *Factoryless Goods Producers in the U.S.*, Working Paper 19396 (National Bureau of Economic Research, August 2013), www.nber.org/papers/w19396; and Kimberly Bayard, David Byrne, and Dominic Smith, *The Scope of U.S. Factoryless Manufacturing* (Upjohn Institute, February 2013), www.upjohn.org/MEG/papers/baybyrsmi.pdf (674 KB).

- Offering preferential tax treatment for the sale or licensing of patented products (for example, allowing manufacturing firms to establish "patent boxes" that shelter a firm's patent-related profits).

The first proposal could be easier to implement than the second. Accurately determining the amount of a firm's profits that would be eligible to be sheltered in a patent box could be a problematic accounting exercise susceptible to misreporting. In addition, the prospect of offering preferential tax treatment for patented products could encourage firms to apply for a patent when they otherwise would not—for example, when the invention does not clearly meet the requirements for patentability—and thereby increase the number of low-quality patents and the costs to the economy associated with them (an issue that is discussed later in this report).

Federal Loan and Loan Guarantee Programs That Support Innovation

The federal government also supports innovation through credit programs that provide loans and loan guarantees to finance investments in innovative products or services. A limited number of federal credit programs provide loans or loan guarantees to private firms that bring new technologies to the market. However, those federal credit programs typically promote new technologies in the context of pursuing other policy goals, such as fostering renewable-energy technology to reduce carbon emissions. Increasing financial support for such federal credit programs may be difficult without funding projects that could obtain private funding anyway or whose social costs outweigh their benefits.

Current Federal Loan and Loan Guarantee Programs That Support Innovation

Federal credit programs that attempt to promote innovation rarely target innovation for its own sake; they typically promote new technologies in the context of pursuing other goals. Some programs increase the demand for existing high-tech products, such as airplanes or broadband equipment, by promoting exports or subsidizing their use in rural areas. The Small Business Administration provides loan guarantees ($2 billion in 2012) to Small Business Investment Companies, which in turn invest in small businesses, including some high-tech companies. The loans and loan guarantees that DOE has provided to businesses are perhaps the most prominent examples of the federal government's efforts to promote the deployment of new energy technologies through credit. The Administration has recently revived, after a hiatus of several years, three major credit programs administered by DOE that had issued more than $18 billion in loans and loan guarantees as of the end of fiscal year 2013:

- The Advanced Technology Vehicle Manufacturing (ATVM) program—a permanent loan program established in 2007 that aims to improve the energy efficiency of automobiles;
- The Section 1705 program—a temporary loan guarantee program authorized in 2009 that supported loans for some renewable-energy systems, electric power transmission, and innovative biofuel projects; and
- The Section 1703 program—a permanent loan guarantee program created in 2005 that aims to increase investment in nuclear facilities or other innovative energy facilities.

Roughly $4 billion remains available from prior appropriations to cover the subsidy cost of new loans under the ATVM program. Although the Section 1705 program expired on September 30, 2011, DOE has $170 million available for the subsidy costs of loan guarantees for certain projects under Section 1703. The Section 1703 program also is authorized to guarantee another $27.8 billion in debt, provided that recipients pay a fee covering the projected subsidy cost of those loans.[54]

To reduce their impact on the federal budget, the federal credit programs that support innovation often require the recipients of loans and guarantees to pay for the expected costs of that credit, which include losses from defaults net of any recoveries on the loans and guarantees.[55] Federal

54. For a discussion of factors that influence the credit risk of some of the projects eligible for assistance under the Section 1703 program, see Congressional Budget Office, *Federal Loan Guarantees for the Construction of Nuclear Power Plants* (August 2011), www.cbo.gov/publication/41510.

55. Estimates of the risks of default, and the consequent budgetary costs, change over time as economic conditions evolve and government agencies gain more experience with their loans and loan guarantees. As a result, the estimated subsidy cost of federal loans and loan guarantees is frequently revised. Under the Federal Credit Reform Act, such revisions are recorded in the budget as "credit re-estimates" on an annual basis.

credit programs operate under the rules established by the Federal Credit Reform Act of 1990 for calculating the budgetary cost of direct loans and loan guarantees issued by the federal government. In general, before an agency can make loans or loan guarantees, lawmakers must provide funding sufficient to cover the government's cost, referred to as the subsidy cost, less fees paid by borrowers. Lawmakers control the amount of federal credit assistance either by appropriating the amount needed for the subsidies or, in cases in which net subsidy costs are negative, by setting limits on the volume of loans or loan guarantees. (As noted above in connection with student loans, the budgetary cost calculations established by the Federal Credit Reform Act do not provide the most comprehensive estimate of the costs of the loans or loan guarantees.)

Policies to Expand Federal Loan and Loan Guarantee Programs That Support Innovation

The rationale for increasing federal credit assistance to promote innovation is that young, innovative firms may lack adequate access to capital markets and face difficulties in getting private financing during the start-up phase. When a firm decides to transform its research and development efforts into a commercial product, little funding—federal or otherwise—may be available for the process of bringing a product to market.

However, investors and institutions already devote substantial resources to bring innovative new products and services to market throughout the U.S. economy—in 2012, an amount equivalent to between $30 billion and $45 billion (in 2013 dollars)—undercutting arguments about a lack of capital.[56] Federal efforts (largely in R&D, not in credit activities) account for one-fifth to one-quarter of those figures.

Providing federal credit to promote innovation, such as new energy technology, without funding projects that could obtain private funding anyway or whose social costs outweigh their benefits, has proved challenging. For example, projects funded by DOE now account for a small fraction of U.S. solar capacity, with the great majority of capacity funded by sources other than DOE. The projects backed by DOE typically had secure streams of income in the form of power purchase agreements, usually from utilities promising to buy the energy that the projects produced.[57] Those factors suggest that much of the credit activity undertaken by DOE was replacing credit that could have been provided by the private sector. (However, the general tightening of credit after the fiscal year spanning 2008 through 2009—attributable both to market forces and to increased credit regulation—reduced the availability of credit for solar projects, so DOE may have supported some projects that could not have been undertaken otherwise.) Furthermore, much of the credit offered by DOE went to large companies, which are typically capable of accessing sufficient credit, rather than to start-ups, which are more likely to have had problems obtaining credit.[58]

56. A survey of corporate R&D activity estimated that the outer bounds of the amount of resources used for commercializing new products and services was between 2 percent and 14 percent of aggregate R&D spending in the economy. CBO estimates a likely range for those amounts in 2012 to be between $30 billion and $45 billion. See also Lewis M. Branscomb and Philip E. Auerswald, *Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development* , NIST GCR 02-841 (National Institute of Standards and Technology, November 2002), p. 62, http://go.usa.gov/76Qk (PDF, 631 KB).

57. Jeff St. John, "After a Hiatus, DOE's Clean Energy Loan Program Will Soon Be Back in Action," *GreenTechMedia* (February 27, 2014), http://tinyurl.com/qef4tqo. Unlike the utility purchase guarantees associated with producing solar electricity, DOE's loan guarantees for manufacturing solar equipment were not backed by such agreements.

58. Testimony of Veronique de Rugy, Senior Research Fellow, George Mason University, before the House Committee on Oversight and Government Reform, *Assessing the Department of Energy Loan Guarantee Program* (June 19, 2012), http://tinyurl.com/qfneumu.

CHAPTER

3

Altering the Legal and Regulatory Framework to Spur Innovation

To further encourage innovative activity in the United States, lawmakers could modify the legal and regulatory framework in which such activity takes place. For instance, foreign-born workers have long made the U.S. economy more innovative; therefore, easing the process by which highly skilled noncitizens are allowed to legally enter the country and secure employment could be expected to help boost innovation. Patent laws are meant to encourage innovation by allowing firms to capture more of the benefits of their investment in research and development; however, in spite of recent patent reform legislation passed by the Congress, persistent strains on the patent system suggest that additional measures may be needed to strengthen the link between patenting and innovation. And federal regulations governing the ways in which industries' products and services are introduced into the economy can affect their cost and the pace of their development.

Immigration of Highly Skilled Workers

Economic studies have generally found that increased immigration of foreign-born workers—and in particular those who are highly skilled—fosters innovation and productivity growth in the United States. However, U.S. immigration policy is more oriented toward family reunification than admitting workers who would be likely to contribute to innovation. Skilled workers represent only a modest share of the flow of the foreign born into the United States, receiving fewer temporary ("nonimmigrant") visas and permanent resident cards ("immigrant visas") than other groups of the foreign born receive. Recently, some policymakers have proposed changing immigration policy to increase the number of highly skilled noncitizens that are allowed to work in this country.

The Contribution of Skilled Immigrants to Innovation

Evidence suggests that foreign-born workers contribute disproportionately to innovation. In 2010, the foreign-born population accounted for 13 percent of the population of the United States.[1] Yet, in that same year, they accounted for 27 percent of all full-time workers specializing in the fields of science and engineering in the United States and 43 percent of all workers in this country with doctorates in science and engineering.[2] (At the same time, the foreign born are also disproportionately represented at the low-skill end of the workforce.)

Some of the contributions that certain immigrants make to innovation are related to their high level of educational attainment. High-tech firms, research hospitals, and universities, which account for much of the innovation in the economy, hire a disproportionate number of skilled foreign-born workers, and skilled workers in those institutions tend to invent and patent more than most other types of workers.[3]

But the presence of highly skilled foreign-born workers in high-tech industries does not tell the complete story: Foreign-born scientists also account for a disproportionate number of the star researchers in science. That is

1. Congressional Budget Office, *A Description of the Immigrant Population—2013 Update* (May 2013), Exhibit 1, www.cbo.gov/publication/44134.

2. National Science Foundation, *Science and Engineering Indicators 2014* (February 2014), Table 3-27, www.nsf.gov/statistics/seind14/.

3. Jennifer Hunt and Marjolaine Gauthier-Loiselle, "How Much Does Immigration Boost Innovation?" *American Economic Journal: Macroeconomics,* vol. 2, no. 2 (April 2010), p. 52, http://dx.doi.org/10.1257/mac.2.2.31.

important because those exceptional individuals account for many of the big discoveries and conceptual breakthroughs that drive science. One team of science policy analysts, using a variety of measures—most highly cited 250 authors by field, highly cited papers and patents, and membership in the National Academies of Science and Engineering—concluded: "Although there is some variation by discipline, individuals making exceptional contributions to S&E [Science and Engineering] in the U.S. are disproportionately drawn from the foreign born."[4]

In an analysis of the effects of enacting S. 744, the Border Security, Economic Opportunity, and Immigration Modernization Act, the Congressional Budget Office concluded that its enactment would lead to higher productivity of both labor and capital because the increase in immigration—particularly of highly skilled immigrants—would tend to generate additional technological advancements, such as new inventions and improvements in production processes. CBO estimated that total factor productivity would be higher under that act by roughly 0.7 percent in 2023 and by roughly 1.0 percent in 2033, compared with what is projected to occur under current law.[5]

Policies Regarding the Immigration of Highly Skilled Workers

Highly skilled noncitizens in the workforce fall into one of three categories: lawful permanent residents on the path to U.S. citizenship ("immigrants"); legal temporary residents here for a limited time using one of several types of visa ("nonimmigrants"); and people working here without authorization. (Authorized *visitors*, such as tourists, are not counted in the foreign-born working population.) In addition to workforce members, there are also noncitizens studying in U.S. schools under student visas.

In 2013, U.S. authorities issued almost a million immigrant visas (commonly referred to as green cards). Almost two-thirds of those visas were issued under family-sponsored preference policies. Current policy limits the number of new employment-based immigrant visas to 140,000 plus the difference between the number of family-sponsored immigrant visas issued in the previous fiscal year and the cap on such visas. As a result, only 160,000 immigrant visas issued in 2013 were related to employment; most of those were issued to people with advanced degrees or special skills.[6] About half of the recipients already lived in the United States when their visa was issued.

The most prominent employment-based visas that admit highly skilled workers on a temporary basis are the H-1B and L-1 visas, which are work permits issued to specific employers.[7] Whereas H-1B visas are issued to permit the hiring of new employees, L-1 visas authorize intracompany transfers. In 2013, the Department of State issued 153,000 H-1B and 67,000 L-1 visas.[8] (The statutory cap on H-1B visas is 65,000, but a substantial number of exclusions apply.) Visas are valid for several years but can be extended. Sometimes they are not used immediately, but rather banked by the companies. Consequently, there is no official count of the actual number of workers holding such temporary work permits. One recent estimate suggested that there are roughly 1 million holders of H-1B or L-1 visas in the United States.[9]

Three types of institutions use those employment-based visas extensively: nonprofit research organizations, such as universities and research hospitals; U.S.-based multinational corporations; and offshore firms with a U.S. presence. H-1B visas issued to nonprofit research

4. Paula E. Stephan and Sharon G. Levin, "Exceptional Contributions to U.S. Science by the Foreign-Born and Foreign-Educated," *Population Research and Policy Review,* vol. 20, no. 1–2 (April 2001), pp. 59–79, http://dx.doi.org/10.1023/A:1010682017950.

5. Congressional Budget Office, *The Economic Impact of S. 744, the Border Security, Economic Opportunity, and Immigration Modernization Act* (June 2013), pp. 12–13, www.cbo.gov/publication/44346.

6. Randall Monger and James Yankay, *U.S. Lawful Permanent Residents: 2013 Annual Flow Report* (Department of Homeland Security, May 2014), Table 2, http://go.usa.gov/76fd.

7. Other, smaller visa programs cover people with certain extraordinary abilities and their assistants.

8. Department of State, *Report of the Visa Office 2013*, "Nonimmigrant Visas Issued by Classification (Including Crewlist Visas and Border Crossing Cards): Fiscal Years 2009–2013," Table XVI (B), http://go.usa.gov/76GT.

9. Ron Hira, *Bridge to Immigration or Cheap Temporary Labor? The H-1B & L-1 Visa Programs Are a Source of Both*, EPI Briefing Paper 257 (Economic Policy Institute, February 2010), p. 3, www.epi.org/publication/bp257/.

institutions are not subject to the same numerical quotas as those issued to private firms and are typically used to employ postdoctoral graduates and other skilled personnel to do research. Given the substantial role played by postdoctoral graduates in conducting and publishing scientific research, the importance of such visas to innovation is clear. Offshore firms often use temporary employment-based visas to educate their workforce and to transfer U.S. expertise to their home country.[10] Congruent with that strategy, the largest such users of H-1B and L-1 visas rarely sponsor their temporary workers for U.S. immigration visas. After those workers return to other countries, the productivity of the workforce abroad might be enhanced by their preceding time in this country but U.S. productivity might not be affected very much. However, while working in the United States for such offshore firms, workers holding H-1B visas are presumably productive members of the U.S. labor force, making contributions as other employees do. The U.S.-based multinational firms are more varied in their use of H-1B and L-1 visas.

Roughly one million foreign-born students were enrolled in certified academic or vocational programs in July 2014.[11] Arriving in the United States under a student visa and eventually becoming a permanent resident is a major path to immigration for highly skilled workers.

Effects of the Immigration of Highly Skilled Workers on Domestic Wages and Employment

Analysts disagree as to the effects of the immigration of highly skilled workers on the employment and wages of similarly skilled native-born workers, but generally the effects are believed to be small.[12] Some studies find that highly skilled native-born workers suffer job losses or reduced wages when faced with competition from highly skilled immigrants, whereas other studies—addressing different circumstances and using different data sets—find that an increase in the immigration of highly skilled workers increases the demand for skilled native-born employees.[13] In the face of an increase in the supply of highly skilled, foreign-born workers, native-born scientists and other workers in the fields of science, technology, engineering, and mathematics may shift to jobs and occupations (such as management and the sale of services and goods produced in STEM industries) in which their better command of the language and customs provides them with a comparative advantage, leaving the more technical aspects to skilled immigrants.[14] Native-born workers who, in terms of skills and inclination, are the closest substitutes for immigrants may have opportunities diminished by the immigration of talented scientists and other STEM workers. In its analysis of the effects of enacting S. 744, CBO estimated that relative wages would decrease slightly over several years for workers in the top quintile of the skill distribution relative to the wages that would occur under current law.[15]

Increasing the employment of young, highly skilled immigrants does seem to decrease the employment of older native-born workers, either absolutely or as a share of total employment, depending on the study.[16]

10. Ibid.

11. Immigration and Customs Enforcement, Student and Exchange Visitor Information System, "General Summary Quarterly Review: SEVIS by the Numbers" (July 2014), p. 8. www.ice.gov/sevis.

12. Congressional Budget Office, *The Economic Impact of S. 744, the Border Security, Economic Opportunity, and Immigration Modernization Act* (June 2013), pp. 19–20, www.cbo.gov/publication/44346.

13. For a review of the conflicting studies, see William R. Kerr, *U.S. High-Skilled Immigration, Innovation, and Entrepreneurship: Empirical Approaches and Evidence*, Working Paper 19377 (National Bureau of Economic Research, August 2013), pp. 9–17, www.nber.org/papers/w19377.

14. Ibid., p. 16.

15. Economic studies have generally found that increases in the number of skilled workers raise the productivity of less skilled workers. See Congressional Budget Office, *The Economic Impact of S. 744, the Border Security, Economic Opportunity, and Immigration Modernization Act* (June 2013), p. 20, www.cbo.gov/publication/44346.

16. One analyst notes that substituting older native-born workers with younger foreign-born workers offers a firm two types of cost savings: using less-costly foreign workers instead of relatively expensive natives, and shifting away from older workers (who tend to command higher salaries) toward younger ones. See Norman Matloff, "On the Need for Reform of the H-1B Non-Immigrant Work Visa in Computer-Related Occupations," *University of Michigan Journal of Law Reform*, vol. 36, no. 4 (2003), p. 816. Furthermore, in STEM fields, there is a move away from older workers toward younger workers generally. Sari Pekkala Kerr, William R. Kerr, and William F. Lincoln, *Skilled Immigration and the Employment Structures of U.S. Firms*, Working Paper 19658 (National Bureau of Economic Research, November 2013), p. 4, www.nber.org/papers/w19658. For a more general review, see William R. Kerr, *U.S. High-Skilled Immigration, Innovation, and Entrepreneurship: Empirical Approaches and Evidence* (National Bureau of Economic Research, August 2013), pp. 14–19, www.nber.org/papers/w19377.

Policies to Increase the Immigration of Highly Skilled Workers

Policymakers have proposed changing immigration law in different ways to increase the immigration of highly skilled workers, including the following:

- Issuing more H-1B visas for foreign-born workers,
- Increasing immigrant visas for foreign-born workers, and
- Allowing foreign students in STEM fields to stay in the United States after graduation, either temporarily or permanently.

Issue More H-1B Visas. Eliminating or raising the quotas for H-1B temporary workers would increase the number of highly skilled workers in the United States. Such a change might also provide skilled noncitizens with an easier or quicker path to working in the United States than immigrant visas because of the current backlog in issuing immigrant visas.

However, some observers raise concerns that this approach would not be the best way to increase the immigration of highly skilled workers. Adding more visas for temporary workers could increase the pressure for the government to issue immigrant visas in the long run as workers already in the country seek to gain permanent resident status. And some view the H-1B system as flawed because it gives employers more control over workers as those workers become dependent on their employers to sponsor or renew their visas, which can keep wages low. Finally, the institutions using H-1B visas that are most likely to use them to further research—universities, research hospitals, and other nonprofit research organizations—are not bound by the current H-1B limits and so would not benefit from increases in H-1B quotas.

Increase Immigrant Visas for Highly Skilled Workers. Policymakers could also increase the number of immigrant visas for skilled workers. That would allow more highly skilled immigrants to stay in the country permanently, although that approach runs counter to the long-standing family-oriented focus of U.S. immigration policy. The processes that employers must generally undertake before seeking to hire a foreign-born worker (on either an immigrant visa or nonimmigrant visa) are designed to ensure that no American worker is displaced and that hiring a foreign-born worker does not permit an employer to depress wages or work conditions—but some researchers question how effective those processes are in achieving those goals.

Grant Foreign STEM Students Visas Upon Graduation. This approach would allow foreign students in STEM fields to stay in the United States after graduation, either temporarily or permanently. Under the current system, many students who specialize in STEM-related fields do remain in this country after graduation. According to one study, 64 percent of foreign recipients of a Ph.D. in a STEM-related field were still in the United States five years after graduation. Foreign-born workers with Ph.D.s in computer science and electrical engineering remained in the United States at even higher rates.[17]

Providing temporary employment-based visas for foreign students specializing in STEM fields would make it much easier for those students to remain in the United States after they graduate.[18] Immigrant visas for STEM students, for example, could take the form of granting lawful permanent resident status, commonly known as a green card, for graduates in STEM fields. Linking education in the United States to immigration prospects would affect foreign students' incentives for obtaining such a degree and U.S. universities' incentives to provide them to foreigners. In some countries that have tried such policies, certain educational institutions have increased their foreign enrollment substantially while lowering their educational standards.[19]

The Patent System

The patent system contributes to innovation and economic growth in two principal ways. First, it provides an

17. Michael G. Finn, *Stay Rates of Foreign Doctorate Recipients From U.S. Universities, 2009* (Oak Ridge Institute for Science and Education, January 2012), http://tinyurl.com/pelzz7l.
18. The Optional Practical Training program allows some student visa holders to stay in the United States for up to an additional year after graduation, if they are working in their field of study, and students in STEM fields can apply to stay longer.
19. See Lesleyanne Hawthorne, *Competing for Skills: Migration Policies and Trends in New Zealand and Australia* (New Zealand Department of Labour, 2011), pp. 108–114, http://tinyurl.com/kod79vz.

incentive for innovative activity by enabling inventors—and those who commercialize an invention through a patent transfer or license—to make money from their efforts by excluding others from applying the technical solution in question. Hence, the patent system effectively conveys a monopoly to the patent owner that can be very profitable.[20] Second, the patent system provides for the dissemination of useful technical knowledge by requiring that a patent be published, rather than kept as a trade secret. Innovative products like computers and pharmaceuticals are covered under the patent system.

However, problems with the patent system—including too many low-quality patents, the considerable length of time required to process patent applications, and the rising cost of patent infringement litigation—may have weakened the linkage between patenting and innovation. A variety of proposals have been made for improving the patent system, ranging from increasing the resources available to the U.S. Patent and Trademark Office (USPTO) and to the federal courts that adjudicate patent disputes, to making further changes to the USPTO's administrative practices and to patent law in general.

Identifying policies that would clearly make the patent system more conducive to innovation is challenging. Efforts to address one problem could exacerbate others or weaken the incentive to innovate, and research on the extent of those problems and their impact on innovation is limited or still in its early stages.[21]

Concerns About the Patent System

Those arguing for reform of the patent system claim that it makes little contribution to innovation and economic growth outside of a few industries (such as pharmaceuticals and life sciences) and, in some cases, may actually be an impediment. They emphasize poor patent quality, the increase in the time that patent applicants must wait for a decision about their application, and rising litigation and settlement costs associated with patent infringement suits. Such concerns contributed to the passage of patent reform legislation in 2011—the Leahy-Smith America Invents Act (AIA)—and they persist today.

Although domestic patenting by U.S. citizens and foreigners combined grew at about the same annualized rate as TFP from 1963 to 1983, the rate of increase in patent applications and grants is much higher than the growth in TFP since then (see Figure 3-1). This suggests that the large increase in patenting activity since 1983 may have made little contribution to innovation.[22]

Many critics of the patent system today argue that an overburdened USPTO has made it too easy to obtain a patent. As a result, patents are often of low quality—meeting only the lowest standards of usefulness, novelty, and "nonobviousness"— yet still allow an inventor to exclude others from using the patented technology. The claims of a low-quality patent also may not be drafted clearly, stating the invention in an overly broad way that encompasses many applications. In addition, a

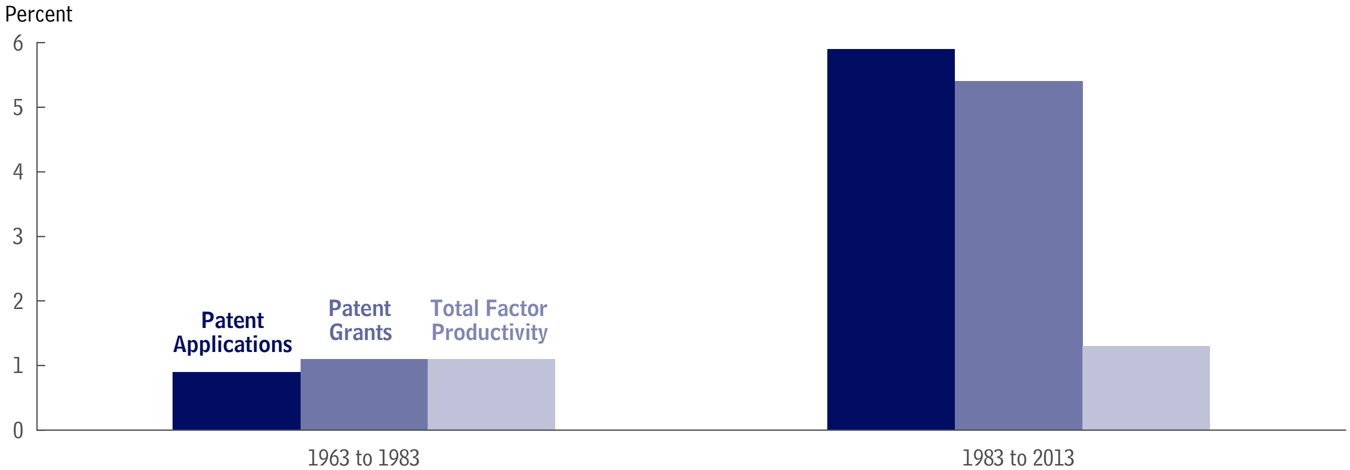
20. However, to the extent that a patent-protected good faces competition from products that are similar to it, but do not apply the technology in question, the patent owner's ability to raise prices and restrict output through that monopoly will be diminished.

21. Of particular relevance is ongoing research that explores how the importance of patents varies across industries and how strategies for protecting intellectual property can vary significantly across firms; see Bronwyn Hall and others, "The Choice Between Formal and Informal Intellectual Property: A Review," *Journal of Economic Literature*, vol. 52, no. 2 (June 2014), pp. 375–423, http://dx.doi.org/10.1257/jel.52.2.375.

22. Several factors that are unrelated to the patent system's performance in supporting innovation could have contributed to the apparent discrepancy in Figure 3-1. For example, innovation may have taken the form of improvements to capital rather than TFP. Also, innovation in some fields may have experienced diminishing economic returns over time. Research has found that since about 1980, increases in computing power (and associated decreases in computing costs) as measured through technical performance criteria have outstripped economic measures of computing productivity (which are based on users' valuation of computing power relative to other features of computer systems); see William D. Nordhaus, "Two Centuries of Productivity Growth in Computing," *Journal of Economic History*, vol. 67, no. 1 (March 2007), pp. 151–154, http://tinyurl.com/k454h9v (PDF, 236 KB). Finally, the relationship between patenting and TFP growth could have weakened over time if innovation increasingly took the form of goods and services (such as pharmaceuticals) whose returns may generally not be well captured by economic indicators such as GDP. However, those effects do not appear to be important here, for two reasons. First, the average annual growth in capital services actually fell between the two periods in Figure 3-1. Second, much of the increase in patenting activity since the early 1990s can be attributed to software-related patents, including business-method patents. See Government Accountability Office, *Intellectual Property: Assessing Factors That Affect Patent Infringement Litigation Could Help Improve Patent Quality*, GAO-13-465 (August 2013), Figure 1, p. 12, www.gao.gov/products/GAO-13-465.

Figure 3-1.

Annualized Growth in Patenting Activity and Total Factor Productivity, 1963 to 2013



Source: Congressional Budget Office based on U.S. Patent and Trademark Office, Patent Technology Monitoring Team, "U.S. Patent Statistics Chart Calendar Years 1963–2013" (last modified July 24, 2014), http://go.usa.gov/VnbC.

Note: Total factor productivity is the growth in output that remains after removing the contributions from growth in labor hours and capital services. Capital services are a measure of the flow of services available for production from the real (inflation-adjusted) stock of capital (typically, the physical structures and equipment used in production, along with intangible capital, such as computer software and knowledge gained from spending for research and development).

low-quality patent may describe an invention too vaguely for the disclosure of the technical knowledge to be informative to practitioners.[23]

The proliferation of low-quality patents is especially likely to result in "patent thickets," groups of patents that are relevant to developing a particular technology, which can slow the introduction of new products by making it time-consuming and costly to obtain licenses for all of the necessary patents. Smaller innovating firms also tend to suffer disproportionately because patent thickets provide a greater competitive advantage to the typically large firms that hold more patents than those firms would realize solely on the basis of their innovativeness.[24]

Another common cause for concern about the patent system is the increased time required for the USPTO to process patent applications. Patents can be an important way for start-up firms—particularly in the life-science industries—to signal to capital markets that they offer innovative products and, as a result, that they are a good investment. Delays in patent processing can deprive such firms of external funding. The amount of time that patent applicants had to wait for a decision about their applications increased from 19 months in 1992 to 29 months in 2013 (down from a high of over 35 months in 2010), with the number of pending patent applications increasing from approximately 270,000 to over 1.1 million.[25]

23. See Stephen A. Merrill, Richard C. Levin, and Mark B. Myers, eds., *A Patent System for the 21st Century* (National Research Council of the National Academies, 2004), www.nap.edu/catalog.php?record_id=10976; Federal Trade Commission, *To Promote Innovation: The Proper Balance of Competition and Patent Law and Policy* (October 2003), http://go.usa.gov/ETjH (PDF, 2.3 MB); and Federal Trade Commission, *The Evolving IP Marketplace: Aligning Patent Notice and Remedies with Competition* (March 2011), http://go.usa.gov/ETD4 (PDF, 2.6 MB).

24. See, for example, Adam B. Jaffe and Josh Lerner, *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do About It* (Princeton University Press, 2004); and Michael Heller, *The Gridlock Economy: How Too Much Ownership Wrecks Markets, Stops Innovation, and Costs Lives* (Basic Books, 2008).

25. On the usefulness of patents as a tool for small firms to raise capital, see Stuart Graham and others, "High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey," *Berkeley Technology Law Journal*, vol. 24, no. 4 (2009), pp. 1248–1318, http://btlj.org/category/journal/volume-24-2009/ and Michael J. Meurer, "Inventors, Entrepreneurs, and Intellectual Property Law," *Houston Law Review*, vol. 45, no. 4 (2008–2009), pp. 2001–2037, www.houstonlawreview.org/2009/01/. Data on the pendency of patent applications comes from United States Patent and Trademark Office, *Performance and Accountability Report, Fiscal Year 2013*, and *Annual Report, Fiscal Year 1993*, www.uspto.gov/about/stratplan/ar/.

The patent system has also seen an increase in litigation and associated costs over the years. When a patent makes very ambiguous or broad claims to knowledge, it may be infringed upon inadvertently by many practitioners, which may allow the patent holder to assert its monopoly more broadly than would otherwise be warranted. The number of defendants in patent infringement lawsuits rose by 129 percent from 2007 through 2011, with lawsuits involving software-related patents (including patents on business methods) accounting for almost nine-tenths of that increase.[26]

Of particular concern are companies that accumulate patents without intending to apply that knowledge to the production of goods or services. Although defenders of such firms—referred to as patent assertion entities, or PAEs—argue that they provide a way for individual inventors to assert their patents more effectively than they could do on their own, critics emphasize that PAEs have an inherent advantage in patent litigation because they make no products and, as a result, are not vulnerable to infringement countersuits.[27] Evidence on the economic impact of PAEs remains sparse, but some studies have found that litigation involving those firms is very expensive and that inventors benefit relatively little from it. Research has also found that PAE lawsuits, or the threat of such litigation, impose a substantial burden on start-up firms (especially in information technology industries). Moreover, the patents asserted by PAEs often apply to products that small firms have simply purchased and are using in their business operations—rather than on patented technology that those firms have replicated without a license from the patent owner.[28]

26. See Government Accountability Office, *Intellectual Property: Assessing Factors That Affect Patent Infringement Litigation Could Help Improve Patent Quality*, GAO-13-465 (August 2013), pp. 14–16, www.gao.gov/products/GAO-13-465. For a defense of the quality of software patents, see Stuart Graham and Saurabh Vishnubhakat, "Of Smart Phone Wars and Software Patents," *Journal of Economic Perspectives*, vol. 27, no. 1 (Winter 2013), pp. 67–86, http://dx.doi.org/10.1257/jep.27.1.67.

27. Because the average PAE lawsuit has, historically, named more defendants than a patent infringement lawsuit brought by another type of plaintiff, litigation initiated by PAEs accounted for about one-half of the increase in the total number of patent infringement defendants from 2007 to 2011. See Government Accountability Office, *Intellectual Property: Assessing Factors That Affect Patent Infringement Litigation Could Help Improve Patent Quality*, GAO-13-465 (August 2013), p. 18, www.gao.gov/products/GAO-13-465.

Policies for Improving the Patent System

To address concerns about the quality of patents, reduce the length of time to process patent applications, and lower the cost and frequency of patent litigation, lawmakers could provide more resources to the patent system or make further changes to the USPTO's operational methods and to patent law beyond those put in place by the AIA.

Make More Resources Available. Under current law, the USPTO is funded by fees collected for the services it provides, such as patent application examinations and postgrant reviews. Reforms enacted in the AIA give the USPTO greater flexibility in setting those fees, thereby allowing the agency to align its fees more closely with its costs. However, the USPTO requires an appropriation from the Congress in order to spend the fees that it collects. Thus, USPTO's funding is considered to be discretionary and as such is limited by the caps on discretionary funding imposed by the Budget Control Act of 2011. Under those caps, the USPTO's funding has declined.

The Congress could increase the resources available to the patent system by making the revenues the USPTO collects independent of the appropriation process, by providing additional funding to the USPTO (say, by supplementing user fees with appropriations from the Treasury's general fund), by providing additional funding to the federal courts for handling patent cases, or through a combination of those actions.

Some observers argue that the USPTO should be granted additional appropriations because its need for more patent examiners, judges specializing in administrative law, and computer hardware and software exceeds what that agency could generate through a revised fee structure. Some observers also argue that if additional appropriations were provided to create more federal judgeships, the spreading of the existing workload across a larger number of judges would mean that patent lawsuits would be concluded more quickly and at less cost to

28. See James E. Bessen and Michael J. Meurer, *The Direct Costs From NPE Disputes*, Law and Economics Research Paper 12-34 (Boston University School of Law, revised July 2013), http://tinyurl.com/loqcl5f; Michael Risch, "Patent Troll Myths," *Seton Hall Law Review* (2012), http://works.bepress.com/michael_risch/16; and Colleen Chien, *Patent Assertion and Startup Innovation* (New America Foundation, September 2013), http://tinyurl.com/ob7k83j.

litigants.[29] Some newly created judgeships could be for specialized patent litigation courts, set up along the same lines that bankruptcy courts are currently.

Improvements in the timeliness of patent decisions and legal rulings for patent enforcement could lead to greater demand for patents, to an extent limiting the improvements from providing further resources to the USPTO and federal courts. However, using more funds to increase the number of patent examiners could raise the quality of patents that are granted and thereby reduce low-quality patent applications by making it less likely that a patent would be awarded in such cases.

Change the Patent System. It is difficult to evaluate how proposals to change the patent system would ultimately affect the problems attributed to the patent system or its ability to better foster innovation. Efforts to address one problem could make other problems worse or reduce the incentive to innovate. For example, proposals that make it more costly to obtain and renew a patent or that weaken some of the protections enjoyed by patent owners might reduce the burdens on the patent system—thereby allowing patents to be processed more quickly, and litigation costs to fall—but could diminish the financial incentive to obtain a patent. Furthermore, research on a number of challenges to the patent system, such as those posed by the increase in litigation attributed to PAEs, is limited or still in its early stages.[30]

Policies to Reduce the Number of Low-Quality Patents. A number of changes have been suggested that aim to reduce the number of low-quality patents by modifying how the USPTO administers patent law:

- Charging higher fees to apply for or maintain a patent in order to discourage patents that have little economic value;
- Requiring that applications be reviewed by two examiners, independently, before a patent is granted;
- Making it more difficult or more costly to resubmit an application that was rejected; and
- Requiring the technical specifications of an invention to be described more precisely so that others may replicate the claimed invention.

Although increasing the scrutiny given to patent applications would reduce the number of low-quality patents that are granted, it might at the same time deter patent applications more broadly and could lengthen the processing time required for applications.[31] Currently, patent applications that have been rejected can be resubmitted—with only minor changes—for a new examination. Making it more difficult to resubmit a rejected application could reduce the processing time for the average patent application because such submissions (or "requests for continued examination") have been found to impose a significant burden on the USPTO. However, making it more difficult to obtain a patent could again negatively affect the incentive to patent.[32]

Policies to Reduce the Cost to Defendants of Infringement Litigation and to Reduce the Frequency of Nuisance Lawsuits. Most proposed changes to patent law are intended to reduce the cost to defendants of patent infringement lawsuits and the frequency of nuisance lawsuits. Those changes could involve reducing the potential payoff from engaging in patent litigation, making it

29. See "Inside Views: Interview With Chief Judge Paul R. Michel on U.S. Patent Reform," *Intellectual Property Watch* (July 7, 2011), http://tinyurl.com/ndqvc9a.

30. For example, the Federal Trade Commission is currently collecting information about PAEs to determine the impact that their activity has on competition in the market for patented products. See Federal Trade Commission, "Agency Information Collection Activities; Submission for OMB Review; Comment Request," *Federal Register*, vol. 79, no. 96 (May 19, 2014), pp. 28715–28729, http://go.usa.gov/7qKG (PDF, 241 KB).

31. For roughly a decade beginning in March 2000, the USPTO required that business method patents be reviewed by two examiners. Although this resulted in a higher rejection rate (compared with other groups of patent applications for which there are a large number of submissions to the USPTO), it also considerably lengthened the examination time. See Mark A. Lemley, *Fixing the Patent Office*, Working Paper 18081 (National Bureau of Economic Research, May 2012), pp. 7–8, www.nber.org/papers/w18081.

32. Research has found that roughly 28 percent of the patent applications from 1993 to 1998 were actually resubmissions of rejected patent applications; see Cecil D. Quillen Jr. and Ogden H. Webster, "Continuing Patent Applications and Performance of the U.S. Patent Office," *Federal Circuit Bar Journal*, vol. 11, no. 1 (August 2001), pp. 1–21; and United Kingdom Intellectual Property Office and United States Patent and Trademark Office, *Patent Backlogs, Inventories and Pendency: An International Framework*, Working Draft (June 26, 2013), pp. 68–69, www.ipo.gov.uk/ipresearch-uspatlog-201306.pdf (4 MB).

harder for plaintiffs to prevail in patent infringement lawsuits, and limiting the scenarios in which patent infringement can be asserted.

Within that group, one set of proposals is focused more on the potential costs that defendants may bear as a result of going to court. That set of proposals includes the following measures: establishing legal protections for end users of products that embody technologies subject to a patent dispute; implementing "fee-shifting" in patent infringement lawsuits—and in particular, those initiated by PAEs—by requiring that the plaintiffs be required to pay all court costs in the event that they lose; and requiring that the damages awarded upon a finding of patent infringement be apportioned according to the contribution of the technology that is covered by the infringed patent or patents to the price of the good or service in question. However, the effects of the fee-shifting may be limited to the extent that some PAEs might engage in a nominal amount of production associated with a patent to be asserted in litigation so that they would not be considered a PAE. In addition, because a given product can encompass one or more technologies on which a number of patents have been granted, it could be very difficult to determine accurately how much of the value of that product was attributable to a small subset of those technologies.[33]

Another set of proposals is focused more on the likelihood that a patent-owner will prevail in a patent infringement lawsuit and includes the following measures: lowering the legal standard for finding that a patent is invalid (from the current "clear and convincing" threshold to a less stringent requirement of a "preponderance of the evidence") and, perhaps most controversially, establishing an "independent inventor defense" that would provide a safe harbor for users of a patented invention if they could prove that they did not copy the patent or otherwise learn about the technique from the patent owner. Some argue that lowering the threshold for finding a patent invalid would align the criteria that judges and juries use to determine whether a patent is valid with the diminished quality of patents that are currently granted. Allowing those accused of patent infringement to make an independent inventor defense would address research findings that the outright copying of a patent is seldom claimed in patent infringement lawsuits. However, both proposals would represent profound changes to patent law and could potentially dampen incentives to innovate.[34]

Still another set of changes that the Congress could make to patent law would be to modify patent law for particular kinds of inventions. Such changes would address the concern that the current unitary patent system, in which the same basic protections apply regardless of the type of invention, might not be appropriate for a variety of industries when the nature of technology development can be industry specific. Although patent protection is widely understood to provide an important incentive for the development of new drugs—which is typically very costly—the contribution of patents to innovation in software or business methods is often questioned because the costs of developing such new products and processes may be modest. One possible change to patent law that could reduce the cost and frequency of litigation would be to limit patent protections for inventions that were relatively inexpensive to develop. For example, patents on software and business methods could expire sooner than is the case today (which, with renewals, is after 20 years), reducing the incentive to obtain those patents. Another change that could address patent quality, the processing burden on the USPTO, and the cost and frequency of litigation would be to limit the ability to obtain a patent on certain inventions.

Critics of proposals to move away from a unitary patent system argue that the benefits of such a switch would be limited by efforts on the part of patent applicants to thwart industry-specific restrictions on patent protections by stating their patent claims in such a way as to have them classified with inventions that qualify for the strongest protections (indeed, because there is no one category for "software" in the USPTO's patent classification scheme, researchers have developed several

33. A number of the proposals discussed in this section—in particular, those that would enable the courts to offer (limited) legal protections for end users and to implement fee-shifting—are among the provisions of the Innovation Act (H.R. 3309), which passed the House of Representatives on December 5, 2013.

34. Another measure intended to reduce the cost of patent infringement litigation, which is incorporated in several current legislative proposals to modify the patent system, is to extend to software patents the AIA's Covered Business Method program. That would allow the validity of some software patents to be determined by administrative judges at the USPTO rather than by judges (and juries) in federal court; as a result, the cost of patent litigation in such cases should fall.

alternative categories that overlap in varying degrees). They also argue that making some types of inventions ineligible for a patent would not be permissible under the intellectual property treaties that the United States has signed with other countries. However, some legal scholars have questioned whether the United States is prohibited under international treaties from deviating in any way from a unitary patent standard (for example, drug manufacturers benefit from an exemption from patent infringement when they conduct clinical trials to establish the bioequivalence of a generic drug with a patented pharmaceutical).[35]

One consideration that surrounds a number of the modifications suggested for the patent system is whether actions already taken by the USPTO and federal courts will resolve those concerns. For example, some observers argue that the reforms implemented by the AIA have not yet had their full effect on the patent system, and so enacting additional measures in the near future would be premature. Beyond the provisions of the AIA, the USPTO has joined with the private sector to improve the quality of software patents (the Software Partnership) and is also implementing a number of Executive Orders to address other concerns about the patent system. In addition, recent court decisions may mitigate, if not make unnecessary, the need for the Congress to legislate reform in those areas.[36]

Regulatory Goals and Tools

Lawmakers could enact legislation modifying regulations that affect the introduction of new products and services in order to promote innovation. For example, the Congress could reconsider the federal government's regulatory goals and reassess the way certain risks are balanced against the potential benefits provided by innovation. Separately, the Congress could change the tools of regulatory policy in some areas to allow for more flexibility in meeting regulatory goals, which would reduce the costs imposed by regulation and promote more innovation. Finally, in some instances, federal lawmakers could address the balance of risks and rewards codified by state and local governments.

Modifying Regulatory Goals

Society's decisions about how to regulate new products and services generally involve balancing the risks and rewards associated with those innovations. Regulation that aims to diminish the risks that accompany innovations can restrict innovations that have the potential to bring substantial benefits to society. In addition, regulation can deter innovation by imposing administrative costs associated with compliance, by creating uncertainty and delays, and by redirecting managerial attention from innovative activity to meeting regulatory requirements. Regulation may also create incentives for firms to divert resources to less promising investments to avoid the regulation.

Individual regulatory agencies are often limited in their ability to assess the full, long-term impact of regulations. Even if the cost of any individual regulation imposed by a single agency is small, the cumulative effect of a large body of regulations imposed by multiple agencies might be considerable. Furthermore, the ever-changing nature of technological innovation implies that regulations that appropriately balanced the risks and rewards of innovation in the past might now be outmoded, and new technology might open opportunities that were not considered when the regulations were designed. In such circumstances, it might be advantageous to reassess regulations on a recurring basis.

Regulation of financial markets is one important example of the trade-off between innovation and risk. Many financial innovations have greatly benefited consumers. For example, the use of credit cards and automated teller machines is now essential to the workings of the financial system. However, financial innovations also create risks. In the years leading up to the financial crisis, the enormous growth in nontraditional mortgages and mortgage-related securities and derivatives facilitated a sharp increase in leverage among households and financial institutions. That leverage increased the risk in the financial system and the economy, as became apparent during the financial crisis and severe recession. In response,

35. See John R. Thomas, *Tailoring the Patent System for Specific Industries*, Report for Congress R43264 (Congressional Research Service, October 2013).

36. For current USPTO efforts to improve the patent system, see U.S. Patent and Trademark Office, "Initiatives and Events" (last modified October 21, 2014), www.uspto.gov/patents/init_events/. Recent Supreme Court decisions have granted lower courts greater discretion to award attorney fees to prevailing parties in patent infringement lawsuits (*Octane Fitness LLC. v. Icon Health and Fitness* and *Highmark, Inc., v. Allcare Health Management System*); made it more difficult to assert a claim of patent infringement (*Limelight Networks, Inc., v. Akamai Technologies, Inc.*); heightened the requirement that a patent describe an invention in a clear and distinct way (*Nautilus v. Biosig Instruments*); and reaffirmed the ineligibility for patent protection of abstract ideas (*Alice Corporation Pty., Ltd., v. CLS Bank International et al.*).

policymakers have sought to mitigate the costs and risks generated by financial innovations through regulation.[37] Often, regulations put in place to reduce the risks that accompany financial innovations also diminish the profits that flow to the creators of those innovations. In turn, that reduction in profits dampens the incentive to innovate.

Some regulatory activity serves to limit investment or raises the cost of providing an existing product or service. For example, federal regulations to reduce emissions from coal-burning plants, industrial boilers, and some other industrial process heaters may require tens of billions of dollars of specialized investment by the affected companies.[38] In the absence of regulations requiring the firms to make such investments in pollution-control technology, the affected companies might make additional investments in productivity-enhancing equipment. However, the magnitude of any reduction in productivity-enhancing investment because of environmental regulations is unclear. More generally, the relationship between different types of investment and innovation is not straightforward. For example, some environmental requirements can be fulfilled only by introducing new technology.[39]

Adopting Flexible Regulatory Tools

In recent decades, the Congress has sometimes increased the flexibility of regulation by allowing firms to focus on what is to be achieved, such as safety or emission goals, rather than specifying how those goals are to be achieved. For example, instead of mandating that firms install certain pieces of equipment to reduce emissions, the 1990 amendments to the Clean Air Act created a market in tradable allowances that permitted firms to bank or trade the right to emit sulfur dioxide. Firms with low compliance costs could sell their allowances to firms with high compliance costs, reducing the aggregate costs of emissions control. Firms could also save their allowances to be used as needed to reduce their future compliance costs.[40]

However, such regulatory flexibility is still unevenly provided. Analysts point out that federal regulations are increasing in both number and complexity even as some agencies experiment with more flexible forms of regulation.[41] The number of restrictions or binding legal obligations imposed by federal regulations continues to rise. That "regulatory accumulation" can impose costs beyond the costs of individual regulations through interactions or by overburdening the management of affected companies with regulatory compliance. Even the successful trade in sulfur emission permits discussed above was largely brought to a halt after more than a decade in operation by other parts of the Clean Air Act.[42]

Several Administrations have also launched efforts to make regulation less costly to the economy. The current Administration has had a "look back" initiative under way since 2011, aimed at having regulatory agencies reconsider their existing rules and explore ways to reduce the number of regulatory requirements or to make them less costly to implement.[43] Nevertheless, at present, the process of reviewing existing regulations is less well institutionalized than the process of examining regulations prospectively, as agencies receive little detailed guidance on how to reconsider regulations that are currently in effect. Some analysts have suggested creating a

37. See Michael S. Barr, "The Financial Crisis and the Path of Reform," *Yale Journal on Regulation*, vol. 29, no. 1 (2012), pp. 91–119, http://tinyurl.com/oo8njtt.

38. Testimony of Douglas W. Elmendorf, Director, Congressional Budget Office, before the Senate Committee on the Budget, *Policies for Increasing Economic Growth and Employment in 2012 and 2013* (November 15, 2011), www.cbo.gov/publication/42717.

39. Luke A. Stewart, *The Impact of Regulation on Innovation in the United States: A Cross-Industry Literature Review* (Information Technology and Innovation Foundation, June 2010), http://tinyurl.com/oo5qsf2 (PDF, 340 KB).

40. The earlier deregulation of railroad rates also helped firms meet the sulfur reduction goals, as competition in rate setting sufficiently reduced the cost of shipping low-sulfur coal from the West to make it more viable. See Richard Schmalensee and Robert N. Stavins, *The SO_2 Allowance Trading System: The Ironic History of a Grand Policy Experiment*, RFF Discussion Paper 12-44 (Resources for the Future, August 2012), pp. 8–10, http://tinyurl.com/pcxesz9. In this instance, deregulation in one area helped make market-oriented regulation in a different area successful.

41. Testimony of Patrick A. McLaughlin, Senior Research Fellow, George Mason University, before the Subcommittee on Regulatory Reform, Commercial, and Antitrust Law of the House Committee on the Judiciary (February 11, 2014), http://tinyurl.com/n99d6om.

42. See Richard Schmalensee and Robert N. Stavins, *The SO_2 Allowance Trading System: The Ironic History of a Grand Policy Experiment*, RFF Discussion Paper 12-44 (Resources for the Future, August 2012), pp. 8–11, http://tinyurl.com/pcxesz9.

43. Cary Coglianese, "Moving Forward With Regulatory Lookback," *Yale Journal on Regulation*, vol. 30, no. 57 (2013), pp. 57–66, http://tinyurl.com/pgld656.

formal framework for evaluating those regulations regularly, either in established agencies or by creating a new one for that purpose.

Influencing State and Local Regulation

Federal policymakers could also act when other regulatory actors in the economy place a lower value on the rewards of innovation and a higher value on its risks than do federal lawmakers. For example, in 1986, the Congress passed the National Childhood Vaccine Injury Act, which was designed, among other things, to reduce the risk of liability associated with the development and sale of vaccines. Product liability is typically governed by state law, but that act, which created a federal alternative dispute resolution mechanism for drug companies and aggrieved individuals, has been generally regarded as a success in encouraging the development of new vaccines.[44]

Policymakers could extend that experience in restricting liability rules into new areas in which innovation is likely to be inhibited by liability laws, such as the development of self-driving automobiles. Advocates argue that the widespread use of such automobiles would reduce the number of traffic fatalities, which currently stand at 33,000 deaths per year, a substantial portion of which are caused by drunken or distracted drivers.[45] Yet, despite those automated vehicles having the potential to improve national traffic safety, rules regarding strict liability for new products could cause the producers of the first self-driving cars to be judged not against the 33,000 actual deaths, but against an ideal of no deaths. If policymakers wanted to set a different standard, they could revisit the balance between liability and innovation for this nascent technology. Other analysts argue that federal preemption is not necessary: State liability law has been regularly interpreted by state courts to accommodate new technology.[46] Alternatively, federal policymakers could help create appropriate liability insurance markets—much as they did with reinsurance against terrorist attacks after 2001.

Even as the Congress considers how to best balance innovation against other policy goals, the federal system of government places limits on its jurisdiction. For example, in the case of broadband transmission facilities, policies of local governments and regulatory authorities—local zoning regulations and access to local infrastructure such as utility poles and rights of way—are important determinants of the pace of the expansion. The Congress, most recently through the Middle Class Tax Relief and Job Creation Act of 2012, and the Federal Communications Commission have both placed certain limitations on local zoning authorities' regulation of the placement of broadband equipment and facilities without totally preempting state and local law.[47] In this case and others, federal agencies can influence the policies of local government and regulatory authorities only slowly and with some difficulty.

44. For other examples of federal efforts to mitigate state court tort litigation, see James M. Anderson and others, *Autonomous Vehicle Technology: A Guide for Policymakers* (RAND Corporation, 2014), pp. 131–132, www.rand.org/pubs/research_reports/RR443-1.html.

45. See National Highway Traffic Safety Administration, "Early Estimate of Motor Vehicle Traffic Fatalities in 2013," DOT HS 812 024 (May 2014), http://go.usa.gov/wn7w.

46. See John Villasenor, *Products Liability and Driverless Cars: Issues and Guiding Principles for Legislation* (Brookings Institution, April 2014), http://tinyurl.com/k6921d3.

47. See Kathleen Ann Ruane, *Broadband Deployment: Legal Issues for the Siting of Wireless Communications Facilities and Amendments to the Pole Attachment Rule,* Report for Congress RS20783 (Congressional Research Service, April 2013).

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About This Document

This report was prepared at the request of the Ranking Member of the Senate Committee on Health, Education, Labor, and Pensions. In keeping with the Congressional Budget Office's (CBO's) mandate to provide objective, impartial analysis, the report makes no recommendations.

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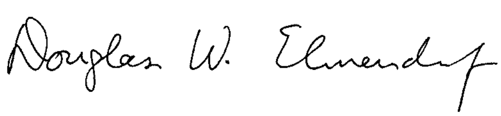

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