Introduction

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Introduction

THE PREVAILING ECONOMIC STAGE

The U.S. economy is slowly recovering from what has been the longest and arguably the most severe economic downturn since the Great Depression. The National Bureau of Economic Research (NBER) dates this recession as having lasted from December 2007 to June 2009—a period of 18 months. The civilian unemployment rate rose over that period from 5 percent to 9.5 percent, and it increased to and remained at a double-digit level throughout the rest of 2009.

The George W. Bush administration, with the support of the U.S. Congress, took some immediate steps to strengthen the economy. The Emergency Economic Stabilization Act of 2008 (Public Law [P.L.] 110-343), signed in October 2008, permitted the government to purchase failing bank assets in an effort to stabilize financial markets in the wake of the subprime mortgage crisis and to pay for these assets through the newly created Troubled Asset Relief Program (TARP).

The American Recovery and Reinvestment Act (ARRA) of 2009 (P.L. 111-5), also known as the Recovery Act, was signed by newly inaugurated President Barack Obama in February 2009. The premise of this fiscal stimulus was that government spending would quickly lead to business investments and subsequent consumer spending, thus mitigating the current recession. Two of the stated purposes of ARRA are to “preserve and create jobs and promote economic recovery.” Another stated purpose of the act is to “provide investments needed to increase economic efficiency by spurring technological advances,” and throughout the act there is an emphasis on small-business investment.

In September 2009, the National Economic Council (2009) released A Strategy for American Innovation: Driving towards Sustainable Growth and Quality Jobs. The report, put out by the Executive Office of the President, lays “the foundation for the innovation economy of the future” (p. i). This initiative “seeks to harness the inherent ingenuity
of the American people and a dynamic private sector to ensure that the next [economic] expansion is more solid, broad-based, and beneficial than previous ones” (p. i). Under the heading “A Vision for Innovation, Growth, and Jobs,” the report states that “innovation is essential for creating new jobs in both high-tech and traditional sectors . . . A more innovative economy is a more productive and faster growing economy, with higher returns to workers and increases in living standards . . . Innovation is the key to global competitiveness, new and better jobs [emphasis added], a resilient economy, and the attainment of essential national goals” (p. 4).

To accomplish this, *A Strategy for American Innovation* emphasizes that the economy must invest in the building blocks of American innovation by, among other things, restoring American leadership in fundamental research. Such building blocks will promote competitive markets that spur productive entrepreneurship, and that in turn will catalyze breakthroughs for national priorities.

Three broad and related themes are evident from the economic policies of the past several years: 1) public-sector and private-sector investments in research and development (R&D) support the innovation process; 2) innovation is closely tied to entrepreneurial activity, and new and existing small firms are more entrepreneurial than large firms; and 3) entrepreneurship and innovation are the drivers of competitiveness, new jobs, productivity growth, and overall economic well-being.

The Obama administration is not the first to embrace these themes in response to an economic crisis. In the early 1970s, and then again in the late 1970s and early 1980s, productivity growth in the U.S. industrial economy declined precipitously, thus rendering many sectors of the economy vulnerable to global competitive forces. While many explanations have been offered as to the cause of the so-called productivity slowdown, one clear policy response was to increase the level, effectiveness, and diffusion of private-sector industrial R&D and innovative activity through a series of policy initiatives. These initiatives included the passage of the Bayh-Dole Act of 1980; the R&E Tax Credit of 1981; the Small Business Innovation Development Act of 1982, which created the Small Business Innovation Research program (the empirical focus of this book); and the National Cooperative Research Act of 1984.
AN INNOVATION-BASED ECONOMIC GROWTH STRATEGY

The three themes listed above are not without an academic foundation. Before we discuss the related literature, some initial definitions might be in order. First, invention is the creation of new knowledge, technology is the application of new knowledge, and innovation is the commercialization of the new technology—innovation puts a new technology to general use. And second, entrepreneurship involves the perception of new opportunities and the ability to act on those perceptions.8

The premise that the rise of technology leads to productivity growth can be traced historically to Adam Smith’s *The Wealth of Nations*. A careful reading of his argument leads one to conclude that improvements in technology result from the division of labor, and a greater division of labor stimulates productivity growth. Productivity growth in turn leads to overall economic growth.

Abramovitz (1956) showed, through his pioneering analysis of aggregate economic activity in the post–Civil War economy (covering from 1869–1878 to 1944–1953), that productivity growth at the aggregate level was not due to an increase in the availability and use of resources but rather to growth in the stock of knowledge, which in turn was due to research and education. Following Abramovitz, Solow (1957) formalized the study of productivity growth, and he concluded that between 1909 and 1949 gross output per man-hour doubled, with nearly 90 percent of the increase due to technical change. This pioneering Solow study has motivated volumes of research. Nearly all of that literature substantiates the impact of investments in technology—research and development (R&D) investments in particular—on productivity growth.9

Regarding the role of small firms, we first focus on the scholarship of Jewkes, Sawers, and Stillerman (1958). They were among the first scholars to shed light on industrial R&D as a source of technological progress. Of the 61 important inventions they name that were made in the United States and Great Britain during the first half of the twentieth century, more than half could be attributed to entrepreneurs working on their own (i.e., as small firms) without the research resources of large firms or laboratories. More recently, in research more focused on
small- versus large-firm behavior, Acs and Audretsch (1990) show that the average number of innovations per 1,000 employees made by small firms (i.e., firms with fewer than 500 employees) in the U.S. manufacturing sector in 1982 was 0.309, compared to 0.202 for large firms.\textsuperscript{10}

In that same vein, the National Science Foundation’s (NSF’s) \textit{Survey of Industrial Research and Development}, as summarized by Rausch (2010), shows that small R&D firms invest more in R&D relative to their size than do larger firms.\textsuperscript{11} In 2007, the ratio of R&D to firm sales in small R&D firms was 8.6 percent, compared to 3.4 percent in large firms.\textsuperscript{12}

Finally, a study by Breitzman and Hicks (2008) under the sponsorship of the Small Business Administration’s (SBA’s) Office of Advocacy concludes that small technology firms obtain more patents per employee than large firms. Over the 2002–2006 period, small technology firms received 26.5 patents per 100 employees, compared to 1.7 for large firms. On a patent-per-employee basis, the ratio was 1.89 for technology firms with fewer than 25 employees and 0.014 for firms with 25,000 or more employees.

At a nonstatistical level, Baumol, Litan, and Schramm (2007) emphasize the creative individual—the entrepreneur, which to many is synonymous with a newly created firm—as the originating force behind innovation. They suggest that “if the United States wishes to continue enjoying rapid growth, it must find a way both to launch and promote the growth of innovative entrepreneurial enterprises and to ensure that the successful entrepreneurs who grow their [small] businesses into large firms continue to innovate. We believe that this requires policies that encourage what we call ‘productive entrepreneurship’” (p. 2).

Introducing a more nuanced and balanced view, Baumol (1990, p. 3) has also argued that not all entrepreneurial efforts are productive. He writes the following:

\begin{quote}
Entrepreneurs are always with us and always play some substantial role. But there are a variety of roles among which the entrepreneur’s efforts can be reallocated, and some of those roles do not follow the constructive and innovative script that is conventionally attributed to that person. Indeed, at times the entrepreneur may even lead a parasitical existence that is actually damaging to the economy. How the entrepreneur acts at a given time and place depends heavily on the rules of the game—the reward structure in
the economy—that happen to prevail. Thus . . . it is the set of rules and not the supply of entrepreneurs or the nature of their objectives that undergoes significant changes from one period to another and helps to dictate the ultimate effect on the economy via the allocation of entrepreneurial resources.

Baumol, Litan, and Schramm (2007) argue for policies to encourage productive entrepreneurship by suggesting a number of policy initiatives that should be considered, including everything from tax policies to encourage risk taking, to reform of bankruptcy laws to promote the formation of new businesses, to revision of the patent system. Such policy actions will “adjust the rules of the game to induce a more felicitous allocation of entrepreneurial resources” (Baumol 1990, p. 4).

It should be noted that not all are in agreement with Baumol and his colleagues. Friedman (2007, p. 4), for example, is critical of this point of view, and he has argued that “implementation of changing technologies shifts the balance of skills demanded in the market for heterogeneous labor, and if the change is sufficiently rapid the mix of skills that the labor force supplies cannot keep pace. [And], advancing technology is also rendering an ever wider array of goods and services conveniently tradable across international boundaries, thereby exposing American workers to the actual or incipient threat of competition from workers willing to accept extremely low wages compared to American standards.”

Academic and empirical evidence aside, there is also a well-developed theoretical foundation for government support of innovation, as is discussed next.

**GOVERNMENT’S ROLE IN INNOVATION**

One theoretical basis for government’s role in market activity is the concept of market failure. Market failure is typically attributed to market power, imperfect information, externalities, and public goods. The explicit application of market failure to justify government’s role in innovation—in R&D activity in particular—is a relatively recent phenomenon within public policy.
Public interest in innovation can be traced back to President Washington’s address to Congress in 1790: “The advancement of agriculture, commerce, and manufactures, by all proper means, will not, I trust, need recommendation; but I cannot forbear intimating to you the expediency of giving effectual encouragement, as well to the introduction of new and useful inventions from abroad, as to the exertions of skill and genius in producing them at home . . . ” (PBS 2002).\(^\text{13}\)

Still, many point to the first President Bush’s Office of Science and Technology Policy, which issued a document titled *U.S. Technology Policy* in 1990 as the United States’ first formal domestic technology policy statement. While it was an important initial policy effort, it failed to articulate a foundation for government’s role in technology and innovation. Rather, it implicitly assumed that government had a role, and then set forth the general statement, “The goal of U.S. technology policy is to make the best use of technology in achieving the national goals of improved quality of life for all Americans, continued economic growth, and national security” (Executive Office of the President 1990, p. 2).

President Clinton took a major step forward from the 1990 policy statement in his 1994 *Economic Report of the President* by articulating first principles about why government should be involved in the technological process (Council of Economic Advisers 1994, p. 191): “The goal of technology policy is not to substitute the government’s judgment for that of private industry in deciding which potential ‘winners’ to back. Rather, the point is to correct market failure.”\(^\text{14}\)

Subsequent Executive Office policy statements have echoed this theme; *Science in the National Interest* (Clinton and Gore 1994) and *Science and Technology: Shaping the Twenty-First Century* (Executive Office of the President 1997) are among the examples. President Clinton’s 2000 *Economic Report of the President* elaborated upon the concept of market failure as part of U.S. technology policy: “Rather than support technologies that have clear and immediate commercial potential (which would likely be developed by the private sector without government support), government should seek out new technologies that will create benefits with large spillovers to society at large” (Council of Economic Advisers 2000, p. 99).

Related to this, Martin and Scott (2000, p. 438) observed that “limited appropriability, financial market failure, external benefits to the production of knowledge, and other factors suggest that strict reliance
on a market system will result in underinvestment in innovation, relative to the socially desirable level. This creates a *prima facie* case in favor of public intervention to promote innovative activity.”

Market failure, as we address it, could be termed “technological or innovation market failure.” Such market failure refers to the market—including both the R&D-investing producers of a technology and the users of the technology—underinvesting, from society’s standpoint, in a particular technology. Such underinvestment occurs because conditions exist that prevent organizations from fully realizing or appropriating the benefits created by their investments.

The following explanation of market failure and the reasons for market failure follow closely from Arrow’s seminal work, in which he identifies three sources of market failure related to knowledge-based innovative activity: “indivisibilities, inappropriability, and uncertainty” (Arrow 1962b, p. 609).15

Consider a marketable technology to be produced through an R&D process where conditions prevent the R&D-investing firm from fully appropriating the benefits from technological advancement. Other firms in the market or in related markets will realize some of the profits from the innovation, and consumers will typically place a higher value on a product than the price paid for it. The R&D-investing firm will then calculate, because of such conditions, that the marginal benefits it can receive from investment in such R&D will be less than could be earned in the absence of the conditions reducing the appropriated benefits of R&D below their potential—namely, the full social benefits. Thus, the R&D-investing firm might underinvest in R&D relative to what it would have chosen as its investment in the absence of the conditions. Stated alternatively, the R&D-investing firm might determine that its private rate of return is less than its private hurdle rate and therefore would not undertake socially valuable R&D.

This basic concept can be illustrated with Figure 1.1, which follows from Tassey (1997) and Jaffe (1998). The social rate of return is measured on the vertical axis, along with society’s hurdle rate on investments in R&D. The private rate of return is measured on the horizontal axis, along with the private hurdle rate on R&D. A 45-degree line (dashed) is imposed on the figure under the assumption that the social rate of return from an R&D investment will at least equal the private rate of return from the same investment. Two separate R&D projects
Figure 1.1 Spillover Gap between Social and Private Rates of Return to R&D

are labeled as Project A and Project B. Each is shown, for illustrative purposes only, with the same social rate of return.

For Project A, the private rate of return is less than the private hurdle rate because of barriers to innovation and technology (discussed below). As such, the private firm will not choose to invest in Project A, although the social benefits from undertaking Project A would be substantial (i.e., above the social hurdle rate).

The principle of market failure illustrated in the figure relates to appropriability of returns to investment. The vertical distance shown with the double arrow for Project A is called the spillover gap; it results from the additional value society would receive above what the private firm would receive if Project A were undertaken. What the firm would receive is less than its hurdle rate because the firm is unable to appropriate all of the returns that spill over to society. Project A is the type of project in which public resources should be invested to ensure that the project is undertaken.
In comparison, Project B yields the same social rate of return as Project A, but most of that return can be appropriated by the innovator, and the private rate of return is greater than the private hurdle rate. Hence, Project B is one for which the private sector has an incentive to invest on its own, even though the social rate of return is greater than the private rate of return. Or, alternatively stated, there is no economic justification for public resources being allocated to support Project B.

For projects of Type A, where significant spillovers occur, government’s role has typically been to provide direct funding or technology infrastructure through public research institutions, which lowers the marginal cost of investment so that the marginal private rate of return exceeds the private hurdle rate.

Note that the private hurdle rate is greater than the social hurdle rate in the figure. This is primarily because of management’s (and employees’) risk aversion and issues related to the availability and cost of capital. These factors represent an additional source of market failure that is related to uncertainty. For example, because most private firms are risk-averse (i.e., the penalty from lower-than-expected returns is weighted more heavily than the benefits from greater-than-expected returns), they require a higher-hurdle rate of return compared to society as a whole, which is closer to being risk-neutral.\textsuperscript{16}

To reduce market failures associated with inappropriability and uncertainty, government typically engages in activities to reduce technical and market risk (actual and perceived). There are several circumstances—termed barriers to technology and innovation—that cause market failure and an underinvestment in R&D.\textsuperscript{17} Stated differently, there are a number of factors that explain why a firm will perceive that its expected private rate of return will fall below its hurdle rate, even when the social rate of return exceeds the social hurdle rate.\textsuperscript{18} Individuals will differ about a listing of such factors, not only because they are not generally mutually exclusive, but also because of the relative importance of one factor compared to another in whichever taxonomy is chosen.
AN OVERVIEW OF THE BOOK

While the literature-based arguments supporting an innovation-based economic growth strategy are clear, many if not most of the empirical studies to date have narrowly focused on the aggregate relationship between R&D (or innovative activity) and productivity (or economic growth). The more micro relationship between innovation and employment has largely been ignored by scholars to date, although in the current economic environment—that of a record federal deficit and unemployment only slightly below 10 percent—job growth is one issue that is raised in connection with nearly every public-sector expenditure.

In subsequent chapters we statistically examine employment growth associated with public support of R&D in small, entrepreneurial firms through the Small Business Innovation Research (SBIR) program. The SBIR program, which is discussed in detail in Chapter 2, is a public/private partnership that provides research grants to small firms to fund projects that are expected to result in commercialized innovations. Any government agency with an extramural research budget in excess of $100 million must set aside 2.5 percent of that budget to fund small-firm research that is aligned with the research mission of the agency. While the objective of the SBIR program is, generally, to stimulate innovation activity, it is reasonable to expect that employment growth at some level will follow from such public support of R&D. Our emphasis on employment growth is motivated not only by the academic literature but also by the current policy emphasis on job growth, especially as it relates to public support of innovation in small firms.

Our empirical analysis is based on information assembled by the National Research Council (NRC) of the National Academies in response to a congressional charge for it to make recommendations for changes in the SBIR program. As we discuss in Chapter 3, to meet this charge, the NRC assembled what is arguably the most complete database available for studying employment issues in innovative small firms; it is used for the empirical analyses presented in the following chapters.

As requested by Congress, the scope of the NRC database is limited to Phase II SBIR awards by the five largest agencies: the Department of Defense (DoD), the National Institutes of Health (NIH), the National
Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the National Science Foundation (NSF). In Chapter 3, we give an overview of the history of the database, and we discuss the methodological approach used by the NRC to construct it. Firm-level and project-level variables in the data that are used in the statistical analysis in subsequent chapters are defined, and descriptive statistics on all variables are presented.

Chapter 4 is the first of three chapters specifically focused on employment impacts associated with SBIR funding. Its emphasis is on project-specific impacts, and the emphasis of Chapters 5 and 6 is on firm-wide impacts. That said, one might reasonably liken our empirical investigation into the innovation-employment relationship to a hunt for a Heffalump. The reason for this is that previous research on the economic impact of R&D, entrepreneurship, and innovation on productivity and economic growth has been at an aggregate level. Whether an innovation-employment relationship will show up in the data at the project or even the firm level is an empirical issue, but logic suggests that the relationship might be there at least for some firms. A firm invests in R&D and, given time, that research results in a new technology. The firm then commercializes the innovation. To meet the market demand for the innovation, assuming the firm plans to sell its innovation in the marketplace, the firm will likely hire new workers to produce it. However, if the firm innovates only with the intent of selling or licensing its innovation to others, job growth might not be present. Moreover, a lack of substantial job growth in the small firms conducting the R&D leading to innovation might even be expected, given that the theoretical foundation of public policy to stimulate innovation is based on market failure grounded in spillovers of value created by the innovating firms but appropriated by others. In any case, the innovation-employment relationship has yet to be studied systematically at any level of aggregation.

In Chapter 4, we identify at the SBIR project level variables that are correlated with the number of employees retained as a result of the technology developed during the SBIR-funded project. This descriptive analysis is narrow in its focus. It relates only to the direct, narrowly focused, and project-specific employment effects that occur from an SBIR project. Anticipating our findings, we know that SBIR-funded projects typically retain very few employees—on average, one to two
employees—after the completion of the funded project to pursue the technology that was developed. In our findings, just over two-fifths of all completed projects retained no employees, and over one-third retained only one or two employees. Among many other findings, we see from the data that the number of retained employees is greater when the government actually uses the technology created with the SBIR award, thereby providing a clear commercial goal and ultimately creating a market for the commercialized result of the SBIR project.

Chapters 5 and 6, in contrast, focus on the broader, longer-term employment impact on the firm as a whole (as opposed to only the funded project) from SBIR funding. We argue that this broader focus is an appropriate next step for understanding more completely the employment impacts associated with these public investments in innovation. The analysis in Chapters 5 and 6 is based on an economic growth model suited to the data limitations in the NRC database, as discussed in Chapter 3. Our model, which is counterfactual in construction and implementation, allows us to make direct causal inferences about the impact of the SBIR-funded innovative activity on overall firm employment growth.

Specifically, in Chapter 5, we estimate the employment impact of SBIR funding on our sample of firms. We compare a firm’s actual level of employment after receipt of an SBIR award and completion of the research project to the level of employment predicted by the firm’s characteristics prior to receiving the award. In other words, our analysis focuses on a comparison of the firm’s actual employment with the firm’s predicted employment had the firm not received the SBIR funding for the sampled project. We find, on average among firms funded by the DoD, NIH, NASA, and DOE (but not by the NSF), that the difference between actual employment growth and predicted employment growth is positive. (The data in the NRC database relate to the year 2005.) For the DoD and NIH samples, the positive employment impact of a sampled award is statistically significant for several of the awards. However, the average difference between actual employment and predicted employment absent the award is not statistically different from zero for any of these agencies. We cannot conclude that, on average, SBIR awards generate a permanent long-run employment benefit to the firms funded by these agencies that are in our sample because, although
there are average employment gains that appear quite substantial, the average gains are not statistically significant.

Despite the lack of statistical significance in the average employment gains for firms after receiving a sampled award, there are numerous individual cases of significant gains (statistically and economically) and large ranges in significance of the gains in the individual cases for all agencies. In Chapter 6, we build on those ranges in the results from Chapter 5 and posit an exploratory model to identify the variables related to SBIR-induced employment growth for the firm as a whole—that is, the variables related to the difference between actual employment for the firm and its predicted employment without the support of the SBIR award. We find, across agency projects, that there is considerable variation in the group of covariates associated with actual employment growth above predicted employment growth. The single covariate that is important, for SBIR-induced employment growth, across all agency samples is the presence of firm investments in intellectual property.

In Chapter 7, we explore the possibility of employment effects beyond the firm. Specifically, we examine descriptively the extent to which SBIR-funded projects result in commercial agreements with other U.S. firms or investors, comparing the extent of agreements made with foreign firms or investors. This inquiry builds on the empirically based discussion in Chapters 4 through 6 regarding such agreements. Our description shows that SBIR funds, and the associated technologies and employment growth, are benefiting not only U.S. firms and investors, but also foreign firms and investors through commercial agreements.

To our knowledge, our analysis is the first to use a counterfactual model to quantify the magnitude of the relationship between investments in innovation through public support of R&D and the resulting employment growth. As such, we view our empirical analysis of the employment growth in the small firms performing the R&D supported with SBIR funds as somewhat exploratory both in scope and in specification.

Our analyses in Chapters 5–7 represent an evaluation of one aspect of the SBIR program, namely employment growth, and such evaluations have attracted the administration’s attention. Specifically, Peter Orszag, then the director of the Office of Management and Budget, wrote in an October 7, 2009, memorandum to the heads of executive
departments and agencies on the subject of increased emphasis on program evaluation, “Rigorous . . . program evaluations can be a key resource in determining whether government programs are achieving their intended outcomes . . . and at the lowest cost. Evaluations . . . can help the Administration determine how to spend taxpayer dollars effectively and efficiently . . .” (Orszag 2009).22

Finally, in Chapter 8 we conclude with a brief summary of our findings, and we reiterate our view of their possible importance for future public policy. Our study of the NRC database reveals that the public’s support of R&D in SBIR firms results at best in only modest employment gains within the SBIR firms themselves. However, our evidence supports the expectation that the accomplishments of these small firms will have employment effects that show up elsewhere in the U.S. economy and in foreign markets. Such employment effects beyond the SBIR firms themselves result from commercial agreements, such as the sale of technology rights to other firms, and through the spillovers of value from the R&D that the SBIR firms do not appropriate at all. As we have explained in this introductory chapter, such spillovers are at the heart of the market failure, which is the raison d’être for the public support of R&D in small, entrepreneurial firms.

Notes

1. The NBER dates the Great Depression as having lasted from August 1929 to March 1933, a period of 43 months. See http://www.nber.org/cycles/cyclesmain.html.
2. These unemployment statistics come from the Federal Reserve Bank of St. Louis. See http://research.stlouisfed.org/fred2/series/UNRATE.
3. The Council of Economic Advisers, as part of accountability and transparency provisions in ARRA, has released quarterly reports assessing the economic impact of ARRA.
4. The policy emphasis in ARRA on jobs, especially innovation-based jobs, can be traced back at least to the National Academy of Sciences report Rising above the Gathering Storm: Energizing and Employing America for a Better Economic Future (Committee on Prospering in the Global Economy 2007). This report was the foundation for the America COMPETES Act of 2007 (P.L. 110-69), which was reauthorized as the America COMPETES Reauthorization Act of 2010 in January 2011.
5. See Link (1987) and Link and Siegel (2003) for the literature related to culprits of the productivity slowdown.
6. R&E refers to research and experimentation activity. Experimentation is a more narrowly defined activity than development, according to National Science Foundation reporting definitions.


8. Hébert and Link (1988, 2009) provide an overview of the intellectual history of thought on who the entrepreneur is and what he or she does.

9. See, Hall, Mairesse, and Mohnen (2010) for a survey of this literature.

10. The Small Business Administration defines small firms as those having fewer than 500 employees. In the Acs and Audretsch (1990) study, innovations were defined by a contracted data-collecting firm as the number of new products reported in technology, engineering, and trade journals. Baldwin and Scott (1987) provide a review of the earlier literature about the relative innovativeness of small versus large firms.

11. The comparison does not necessarily mean that the smaller firms are more effective at producing innovations. Comparisons across firms of different sizes of their proportions of sales taken by R&D expenditures have been criticized because economies in large-scale use of R&D resources could imply that larger, less R&D-intensive firms are more effective at producing innovations than smaller, more R&D-intensive firms. Kohn and Scott (1982) establish the conditions for the possible relationships between the distributions of R&D across firm sizes and the distributions of their R&D output. Importantly, if R&D increased more than proportionately with firm size, then that would imply that the output of R&D activity also increased more than proportionately. However, the reverse relation does not hold. We do have evidence about the distribution of R&D output across firm sizes, however, and much of that supports the relative effectiveness of the smaller firms’ R&D investments.

12. The ratio of R&D to firm sales was 15.8 percent for R&D firms with fewer than 25 employees and 3.1 percent for firms with more than 25,000 employees.

13. Were it not for Kahin and Hill (2010), we would not have known about this statement.

14. The conceptual importance of identifying market failure for policy is also emphasized, although without any operational guidance, in Office of Management and Budget (1996).

15. Although Arrow does not elaborate on indivisibilities and inappropriability in his paper, the concepts are well understood in the innovation literature. Recalling that Arrow (1962b, p. 609) defines innovation “as the production of knowledge,” we know that the market does not price knowledge in discrete bundles, and thus because of such indivisibilities market prices may not send appropriate signals for economic units to make marginal decisions correctly.

16. There are two parts to the answer to the twin questions of how the social hurdle rate is determined and why it is represented as being less than the private hurdle rate. The first is grounded in the practice of evaluations, and the second is grounded in the theory of public policies to address market failure.
1) Regarding practice, the U.S. Office of Management and Budget (OMB) has mandated that a specified real rate of return be used as the rate for evaluation studies—that is, the rate to be considered the opportunity cost for the use of the public funds in the investment projects. The OMB (1992, p. 9) has stated that “constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent.” That real rate of return (and the related nominal rates derived by accounting for expected inflation rates in various periods of analysis) has been far less than what the respondents in case studies have reported (Link and Scott 2011) as the private hurdle rate for comparable investment projects in industry during comparable time periods.

2) Regarding theory, when we evaluate public investment projects, we are invariably looking at cases where there has been some sort of market failure. To improve upon the market solution, the government has become involved (in a variety of ways, in practice) with an investment project. Just as market solutions for the prices of goods may not reflect the social costs for the goods (because of market failure stemming from market power, imperfect information, externalities, or public goods), the private hurdle rates that reflect market solutions for the price of funds—the opportunity cost of funds to the private firms—might not reflect the social cost of the funds. The government might decide that the appropriate social cost—the opportunity cost for the public funds to be invested—differs from the market solution. Typically, in practice, for the public R&D projects we have studied, the government evidently believes that it faces less risk than the private sector firms doing similar investments; hence it will believe a lower yield is satisfactory because the public is bearing less risk than the private sector firm going it alone with a similar investment. More generally, government must decide what the opportunity costs of its public funds will be in various uses, and in general that will not be the same as the market rate. However, all that having been said, clearly we know from Arrow’s thinking about social choice that the government’s decision about what the rate should be cannot possibly reflect the diversity of opinion in the private sector regarding the decision (Arrow 1963). Consequently, as a logical matter, one could not prove that the government’s choice of the right hurdle rate is obviously correct, because diversity of opinion about the correct rate will not be reflected in the government’s choice.

17. These factors are not independent of each other. They include high technical risk associated with the underlying R&D, high capital costs to perform the underlying R&D with high market risk, length of time to complete the R&D and commercialize the resulting technology, the fact that underlying R&D spills over to multiple markets and is not appropriable, that market success of the technology depends on technologies in different industries, that property rights cannot be assigned to the underlying R&D, that resulting technology must be compatible and interoperable with other technologies, and the high risk of opportunistic behavior when sharing information about the technology.

18. As Arrow (1962b) explains, investments in knowledge entail uncertainty of two types—technical and market. The technical and market results from technology
may be very poor, or perhaps considerably better than the expected outcome. Thus, a firm is justifiably concerned about the risk that its R&D investment will fail, technically or for any other reason. Or, if technically successful, the R&D investment output may not pass the market test for profitability. Furthermore, the firm’s private expected return typically falls short of the expected social return, as previously discussed. This concept of downside risk is elaborated upon below and in Link and Scott (2001).

19. This global view is logical in the sense that aggregate economic growth is the overriding long-term objective of most public policies.

20. DOE, as opposed to the other abbreviations of departments here, has a capital “O” because of a departmental policy that capitalized it to distinguish the Department of Energy from the Department of Education.

21. A Heffalump is an imaginary elephant in the dreams of Piglet in the book Winnie-the-Pooh. The Heffalump gained academic notoriety through the writings of Kilby (1971), who wrote, “The search for the source of dynamic entrepreneurial performance has much in common with hunting the Heffalump . . . He has been hunted by many individuals using various ingenious trapping devices, but no one so far has succeeded in capturing him. All who claim to have caught sight of him report that he is enormous, but they disagree on his particularities . . . [But] the search goes on” (p. 1).

22. Hearings before the Senate Budget Committee were held on October 29, 2009, in support of Orszag’s point of view. Also, two chapters about program evaluation have been included in the Fiscal Year 2011 and the Fiscal Year 2012 Budget of the U.S. Government; see http://whitehouse.gov/sites/default/files/omb/budget/fy2011/assets/spec.pdf and http://whitehouse.gov/sites/default/files/omb/budget/fy2012/assets/spec.pdf. Chapter 8 is on program evaluation and Chapter 9 is on benefit-cost analysis (OMB 2010).