THE HAMILTON PROJECT

STRATEGY PAPER

DECEMBER 2006

Promoting Opportunity and Growth through Science, Technology, and Innovation

Jason E. Bordoff, Michael Deich, Rebecca Kahane, and Peter R. Orszag

The Brookings Institution

The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by making economic growth broad-based, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments. Our strategy—strikingly different from the theories driving current economic policy—calls for fiscal discipline and for increased public investment in key growth-enhancing areas. The Project will put forward innovative policy ideas from leading economic thinkers throughout the United States—ideas based on experience and evidence, not ideology and doctrine—to introduce new, sometimes controversial, policy options into the national debate with the goal of improving our country's economic policy.

The Project is named after Alexander Hamilton, the nation's first treasury secretary, who laid the foundation for the modern American economy. Consistent with the guiding principles of the Project, Hamilton stood for sound fiscal policy, believed that broad-based opportunity for advancement would drive American economic growth, and recognized that "prudent aids and encouragements on the part of government" are necessary to enhance and guide market forces.

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Introduction

Americans are facing heightened economic pressures from the effects of globalization as workers from China, India, and other developing nations play a growing role in the world's economy. Advances in technology and transportation now mean that U.S. workers increasingly are competing with workers overseas—not just in manufacturing, but also in high-skill and high-wage sectors (Blinder 2006). Growth in information technologies, in particular, has facilitated deeper integration of economies across the globe while also posing both new opportunities and new challenges for the U.S. economy (Mann and Kirkegaard 2006).

Maintaining our nation's economic leadership in the world and promoting broad-based growth at home will require effective policies to support research, innovation, and access to advanced information and telecommunications technologies. Innovation has long fueled economic growth, often giving rise to new industries and new jobs. According to the National Academies, "Since the Industrial Revolution, the growth of economies throughout the world has been driven largely by the pursuit of scientific understanding, the application of engineering solutions, and continual technological innovation" (National Academies 2005b, p. 2–1). Numerous academic studies confirm that technological progress has accounted for a significant share of U.S. economic growth;[1] a recent study shows that the share of economic growth directly attributable to research and development (R&D) investment has increased over time.[2] What makes knowledge, innovation, and technology such powerful drivers of economic growth is that, unlike capital and labor, they do not suffer from diminishing returns. Indeed, in many cases the creation of knowledge and technological innovation actually increase the return to further knowledge and innovation, thus creating a powerful growth mechanism (Romer 1986).

In the United States, the private sector now accounts for nearly two-thirds—64 percent—of total spending on R&D (National Science Foundation [NSF] 2006b, Figure 4.2), and plays a critical role in the development of new technologies that benefit consumers, increase productivity, and raise standards of living. Nevertheless, especially as the world economy becomes increasingly concentrated in knowledge-intensive industries, government has an essential, complementary role in promoting innovation and access to technology. The crucial role of the government in promoting innovation runs contrary to the view that free markets would generate the maximum possible economic growth if government would just get out of their way.

The need for public investment in research arises because, left to itself, the private sector will invest less in R&D than is justified by the benefits that R&D

1. Work in the 1950s by Nobel Prize Laureate Robert Solow of MIT, for example, estimates that more than 85 percent of the labor productivity (output for each worker) growth from 1909 to 1949 was attributable to technological change (Solow 1957, pp. 321–30). Although later estimates were not as high as Solow's, they all demonstrated the substantial role played by technological advances (Denison 1985; Aghion and Howitt 1992, pp. 323–50; Stiroh 2000).
2. The direct contribution of R&D investment to economic growth in real GDP was 6.7 percent during 1995–2002, up from 4.3 percent during 1974–94 and 4.0 percent during 1959–73 (Bureau of Economic Analysis and National Science Foundation 2006).

offers to society. This underinvestment results from the fact that innovators receive only a small fraction of the benefits from their inventions. Several estimates show that innovators capture less than one-quarter of the total value of their innovations; the remaining benefits accrue to consumers of products that make use of the innovations.[3] As a result, the private sector invests less in R&D than is necessary for the nation to realize its full potential for broad-based economic growth. Such underinvestment is particularly acute in basic research (as opposed to applied R&D), which has important spillover benefits and plays a key role in developing the fundamental technologies that are too distant from the commercial marketplace to attract sufficient private sector investment.[4]

3. One recent survey of the literature shows private investments in R&D with social rates of return estimated to be between 30 and 50 percent, and private rates of return between 7 and 15 percent (Popp 2004, p.4).
4. Although industry-funded R&D has increased steadily since 1991, that increase has occurred almost entirely in near-term, incremental R&D; industry-funded basic R&D has remained largely unchanged and has fallen as a percent of GDP (all adjusted for inflation; American Association for the Advancement of Sciences [AAAS] 2006a).

The Challenge Ahead

By nearly every metric, the United States leads the world in science and technology. The United States is the global leader in scientific output as measured by total articles published (King 2004), number of citations, and share of frequently cited articles. In addition, a recent comparison concluded that thirty-eight of the world's fifty leading research institutions were in the United States; for decades, these institutions have been the destination of choice for the world's best science and engineering students (Shanghai Jiao Tong University 2004).

Because the United States is at the frontier of modern technological and scientific advances, sustaining economic growth depends substantially on our ability to advance that frontier. This is in contrast to countries that are less technologically advanced, which can grow by moving up to the technological frontier. As Richard B. Freeman of Harvard University notes, "the United States is more likely to maintain a healthy share of leading-edge industries, which have the fastest productivity growth, pay higher wages to production workers, and offer spillovers of knowledge to other sectors, if the United States pioneers scientific advances than if other countries pioneer those advances" (Freeman 2006).

To remain at the technological frontier, the United States must make more workers literate in science and engineering (since the nation cannot rely exclusively on skilled immigrants to spur technological advances here; see Box 1); embrace a redesigned system of national investments in—along with a stronger commitment to—scientific research; and adopt more effective incentives for private sector firms to undertake R&D.

This paper focuses on the three key policy priorities to promote U.S. leadership in science and technology and spur economic growth through innovation: individuals, investment, and incentives.

Individuals: Human Talent. The first component involves America's people—its human capital—and the need to improve our education and training, particularly in science and math, in order to develop a high-quality labor force that can prosper in the global information economy. To spur growth and improvements in living standards, the nation must also help families and workers have access to advanced technologies, including broadband.

Investment: R&D. The second component involves the need to revamp and strengthen the federal government's investments in R&D, particularly the type of blue-sky basic research that, by definition, has no immediately apparent commercial viability. This is the kind of research for which government support is particularly needed since the private sector underinvestment is particularly acute.

Incentives: Effective Government Regulation. The third component concerns the need for the federal government to create adequate incentives, through the tax code and an effective intellectual property regime, to encourage private sector investment in growth-enhancing technological innovations. Without such incentives, the private sector would underinvest in science and technology, because the benefits of innovation accrue to society in ways that cannot be captured by individual firms.

Individuals: Human Talent

The productive power of the U.S. economy lies heavily with its people. The Office of Management and Budget (OMB), for example, estimates that all privately owned commercial buildings and equipment in the United States are worth $13 trillion, but that the nation's human capital, as embodied in the skills of its workforce, is worth more than three times that: $48 trillion (OMB 2005, p. 195). Strong skills in math and science, in particular, are one critical step in maintaining a high-quality labor force, which in turn drives robust economic growth. Several studies have found a direct correlation between a nation's science and math skills and its rate of economic growth (Barro 2001, Hanushek and Kim 1995).

Although bolstering our nation's scientific skills has arguably become increasingly important, the number of bachelor's degrees earned in certain critical areas—such as engineering and the physical and mathematical sciences—has been flat or declining (NSF 2003, Figure 1). The United States now lags behind more than sixteen countries in Europe and Asia in the proportion of 24-year-olds holding bachelor's degrees in the natural sciences or engineering (NSF 2004b, Chapter 2). Similarly, the share of bachelor's degrees awarded in natural sciences and engineering (i.e., science and engineering degrees exclusive of social sciences and psychology) in the United States is lower than in China, Germany, Japan, South Korea, and the United Kingdom (NSF 2006b, Appendix Table 2–38). In 2002, for example, 17 percent of

BOX 1

The Limitations of Relying on Immigrant Science and Engineering Talent

Currently, some of the most talented scientists and engineers working in the United States have come from abroad to work and innovate in the United States contributing to U.S. economic growth. In fact, there are many more highly skilled workers that would like to come to the United States than are allowed by U.S. policy.[a] It may thus seem unnecessary to spend resources increasing the supply of U.S. students in science and engineering since the country can benefit from the educational systems of other countries by employing an international talent pool.

As discussed below, the United States must strike a balance that allows the most highly skilled immigrant talent to work and innovate in the United States, while avoiding an excessive reliance on immigrant science and engineering talent. There are three reasons for this position: First, our ability to attract the world's most highly skilled workers may decline as their home countries develop their own high-tech industries, thereby offering greater opportunities to native scientists and engineers.[b] Thirty years ago, most U.S.-educated doctoral science and engineering graduates from Taiwan and the Republic of Korea remained in the United States after earning their degrees; today, a large proportion of these graduates return to their native countries following completion of their programs (Freeman 2006). Many Chinese and Indian students now expect to remain in the United States (90 percent and 86 percent, respectively, as of 2003; Finn 2003), but those numbers are likely to decline as China and India develop their economies and increase opportunities for native students.

Second, our access to high-skilled immigrant scientists and engineers could be limited by changing political or security concerns—a risk that became more salient after September 11, 2001. Since those events, the United States has imposed significantly tighter visa restrictions on international students (National Academies 2005a, Chap. 2, esp. pp. 72–77). Similarly, political factors may limit the willingness of international students to come to the United States (Mazzarol and Soutar 2001, Davis 2003, Johnson 2001).

Finally, security considerations require that research within certain Department of Defense laboratories and the National Security Agency be performed only by U.S. citizens. As a result, the United States needs an adequate supply of highly skilled scientists and engineers who are U.S. citizens to work in those restricted facilities.

a. The cap on the number of H1-B visas (nonimmigrant work visas issued to applicants seeking temporary work in a high-skilled specialty occupation) was lowered to sixty-five thousand for 2007 from one hundred and fifteen thousand in 2000, for example. The cap for fiscal year 2007 was filled in under two months (U.S. Department of Homeland Security 2006).

b. Decisions to stay in the United States appear to be strongly affected by conditions in students' home countries, primarily unemployment rates, percentage of the labor force that works in agriculture, and per capita GDP (Johnson 2001).

undergraduates in the United States earned degrees in natural sciences and engineering, compared with 53 percent in China (NSF 2006b, Appendix Table 2–38). It is estimated that by 2010 China annually will produce more science and engineering doctoral graduates than will the United States (Freeman 2005, p. 4).

For those who choose to continue their education with a graduate degree in science, the time it takes to get the degree and to work in postdoctoral (or similar apprenticeship) roles has been gradually lengthening (Teitelbaum 2002). Although the time it takes to become a scientist has increased, the compensation in science and engineering fields has declined relative to other high-level occupations (Freeman 2005, p. 10.).

Investing in the education of U.S. students in the sciences is critical for the American workforce to prosper in the knowledge-based, technology-driven global economy of the twenty-first century. As former Federal Reserve Chairman Alan Greenspan explains, "If we are to remain preeminent in transforming knowledge into economic value, the U.S. system of higher education must remain the world's leader in generating scientific and technological breakthroughs and in preparing workers to meet the evolving demands for skilled labor" (Greenspan 2000). Several proposals have been put forth to improve different levels of science and engineering education and help us achieve this goal. Some focus on K-12 education by proposing dramatic increases in the number and quality of science and math teachers (National Academies 2005b, Office of Management and Budget [OMB] 2006b). A coalition of prominent business organizations proposes creating financial incentives to double the number of U.S. undergraduate students in science and engineering (e.g., Business Roundtable 2005). Other proposals would increase the number of high school students taking college-level science and math courses (National Academies 2005b); extend special master's degree programs that combine advanced science instruction with practical, professional training (National Innovation Initiative 2004); or reform doctoral education through measures that focus on decreasing time-to-degree, broadening the scope of the degree, and improving retention (Association of American Universities 2006). All these proposals represent interesting approaches, though some are potentially more effective than others.

A new discussion paper released by The Hamilton Project considers a proposal to increase the number of high-quality U.S. scientists and engineers in the near term. Richard Freeman of Harvard University proposes increasing the number of science and engineering graduate students in the United States by increasing both the value and number of NSF graduate research fellowships (GRFs) (Freeman 2006). Freeman builds his proposal on data showing that such an expansion of NSF GRFs can significantly increase the number of students pursuing these fields with little reduction in the quality of those students. Specifically, he proposes that NSF triple the number of GRFs it awards for science and engineering work, and continue to increase the value of those awards relative to earnings elsewhere in the economy. According to Freeman, tripling the number of NSF awards would roughly restore the ratio of GRFs to undergraduate science and engineering degrees to the ratio in the early 1960s, after the Sputnik challenge. Freeman argues that by making the GRF program more generous, many of the most highly qualified U.S. students will continue on to graduate work in science and engineering rather than pursue other more lucrative fields.

Another component of the nation's effort to promote a technically skilled workforce includes continuing to attract skilled scientists and engineers from abroad. High-skilled immigrant workers have contributed greatly to technology development and innovation. More than one-third of all businesses founded in Silicon Valley during the 1990s were started by people born overseas—people such as Russian-born Sergei Brin, who founded Google, thereby revolutionizing how we get information; and Pierre Omidyar, born in Paris to Iranian parents, who founded eBay, thereby creating a powerful economic marketplace where more than 724,000 Americans currently earn their primary or secondary income (eBay 2006). Almost one-half of U.S. Nobel laureates in science fields have been foreign-born (National Academies 2005a, p. 60). These innovators drive economic growth and increase

BOX 2

The Effect of High-Skilled Immigration on U.S. Wages

Most studies of the effect of immigration on wages of U.S. workers have focused on low-skill levels. Several studies have found that low-skilled immigrants may reduce the wages of low-skilled U.S. workers, although significant dispute exists about the magnitude and significance of the effect. George Borjas of Harvard, for example, finds that during 1980–2000, immigration contributed to a decrease in average U.S. wages of roughly 3 percent, and that this impact was felt most acutely by low-skilled workers (Borjas 2003). (Wages of native U.S. workers without a high school degree fell by 9 percent as a result of immigration.)* David Card of the University of California, Berkeley, by contrast, finds that immigration overall does not reduce the labor market opportunities of low-skilled natives (Card 2005).

The evidence is even more mixed for the impact of high-skilled immigrants on the wages of native U.S. workers. Borjas estimates that an immigration-induced increase of 10 percent in the supply of doctorates in a particular doctoral field is associated with a 3–4 percent reduction in the wages of competing U.S. workers (Borjas 2004). Other studies reach different conclusions. Federal Reserve economists Pia Orrenius and Madeline Zavodny find that an increase in the fraction of foreign-born workers in low-skilled occupations tends to lower the wages of native U.S. workers in those occupations, but an increase in the fraction of foreign-born workers in high-skilled occupations has no such effect (Orrenius and Zavodny 2003). Economists Gianmarco Ottaviano and Giovanni Peri find that immigration does not depress wages of U.S. workers because there is no perfect substitutability between similarly skilled workers from different backgrounds, and that lack of substitutability is especially true for high-skilled workers (Ottaviano and Peri 2005). Furthermore, high-skilled immigrants fuel innovation and add to an industry's dynamism and growth, as immigrant workers did for the growth of the technology sector in Silicon Valley. Some of the resultant benefit accrues to native U.S. workers; for example, the Silicon Valley boom not only created more engineering and computer programming jobs, but also boosted demand for intellectual patent lawyers and marketing executives (Ottaviano and Peri 2005).

* For an overview of the costs and benefits of immigration, see Hanson (2004).

the demand for U.S. workers in a given industry, as well as in complementary industries.[5]

Despite the enormous potential for innovation, productivity, and scientific progress from immigrant talent, the United States today is failing to realize fully the benefits of that potential. As noted above, fewer immigrant workers are being granted H1-B visas than in previous years. In addition, U.S. universities have witnessed declining applications and enrollments for some types of international students. New enrollments of international graduate students in U.S. science and engineering programs, for example, declined 20 percent between 2001 and 2004 (NSF 2006a), although recent data suggest that a rebound has begun.[6]

In response to concerns that the United States is failing to take full advantage of the global talent pool, several organizations have advanced reform proposals. The National Academies, for example, has urged the federal government to provide clearer visa and immigration procedures, and to continue discussion with research institutions on issues such as visa duration and reciprocity agreements (National Academies 2005a). In addition to such targeted reforms, more significant structural reforms may be needed, such as shifting the system's focus, at least partly, from a family-based to a skills-based model (Gary S. Becker, "Give Us Your Skilled Masses," Wall Street Journal, November 30, 2005; Chiswick 1995, pp. 46–50; Borjas 1996). Other possible structural approaches, which move away from the idea of a fixed

5. Indeed, one study provides evidence that immigrant skilled workers do not substitute for U.S. skilled workers, but rather add to that talent base ("Our results strongly favor the view that international graduate students and immigrants under technical visas are significant inputs into developing new technologies" Chellaraj et al. 2004, p. 29). Chellaraj and colleagues estimate that a 10 percent increase in the number of international graduate students would raise university patent grants by 6 percent and nonuniversity patent grants by 4 percent.
6. A survey of all graduate students (not just those in science and engineering) shows that first-time enrollments of international students increased 1 percent in 2005 and 12 percent in 2006 (Council of Graduate Schools 2006).

numerical cap, include auctions of H1-B visa–sponsoring privileges to employers, or a floating cap on that visa that varies according to national unemployment (Gary S. Becker, "An Open Door for Immigrants: The Auction," *Wall Street Journal*, October 14, 1992; Becker 2005; National Research Council 2001a, p. 306; see also U.S. Congress 2006b.)

A final component to upgrading the technological sophistication and capacity of the American workforce, as a means of spurring broad-based growth, involves improving access to advanced technologies for more families and workers. In future work, for example, The Hamilton Project will explore ways of expanding broadband access to a wider array of American households.

BOX 3

Multi-billion Dollar IT Industries that Emerged from Federal Basic Research

Broadband in last mile	Portable communication
Client-server computing	RAID/disk servers
Data mining	Relational databases
Graphical user interfaces	RISC processors
Computer graphics	Speech recognition software
Internet	Computer timesharing
LANs	VLSI design
Parallel computing	Computer workstations
Parallel databases	World Wide Web

Source: National Research Council 2003, Figure 1

Investment: R&D

Overall, public investment in R&D yields a high rate of return; one study estimates the rate of return on academic science R&D to be almost 30 percent (Mansfield 1991).

In recent decades, university researchers have looked principally to a dozen or so federal sources for grant support, including NSF, the National Institutes of Health (NIH), the Department of Energy, the Department of Defense, and NASA. Research investments by these agencies often have paid large dividends that benefit society, and federal support for basic science and technology research has been key to the development of several industries (National Academy of Engineering 2003). For example, a recent report by the National Academies lists over a dozen areas in which federally sponsored basic research led to innovations that ultimately became multibillion-dollar IT industries (see Box 3).

Several recent trends, however, raise questions about the effectiveness of U.S. strategy for public investment in R&D. First, some federal funding for basic research, especially at the Department of Defense, has shifted from the long-term, blue-sky research (which is most likely to yield significant technological breakthroughs) to projects designed to reach more-specific findings within shorter time horizons. For example, the Defense Advanced Research Projects Agency (DARPA) has begun to conduct formal go/no go reviews of many projects at twelve- to eighteen-month intervals as opposed to the previous thirty-six-month intervals. The Committee on Science in the U.S. House of Representatives has expressed concern that these reviews shift research to efforts that promise a payoff that is more immediate than the blue-sky research DARPA had previously been willing to fund (U.S. Congress 2005, pp. 14–16). In the past, DARPA-funded blue-sky research led not only to defense products such as stealth technology and precision munitions, but also to many products with civilian applications, including the Internet, communications and weather satellites, global positioning technology, and even some of the search technologies used by Google.

Second, the latter half of the 1990s and early 2000s saw a broad shift in the composition of federal funding for basic research. Between 1995 and 2005, inflation-adjusted spending for biomedical research at NIH increased 115 percent, which is more than four times the rate of increase in spending for the physical sciences, mathematics, engineering, and even biomedical research outside NIH (AAAS 2006b). A recent report by the National Academies applauds the increase in the NIH budget, but questions the wisdom of allowing such unbalanced growth in the basic research portfolio (National Academies 2005b). Increasingly, progress in specific fields such as genomics and nanotechnology requires advances in a broad range of life sciences, physical sciences, and engineering—just as earlier advances in biomedical research, such as endoscopic surgery, smart pacemakers, dialysis, and magnetic resonance imaging were the results of basic research across a range of fields. Absent strong evidence of higher returns to a particular field, the nation's scientific enterprise is best advanced with a broad, balanced research portfolio (National Research Council 2001b).

To address these and other challenges, the National Academies and others have put forward a broad agenda to enhance public investment in research (e.g., National Academies 2005b, 6–1; National Innovation Initiative 2005; Business Roundtable 2005). The principal recommendations from the National Academies include

- increasing funding for long-term basic research, particularly in the physical sciences, mathematics, and engineering;

- providing new research grants of $500,000 each, payable over five years, to two hundred outstanding early-career researchers; and

- establishing a National Coordination Office for Research Infrastructure to manage a centralized research-infrastructure fund of $500 million a year over the next five years to help pay for the construction and maintenance of research facilities including instrumentation and supplies.

In addition to increasing selected investments in basic research, the government needs to use its R&D funding as effectively as possible. At present, most federal R&D funding is distributed through grants or contracts. In a discussion paper released by The Hamilton Project, Thomas Kalil of the University of California, Berkeley, argues that prizes for specific achievements in science and technology sometimes can be more effective than traditional mechanisms, such as grants or contracts, at spurring innovation (Kalil 2006). Examples of inducement prizes include the recently awarded $10 million Ansari X PRIZE for the first nongovernment-funded human spaceflight, and the just-announced $10 million prize for inexpensive and rapid sequencing of the human genome, both sponsored by the X PRIZE Foundation (Nicholas Wade, "$10 Million Prize Set Up for Speedy DNA Decoding," *New York Times*, October 5, 2006). The U.S. government has made limited use of prizes in the past.[7] Kalil proposes expanding the use of prizes and explains the potential and limitations of inducement prizes. For example, prizes may be more suitable than traditional funding (1) when the goal can be defined in concrete terms, but the means of achieving the goal itself are speculative; (2) if government wants to establish a goal without being prescriptive as to how that goal should be met or who is in the best position to meet it; (3) to stimulate philanthropic and private sector investment toward a goal; and (4) to attract teams with fresh ideas who might not otherwise do business with the federal government. In light of these relative advantages, Kalil (2006) argues that inducement prizes would be appropriate in areas such as space exploration, African agriculture, vaccines for developing countries, energy and climate change, and learning technologies. Kalil notes that effective implementation of inducement prizes will require careful design, including consideration of how to define the victory conditions for the prize and how to determine the number and amount of the prizes. Kalil proposes that federal agencies be directed to generate specific ideas for prizes, and that Congress then authorize the appropriate agencies to sponsor those prizes.

Incentives: Effective Government Regulation

In order to create adequate incentives for the private sector technological innovations that drive economic growth, government needs to create an effective and targeted regulatory environment that promotes innovation. In future work, The Hamilton Project will explore the regulatory and legal approaches to risk that may impede innovation. In this paper, we limit our discussion to intellectual property rights.

The granting of intellectual property rights is the only policy instrument expressly ordained by the U.S. Constitution to promote innovation (U.S. Constitution, art. 1, sec. 8, cl. 8). One of the most important ways in which the government grants such rights is through the pat-

7. For other examples of the use of prizes, both public and private, to spur innovation, see NSB 2006. For a general discussion of the use of prizes to encourage technological innovation, see U.S. Congress 2006a, p. 12 (Box 2–3).

ent system.[8] Prior to his election as president, Abraham Lincoln extolled the virtues of the patent system, saying it "added the fuel of interest to the fire of genius" (lecture on discoveries and inventions, delivered to the Phi Alpha Society of Illinois College at Jacksonville, IL, on February 11, 1859; quoted in Miller 2001). Granting intellectual property rights that are overly broad, however, can stifle the development of knowledge and technology (Nelson and Romer 1996). Virtually all innovation builds, to some degree, on prior work. As Isaac Newton famously wrote to Robert Hooke in 1676, "If I have seen further it is by standing on the shoulders of giants." Thus, providing more limited intellectual property protections can permit broader dissemination of creative works and allow future innovators to build more easily on the work of past innovators. From an economic perspective, intellectual property law must strike the appropriate balance between protection of intellectual property and scientific openness.[9]

Numerous recent studies argue that the patent system now has this balance wrong—that it is overwhelmed, inefficient, and, as a result, that it does not optimally promote innovation. The number of patents granted increased at less than 1 percent a year from 1930 to 1982, but increased at about 5.7 percent a year from 1983 to 2002, from sixty-two thousand to one hundred seventy-seven thousand a year, respectively (Jaffe and Lerner 2004). That might be a positive development if the cause were solely an increase of the rate of innovation, but evidence suggests that the explosive growth in the number of patents was accompanied by a sharp increase in the award of so-called bad patents—patents that are overbroad or that should not have been granted in the first place. Many examples have been cited in articles and reports: Patents have been issued for the crustless peanut butter and jelly sandwich, a "bread refreshing method" that involves "exposure to high heat" (i.e., toasting), and a "method of swinging on a swing" (Jaffe and Lerner 2004, pp. 25–35).

Inappropriately granted patents adversely affect innovation by creating high costs for firms that need to litigate patent lawsuits or acquire patents as a defensive measure, thereby deterring individuals and firms from pursing new ventures and keeping an excessive amount of innovation out of the public realm (Merrill et al. 2004, p. 80.). As the Federal Trade Commission concludes, "questionable patents are a significant competitive concern and can harm innovation" (Federal Trade Commission 2003). Economists who have studied the phenomenon do not agree completely on the reasons for the surge in patent applications, grants of bad patents, and patent litigation, but there is broad consensus that at the root of the problem are two recent policy changes that had the effect of strengthening patent rights and weakening the standards for granting patents. The first change was the creation in 1982 of the Federal Circuit Court of Appeals, which hears patent cases. The court has increasingly ruled in favor of patent holders, thereby encouraging more litigation by making patent holders more confident that they will win in court. The second change was congressional treatment of Patent and Trademark Office (PTO) revenues in the 1990s and early 2000s. During this period, the PTO generated large operating surpluses, but Congress used these surpluses as general revenue, leaving the PTO without sufficient resources to assess properly the surge in patent applications. Since 2005, however, the PTO has had full access to its fee revenues (Jaffe and Lerner 2004, pp. 131–132; OMB 2006a, 2006b).

In response to the challenges, various academics and others have articulated a number of different reforms for the patent industry. Perhaps most obvious is the proposal that the government spend more money on the patent system. For example, former Federal Communications Commission Chairman Reed Hundt has proposed tripling the PTO's budget from $1.5 billion to $4.5 billion (Hundt 2006; see also Farrell and Merges 2004, p. 17). The increasing number of patent applications combined

8. The government also protects intellectual property through copyright and trademark law, but The Hamilton Project has focused primarily on the patent system because of the pressing need for reform and "because it affects innovation in more economic sectors than any other form of intellectual property protection" (Merrill et al. 2004, p. 20).

9. See, e.g., Landes and Posner 1989, pp. 325, 325–33, 344–53. For instance, Landes and Posner explain, in the case of copyright, that "copyright protection—the right of the copyright's owner to prevent others from making copies—trades off the costs of limiting access to a work against the benefits of providing incentives to create the work in the first place. Striking the correct balance between access and incentives is the central problem in copyright law." In order to evaluate that trade-off, an economic analysis of intellectual property law balances static and dynamic efficiencies, as first proposed by Yale economist William Nordhaus (Nordhaus 1969, 1972). Whereas static efficiency involves suppressing the time dimension of economic activity and increasing immediate consumer welfare by lowering prices through competition, dynamic efficiency involves taking a longer-term view of economic activity and thus seeking to ensure that the right incentives are maintained for optimal creation of new products over time.

with the fact that only very few patents ever become commercially important, though, suggest that there is a point beyond which it is neither practical nor cost effective to provide the necessary resources to review carefully every patent application. As Stanford Law School professor and patent law expert Mark Lemley argues, “In short, it is true that the PTO doesn’t do a very detailed job of examining patents. But we probably don’t want it to. They are ‘rationally ignorant’ of the objective validity of patents, in economics lingo, because it is too costly for them to discover those facts” (2000, p. 5).

Some scholars have therefore proposed structural reforms through which the PTO can better target its limited resources and leverage information from entities outside the PTO. Because so few patents are ultimately of commercial importance, the PTO would be well advised to concentrate only on those potentially fruitful patent applications—assuming, of course, that those patents can be predicted. Additionally, the PTO’s limited resources unduly constrain its ability to find good information about relevant developments in new, fast-moving technological areas. To address these two issues, Jaffe and Lerner (2004) propose allowing competitors to signal which patents are important and bring relevant information to bear on the application by giving them the opportunity to file a pre-grant opposition to a patent application and request post-grant reexamination of a granted patent.[10]

In a discussion paper released by The Hamilton Project, Douglas Lichtman of the University of Chicago Law School proposes a different approach: aligning the presumption of patent validity with the nature of the review that each patent receives (Lichtman 2006). Presently, the legal doctrine known as the presumption of validity obligates courts to defer to the PTO’s initial determination that a patent qualifies for protection. As interpreted by courts, alleged infringers must bear a relatively heavy burden of proof in order to overcome the presumption of validity, thus making it difficult for courts to overrule the Patent Office even when it erroneously issues a patent. Lichtman argues that the present strong presumption of validity is not only unwarranted (given the inadequacy of current PTO patent evaluation), but also harms innovation (by allowing holders of wrongly issued patents to extract royalties from alleged infringers—in effect taxing legitimate business activity).

Lichtman proposes that the PTO allow applicants to choose between the current review and an alternative, more rigorous process. As under current law, applicants would pay the cost of these reviews, although fees would be higher for the more intensive review.[11] A strong presumption of validity then would attach only to patents that had been subject either to the more rigorous PTO review or to another similarly rigorous process (for example, review by the U.S. International Trade Commission). Lichtman argues that extending a strong presumption of validity only to patents that were adequately reviewed, and making applicants pay the cost of that review, would reduce both the incentive to file undeserved applications and the disruption caused by any undeserved applications.

Conclusion

The dynamic economy and strong economic growth that the United States has enjoyed since World War II is due largely to rapid scientific and technological advancements and the resulting increased productivity of the U.S. worker. Our investments in innovation, research, and the education of a highly skilled workforce have contributed to unprecedented prosperity and helped fulfill the quintessential American promise that each generation would do better than the one that preceded it. At a time when America faces growing challenges to its global economic leadership, that promise of upward mobility is at risk for the next generation. [12] In order to provide future generations with the same prosperity, security, and opportunity as past generations, the United States must renew its commitment to the sort of technological progress and innovation that has fueled our past economic growth.

10. They also propose revamping the current system for judicial review of patents to deal with those bad patents that still slip through the cracks by replacing juries with judges and putting in place special masters to rule on the most difficult technical questions in a patent lawsuit.
11. Lichtman proposes that some of the resulting revenue be used to help small inventors afford the more thorough review process.
12. As the National Academies concludes, “For the first time in generations, the nation’s children could face poorer prospects than their parents and grandparents did. We owe our current prosperity, security, and good health to the investments of past generations, and we are obliged to renew those commitments in education, research, and innovation policies to ensure that the American people continue to benefit from the remarkable opportunities provided by the rapid development of the global economy” (National Academies 2005a, ES-8).

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