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Richard B. Freeman

Investing in the Best and Brightest:
Increased Fellowship Support for
American Scientists and Engineers

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Investing in the Best and Brightest: Increased Fellowship Support for American Scientists and Engineers

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This discussion paper is a proposal from the author. As emphasized in The Hamilton Project's original strategy paper, the Project is designed in part to provide a forum for leading thinkers across the nation to put forward innovative and potentially important economic policy ideas that share the Project's broad goals of promoting economic growth, broad-based participation in growth, and economic security. Authors are invited to express their own ideas in discussion papers, whether or not the Project's staff or advisory council agree with the specific proposals. This discussion paper is offered in that spirit.

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1. Introduction

There is widespread concern that the United States faces a problem in maintaining its position as the scientific and technological leader in the world and that loss of leadership threatens future economic well-being and national security. Business, science, and education groups have issued reports that highlight the value to the country of leadership in science and technology. Many call for new policies to increase the supply of scientific and engineering talent in the United States (see Exhibit 1). While the reports differ in emphasis, the basic message is uniform: the United States should spend more on research and development (R&D) and increase the number of young Americans choosing scientific and technological careers. In his 2006 State of the Union address, President Bush announced the American Competitiveness Initiative that concurred with these assessments: “For the U.S. to maintain its global economic leadership, we must ensure a continuous supply of highly trained mathematicians, scientists, engineers, technicians, and scientific support staff.”

In 1957, faced with the analogous challenge of Sputnik, the United States responded with increased R&D spending and by awarding large numbers of National Science Foundation (NSF) Graduate Research and National Defense Education Act fellowships, which together induced a large number of young Americans to invest in science and engineering careers. In the early 1960s, the country gave about one thousand NSF graduate research fellow-

ships per year (Freeman et al. 2005, p. 4). Forty-five years later, despite a more-than-threelfold increase in the number of college students graduating in science and engineering and a global challenge from the spread of technology and higher education to the rest of the world, the United States still gives the same number of NSF fellowships (see Exhibit 2).¹ With so many more college students, current U.S. NSF fellowship policy gives less of an incentive for students to enter science and engineering than did policies in the earlier period.

And yet . . . for all the concern about the number of scientists and engineers, there is no evidence of a classic labor market shortage for these specialists: no abnormally large numbers of vacancies, slow growth of employment, or rising wages for scientists or engineers. From the 1990s to 2004, employment in science and engineering increased at an annual rate of 3.2 percent to reach approximately 5.8 million in 2004—around 3.9 percent of the workforce (see Exhibit 3).² The number of employed PhD scientists and engineers increased from about 396,000 in 1990 to 581,800 in 2003.³ This occurred while the earnings of scientists and engineers fell relative to those in some other occupations that use highly educated workers. Employment of computer specialists, which boomed in the 1990s, fell short of Bureau of Labor Statistics (BLS) projections as many firms off-shored work to lower-wage countries.⁴ Enrollments in computer sciences fell (Frauenheim 2004). From the perspec-

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1. The NSF includes social science and psychology in their definition of sciences and awards graduate fellowships in those fields, which makes this expansive definition the appropriate one for analysis. The story is much the same if one considers degrees solely in engineering and the natural and biological sciences, however. In 1960, the United States graduated 89,443 persons with natural science and engineering bachelor's degrees (National Science Foundation [NSF] 1965, Table V-13). In 2002, it graduated 219,175 persons with those degrees (NSF 2006a, Table 2–26), a 2.45 times increase.
 2. Estimates of the number of scientists and engineers vary with the definition used and source of data (NSF 2006a, Table 3–1; Pollak 1999).
 3. The 2003 figures are for employed doctorate scientists and engineers from NSF 2005, Table 1. The 1990 data are estimated from NSF 1995 and Lehming 1998; I have averaged the numbers for data from 1991 and 1989. I use the word about for the 1990 statistics because they come from two separate surveys.
 4. Between 2000 and 2002, BLS reduced its projected increases in demand for computer and mathematical scientists over the next decade by one-half, or 1 million jobs (Sargent 2004).

EXHIBIT 1

Drumbeat of Concern about the Science and Engineering Workforce

We must “enhance the science-technology enterprise so the U.S. can compete, prosper, and be secure.” (National Academies 2005)

DoD and the defense industry are “having difficulty attracting and retaining the best and brightest students to the science and engineering disciplines relevant to maintaining current and future strategic strike capabilities.” (U.S. Department of Defense 2006)

“To maintain our leadership amidst intensifying global economic competition, we must make the best use of talented and innovative individuals, including scientists, engineers, linguists, and cultural experts.... The nation must cultivate young talent and orient national economic, political, and educational systems to offer the greatest opportunities to the most gifted American and international students.” (American Association of Universities 2006)

“If trends in U.S. research and education continue, our nation will squander its economic leadership, and the result will be a lower standard of living for the American people.” (National Summit on Competitiveness 2005)

“Together, we must ensure that U.S. students and workers have the grounding in math and science that they need to succeed and that mathematicians, scientists and engineers do not become an endangered species in the United States.” (Business Roundtable 2005)

“It is essential that we act now; otherwise our global leadership will dwindle, and the talent pool required to support our high-tech economy will evaporate.... This is not just a question of economic progress. Not only do our economy and quality of life depend critically on a vibrant R&D enterprise, but so too do our national and homeland security.... A robust educational system to support and train the best U.S. scientists and engineers and to attract outstanding students from other nations is essential for producing a world-class workforce and enabling the R&D enterprise it underpins.” (Task Force on the Future of American Innovation 2005)

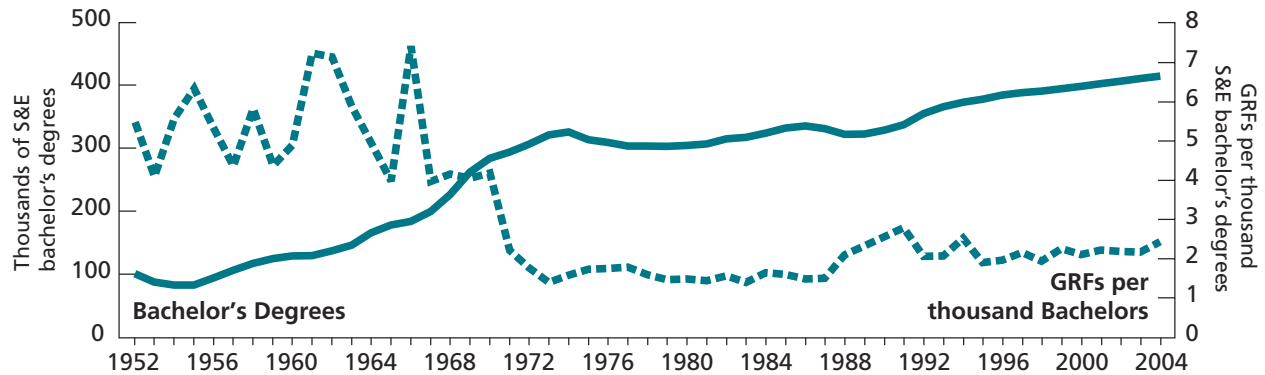
There is “a shortage of U.S. citizen scientists to work in sensitive national security programs.” (Lewis 2005)

“The message is clear. Today’s relentless search for global talent will reduce our national capacity to innovate unless we develop a science and engineering workforce that is second to none.” (Building Engineering and Science Talent 2004)

“The United States is facing a crisis in science and engineering talent and expertise. For the United States to remain competitive in a vibrant global innovative and research environment, it must ... attract, educate, recruit, and retain the best S&E workers. Assuring that the nation has the number and quality of scientists and engineers is a national imperative upon which the nation’s security and prosperity rests entirely.” (Jackson 2003)

“The Federal Government and its agencies must step forward to ensure the adequacy of the U.S. science and engineering workforce. All stakeholders must mobilize and initiate efforts that increase the number of U.S. citizens pursuing science and engineering studies and careers.” (National Science Foundation 2003b)

EXHIBIT 2

Graduate Research Fellowships (GRFs) as Proportion of Science and Engineering Bachelor's Graduates, 1952–2004

Sources: NSF-DGE various years.

S&E = science and engineering.

Note: Cumulative index and related data sets are from NSF-DGE various years. Bachelor's degree data tabulated by NSF Division of Science Resources Studies; data from Department of Education.

tive of persons choosing a career, the prospects in science and engineering seemed highly uncertain.

Past experience with alleged shortages of science and engineering workers shows, moreover, that just because the scientific and technological establishment declares that the country needs more scientists and engineers does not make it so. The United States has sometimes erroneously rung alarm bells about a shortage of scientists and engineers.⁵

Is there a real problem in the job market for scientists and engineers today? If so, what sort of policies might resolve the problem? This paper argues that the country's problem in the science and engineering job market differs greatly from a classical labor market shortage. The problem is twofold: inadequate investment in R&D for the economic and security well-being of the country, which keeps

earnings and opportunities in science and engineering occupations below those that would attract large numbers of young Americans from competing occupations; and unlimited access to immigrant scientists and engineers, who can fill demands at going wages. As long as the United States enjoys an ample supply of immigrant scientists and engineers, it cannot have a classic labor market shortage. The worst it can have is an imbalance between the supply of citizens and immigrants.

I present a policy—increasing the number and value of graduate fellowships in science and engineering—that can augment the supply of U.S. students in science and engineering without impairing access to immigrant scientists and engineers, and I give the evidence that this policy would work. If the United States increases research spending, as laid out in the American Competitiveness Initiative

5. The country first became concerned with shortfalls in the science and engineering workforce in the late 1950s and early 1960s, prompted by the Soviet Union's surprise launch of Sputnik in 1957 and the failure of the first two U.S. attempts to launch a satellite into space. Congress enacted the *National Defense Education Act of 1958* and increased federal R&D. In this period, the earnings of scientists and engineers rose rapidly, so the labor market confirmed that demand had grown relative to supply. In the early 1980s, however, NSF proclaimed a shortage of scientists and engineers that turned out to be unjustified. The shortage was based on policy makers' erroneous use of data, possibly motivated by a desire to reduce the cost of scientists and engineers to large firms (Weinstein 1998). In 1990, Richard C. Atkinson (1990), then president of the American Association for the Advancement of Science (AAAS), predicted that, by the year 2000, demand for scientists in the United States would outstrip supply by almost four hundred thousand. He recommended programs to encourage more young people to pursue doctorates in science and engineering. But four years later, there was no evidence of a shortage. *Newsweek* ran an article on the science workforce under the headline, "No PhDs need apply: The government said we wouldn't have enough scientists. Wrong" (Begley et al. 1994).

EXHIBIT 3

The Science and Engineering Workforce in the United States, 1983–2004

Source: NSF 2006a, Figure 3–04. National Science Foundation, Division of Science Resources Statistics, special tabulations from U.S. Census Bureau, Current Population Survey Monthly Outgoing Rotation files (1983–2004).

and other proposals, and if the nation takes steps to improve the career opportunities for young scientists and engineers, the expanded fellowship policy would help solve the science and engineering workforce issues that have produced the outpouring of concerns documented in Exhibit 1.

Understanding the problem

Since the end of World War II, the United States has had a disproportionate share of the world's science and technology resources. The reasons are largely historic: the destruction of European higher education and science by the Nazis and World War II; U.S. development of mass college education before Europe; R&D expansion after Sputnik; and the low investment in higher education in China, India, and other developing countries. In 2005, the United States employed about 31 percent of

the world's scientist and engineer researchers and financed 35 percent of R&D while accounting for 5 percent of the world's population and 21 percent of the world's GDP (as reported in Freeman 2006a, p. 123). Excellence in science and engineering has spurred U.S. economic growth and created a comparative advantage in high-tech industries.

The U.S. share of global science and engineering activity is declining, however, and will continue to decline in the next decade or so. Some loss is inevitable, as the rest of the world catches up in higher education and R&D from low bases. Between 1970 and 2000, the U.S. share of college students in the world fell from 30 to 14 percent (United Nations Educational, Scientific and Cultural Organization [UNESCO] 2004).⁶ The U.S. share of science and engineering graduates was lower than its share of college students overall because science and engineering attract large proportions of students from overseas (NSF 2006a, Appendix Table 2–38). At the doctorate level, the U.S. share of scientist and engineering degrees fell from about 40 percent in 1970 to 20 percent in 2000, and is expected to reach 15 percent in 2010 (Freeman 2006a, Exhibit 5.1). The U.S. share of world R&D spending has been declining for decades, and that trend continues today: between 1990 and 2003, it declined from 40 to 35 percent (OECD 2006).⁷ Commensurately, the U.S. share of scientific publications and citations has also fallen. Data from the Chemical Abstracts Services show that in 1980 the United States had published 73 percent of papers in the field, whereas in 2003 U.S. researchers had published 40 percent of the papers (Heylin 2004, p. 40). The NSF has documented a downward trend in the U.S. share of citations and of the most-cited articles in science and engineering. Between 1992 and 2003, the U.S. share of the top 1 percent of cited articles fell from 64.6 to 56.6 percent, while its share of the top 10 percent of cited articles fell from 56 to 46.5 percent (NSF 2006a, Figure O-18).

6. I have filled in missing observations by taking the enrollments from the nearest year for which data are available. Tertiary-level students are not always college students, so these data are imperfect. However, using data for college enrollments reported by individual countries, I obtain estimates of the U.S. share comparable to the tertiary enrollment figures of UNESCO.

7. Since these data cover only nine non-OECD countries, U.S. shares given are upper bound estimates (NSF2006a, Figure 0–01).

Responding to the spread of scientific and engineering talent around the world, the multinational firms who undertake most industrial R&D are investing in R&D in China and India. In 2004, China reported that multinationals had established more than six hundred R&D facilities (“Multinational Corporations Establish 600 R&D Centers in China,” *Financial Times*, August 23, 2004), whereas in 1990 they had none. In 1990, the United States spent 7.1 times as much on R&D as China spent; in 2003, it spent only 3.3 times as much.⁸

While the United States will not have the dominance in science and technology in the future that it had from the 1950s through 2000, it can still be the leading center in scientific and technological progress if it invests more in R&D and undertakes policies to make science and engineering careers more attractive to young people.

Why care?

Expansion of modern scientific and technological activity throughout the world will make the lives of Americans better in many ways. More research will produce more knowledge, innovation, technological change, and productivity advance, which should improve living standards. If a medical scientist in China, India, or anywhere else finds a cure for cancer, we will be ecstatic about the spread of scientific excellence around the world. If a German innovation lowers the price of goods and services, we all benefit. Scientific advances and innovations overseas that lead firms to set up production facilities in the United States will create jobs as well as better products. So why do the reports on science and engineering in Exhibit 1 view expansion of the science and engineering workforce overseas with concern?

There are three arguments for greater investment in science and engineering and increasing the supplies of scientists and engineers. First, since the United States is at the frontier of modern technology, American economic growth depends on technological and scientific advances. Other economies can grow by moving their production to the frontier of modern knowledge, but the United States must advance that frontier. 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.⁹ The growth of high-tech employment in Silicon Valley and in university-based locations of scientific excellence suggests that innovation, production, and employment in high-tech fields occur largely in areas strong in basic science.¹⁰ The supply of scientists and engineers is a major factor in the location of these centers of excellence.

Second, the United States’ comparative advantage in trade lies in high-tech research-intensive industries. Were the United States to lose its advantage in those sectors, it would have to sell goods or services with lower technological content on the global market. The gains from trade would lessen and wages would fall for American workers. The United States needs top-flight researchers advancing the technological frontier to maintain our advantage in the face of the growth of scientific and technological capacity in China, India, and other developing countries, which will have a cost edge in high-tech as well as in other sectors until their wages approach ours.¹¹

8. NSF (1993) estimates that China spent \$21.4 billion on R&D in 1990, while the Census Bureau (1995) reports that the United States spent \$151.5 billion in that year. The 2004 figures are from OECD (2006). All estimates for China in the earlier period are problematic.

9. For evidence on the impact of R&D on productivity, see Jones and Williams (1998). Earnings of production and nonsupervisory workers in the three high R&D intensive sectors—aerospace, chemicals, and computers and electronic products—are \$26.48, \$19.17, and \$19.15 per hour, respectively, compared to \$16.70 per hour for production and nonsupervisory workers in the country (BLS 2006, Table B-16, for August).

10. Darby and Zucker (2006) show that industry develops in areas where star researchers work in nearby universities. Similarly, U.S. states with greater supplies of university graduates have been in the forefront of the new economy (Progressive Policy Institute 1999).

11. During the Cold War, the Soviet Union challenged U.S. technological dominance in the military area only. The challenge from Japan in the 1980s in high-tech was limited because Japan had a much smaller population than the United States and had labor costs only

Third, U.S. defense depends on a technically sophisticated military, which requires an ample supply of scientists and engineers to the U.S. Department of Defense and to defense-related industries. Science and technology offer the best defense against chemical, biological, or radiological attacks by terrorists. In addition, the National Security Agency and some Defense Department laboratories hire only U.S. citizens, so the country must ensure a healthy supply of citizens in the relevant fields. The scientist and engineering workforce in security areas has become top-heavy with older workers, which will create large replacement demands for citizen researchers. In sum, there are good reasons for the United States to want to maintain a large science and engineering workforce for the economic strength of the country and national security. But where's the beef in the labor market?

Indicators of the labor market for scientists and engineers—salaries, unemployment rates, the length of time it takes graduates to obtain work, the proportion who obtain jobs in their area of specialization—show no sign of shortages. Rather, the data suggest that the job market has weakened for young workers in science and engineering relative to many other high-level occupations, which discourages U.S. students from going on in the fields. For example, earnings increased more for lawyers and doctors than for PhD scientists and engineers between the 1990 and 2000 censuses (Freeman 2006a, Exhibit 5.3).

A major reason for the absence of any shortage of scientists and engineers is that the United States attracts large numbers of international science and engineering students and immigrant employees to our universities and workplaces. Exhibit 4 shows that the share of immigrant scientists and engineers in 1990 and 2000 increased greatly at every education level, helping to fuel the 1990s boom. As long as the United States remains a highly desirable

EXHIBIT 4

Trend in Immigrant Share of Science and Engineering Employment

	1990	2000
Bachelor's	11%	17%
Master's	19%	29%
All PhDs	24%	38%
PhDs < 45	27%	52%
Post-doc	49%	55%

Source: Freeman 2005, Exhibit 5.2. The census sources were the 1990 and 2000 censuses, IPUMS data, while the source for post-docs was NSF (2006a, Figure 2-29). For post-docs, the numbers refer to temporary residents rather than all immigrants. The IPUMS data are Ruggles et al. 2004.

worksite for scientists and engineers, the country cannot face a classic labor shortage. It can import scientists and engineers just as it imports goods and services, and can obtain whatever number of scientists and engineers it desires.

So, why do the groups whose statements are summarized in Exhibit 1 want to encourage domestic production of scientists and engineers? One reason is that the United States has the leading university system in the world, so that U.S.-trained scientists and engineers tend to be of higher quality than those trained elsewhere. This favors domestic production of graduates, some of whom will be U.S. natives, and some of whom will be international students. Another reason is that reliance on immigrant supplies involves risk—a sudden cutoff of international students or immigrant workers due to political problems or decisions by immigrant workers to return home in large numbers. The post-9/11 fears about visa restrictions on international scholars exemplify this problem. U.S. students are also more likely to respond to the U.S. job market and changes in national priorities than are international students. U.S. students' knowledge of the society and the U.S. can-do culture might also make unique contributions to

modestly lower than those in the United States. It is the combination of large numbers of scientific and engineering workers with low wages that differentiates the current situation from the earlier situation.

the scientific endeavor and to economic innovations, though I know of no evidence to support this possibility. Finally, the government labs and the National Security Agency that limit hires to U.S. citizens rely on U.S. PhDs in science and engineering.

I conclude that the United States should seek some reasonable balance of native and immigrant scientists and engineers in the workforce. The “best and brightest” fellowship policy that I describe next is designed to accomplish this by increasing the supply of citizens in science and engineering without restricting the flows from overseas.

2. The Proposal: More and Higher-Paying Stipends

Stipulate that the United States wants to increase the flow of citizens choosing scientific and engineering careers. An appropriate policy to do this is to increase the number and value of fellowships for graduate work. I propose that the NSF triple the number of graduate research fellowships (GRFs) for science and engineering work and increase the value of those awards relative to earnings elsewhere in the economy. The increased numbers would induce students who have an interest and ability in science and engineering to proceed to graduate training and research careers. The increase in the value of the awards would keep the quality of awardees high even with the larger number being granted.

As noted at the outset, current U.S. NSF fellowship policy offers less incentive for young students to enter science and engineering than it did in the 1950s because NSF gives approximately the same one thousand GRFs that it gave in the 1950s and 1960s when the United States had far fewer undergraduate degrees in science and engineering. Tripling the number of NSF awards would roughly restore the ratio of GRFs to undergraduate science and engineering degrees that the country had after the Sputnik challenge. It would send a dramatic signal to American students that the country wants them to specialize in these areas.

To be sure, NSF is one of many government agencies that award fellowships for graduate study, and fellowships are only one way the government supports graduate students. Seventy percent of government-supported science and engineering graduate students receive research assistantships. In 2004, 7,301 full-time graduate students in science and

engineering fields in doctorate-granting institutions received federal government fellowships. Approximately 3,300 were NSF GRF recipients, which makes NSF the largest grantor of fellowships. The second-largest awarder of fellowships is the National Institutes of Health (NIH), which in fiscal 2005 supported 1,267 fellowships and funded 8,367 students on training grants to institutions in the biomedical fields relevant to its mission.¹²

NSF GRFs operate differently from fellowships from other agencies. NSF awards students depending on the number of qualified applicants in different fields rather than according to disciplines to meet some agency goal. NSF GRFs are, thus, the only awards that can ensure a comprehensive research base and that allow the market, through student choice, to determine the attractiveness of different fields.

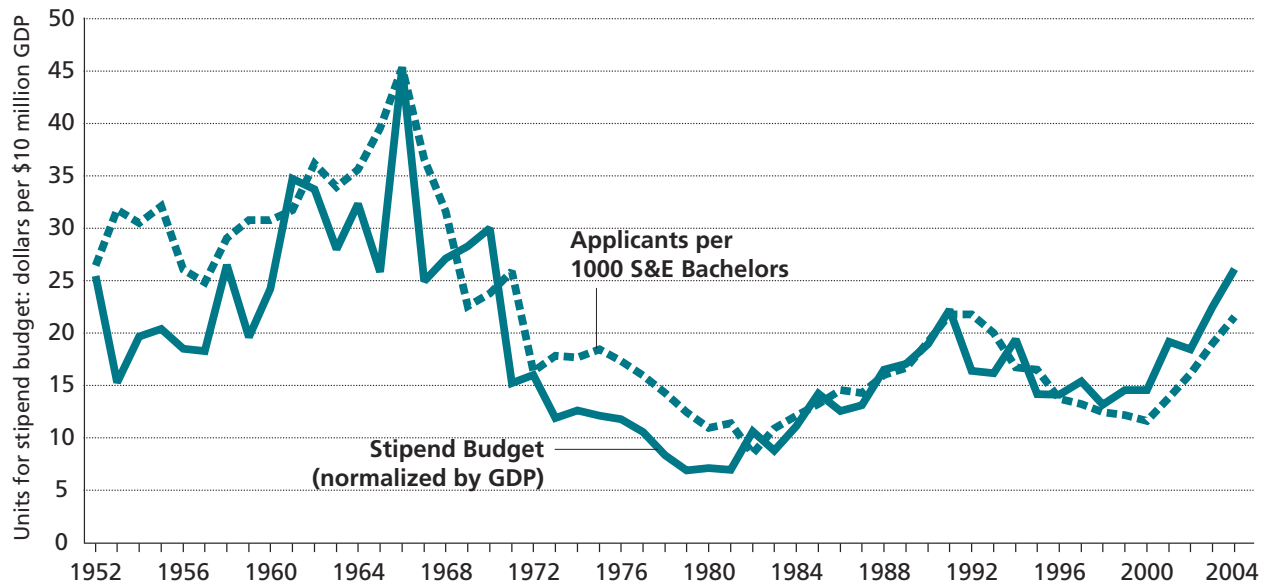
Can fellowship policy affect supply?

Increasing incentives for students to invest in science and engineering can affect the supply of young people to the sciences and engineering if the supply of scientific talent is constrained by economic incentives rather than by any disinterest or lack of ability in science and engineering on the part of young Americans. The evidence in Exhibit 2 of large rising numbers of graduates with bachelor of science or engineering degrees suggests that the country has many able candidates for further education. Greater and higher-valued fellowships are likely to increase the number of these graduates going on to advanced training for two reasons. First, coming early in someone's career, fellowships represent a large proportion of discounted lifetime earnings for science and engineering specialists.

12. All data are from NSF 2004a. For the NIH data, see NIH 2005. Among the other agencies giving awards are the U.S. Department of Defense, which gives National Defense Science and Engineering Graduate three-year fellowships annually; the U.S. Department of Homeland Security, which gives graduate fellowships; different parts of the Department of Energy, which give awards to fields relevant to their mission; and NASA, which gives three hundred awards annually as part of its Graduate Student Researchers Program. NSF (2004a, Table 41) gives the numbers for some of these agencies, as well.

EXHIBIT 5A

Fraction of Science and Engineering Bachelor's Graduates Applying to the GRF Program Compared to Total GRF Budget, Divided by GDP



Sources: NSF-DGE various years, cumulative index of the GRF program and related data sets. Data on the GDP from the Bureau of Economic Analysis.

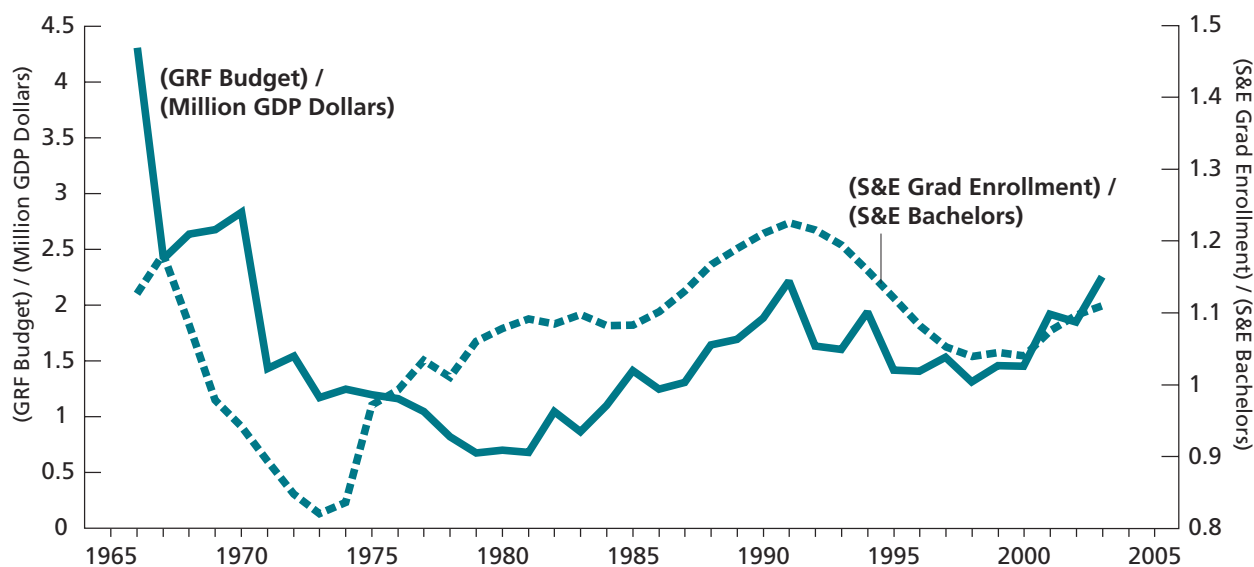
Second, fellowships signal that the person has the talent to have a successful career. Receipt of a prestigious fellowship carries nonmonetary as well as monetary weight in career considerations.

Between 1999 and 2005, NSF altered its GRF policies in a way that allows researchers to estimate the response of students to changes in policies. In 1999, the NSF's Committee of Visitors noted "the GRF awards are no longer as attractive as they once were," and recommended that the stipend value be raised from \$15,000 to \$18,000. NSF went much farther, raising the value of the stipend to \$27,500 in 2002 and to \$30,000 in 2005 without increasing the number of rewards. As can be seen in Exhibit 5a, the result was that the number of applicants per bachelor's degree in science and engineering nearly doubled. Exhibit 5a shows a tight link between the number of applicants relative to the number of science and engineering bachelor degrees and the total amount spent on NSF awards relative to GDP. More-detailed statistical analyses in Freeman and colleagues (2005) show that changes in both the number and value of GRFs taken separately have

greatly affected the number of applicants for those awards. The statistical analysis in Freeman and colleagues (2005, Table 6, Column 4) suggests that a 10 percent increase in the number of NSF awards granted increases the number of applicants by 0.349 log points, or 41 percent, while slight variants of the model give modestly different estimates (author's calculations). While it is difficult to determine if the increase in awards attracts students on the margin of going into science, or if the increase goes largely to students who would study science and engineering in any event, the available evidence supports the notion that an increase of NSF awards raises the supply of students. Exhibit 5b shows that the fraction of bachelor's graduates enrolled in science and engineering programs is positively related to the NSF stipend budget relative to GDP. Statistical analysis suggests that a 10 percent increase in NSF spending on GRFs increases the number of graduate enrollments by 7 to 15 percent (depending on the statistical model; author's calculations, available on request). Since NSF supports a relatively small number of graduate students, this smaller impact on total enrollments than on applicants for awards

EXHIBIT 5B

Fraction of Science and Engineering Bachelor's Enrolling in Science and Engineering Graduate Programs Compared to Total GRF Budget, Divided by GDP



Source: GRF budget divided by GDP, as in Exhibit 5a; bachelor's graduates in science and engineering, as in Exhibit 5a. Enrollments in science and engineering graduate programs from NSF graduate students and postdoctorates in science and engineering (NSF 2004).

makes sense. That the estimates are positive suggests that the spending affects students on the margin, though the channels by which it does so may be complicated.

Another way to assess potential student response to fellowship incentives is to ask students how fellowship support would affect their career decisions. In winter 2006, one of my students asked nearly 1,800 Harvard undergraduates, “If you won a national fellowship for graduate study of a year, would you go on to graduate work in science and engineering?” (Shukla 2006). Seventy-three percent of the science concentrators said that they would go on. Forty percent of all students said they would go on to graduate study in science—which was more than twice the 18 percent who said that they intended to go on to careers in science and engineering. She also asked the students, “If you were offered a scholarship of \$20,000 annually in college to pursue a career in science and engineering research, would this affect your career choices?” Fourteen percent of all students said they would change their career plans and pursue a science and engineering career,

which would bring the proportion to 32 percent. While the questions are hypothetical, the responses show potentially sizable responsiveness to fellowship support.

Can the number of fellowship awards be increased without greatly reducing the quality of those obtaining the awards?

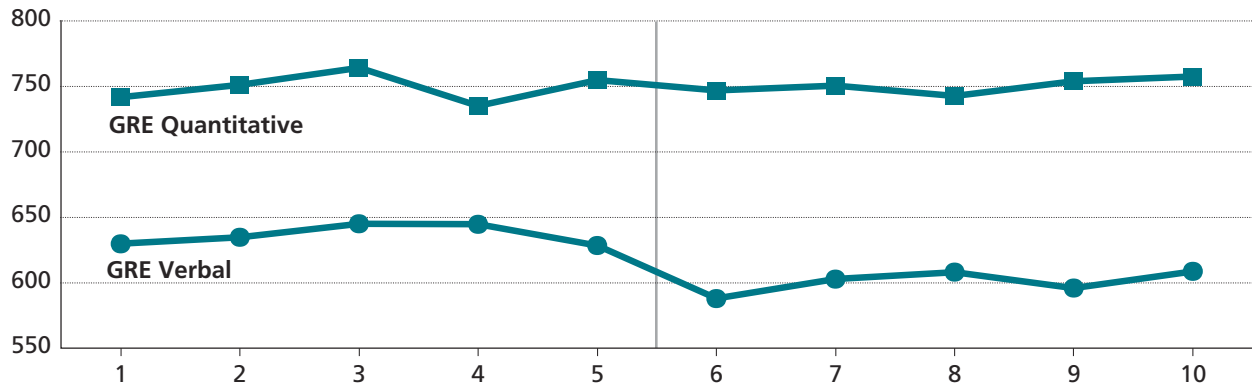
Exhibit 6 shows that a significant number of applicants who did not receive awards have characteristics only modestly weaker than those of awardees, so that the number of awards can be increased substantively without greatly reducing the quality of students. In addition, the fact that higher value stipends attract some applicants that are more able could offset any potential reductions in quality.

How would other stipend providers react if NSF raised the number and value of awards?

Universities, foundations, and other agencies responded to the large 1999–2005 increased value of NSF awards by raising the value of their own

EXHIBIT 6

Quality of GRF Program Applicants on the Margin of Getting an Award Compared to the Quality of Awardees, 2004



Notes: All persons to the left of the line were given awards. All persons to the right of the line were not given awards. The numbers relate to groups of fifty persons, ordered by the estimated probability they would win an NSF award. The fifth group consists of fifty awardees with the lowest probability of getting an award, the fourth group consists of fifty awardees with the next lowest probability, and so on. The sixth group consists of the fifty nonawardees with the highest probability of getting an award. The probabilities are predicted values from an OLS regression of an award receipt dummy variable on panel rating, female dummy, underrepresented minority dummy, and eight field dummies.

awards. Some complained to NSF about this. Because universities depend greatly on direct government moneys for research and indirect government moneys for teaching, the government ultimately paid some of these added costs. However, the propagation of the increase beyond the one thousand recipients presumably helped boost overall graduate enrollments. Increasing the number of fellowship awards is unlikely to have such an effect, since the other awards will remain competitively valued with the NSF's awards.

Would an expanded NSF fellowship program largely benefit the elite universities?

The elite universities would undoubtedly attract a large share of an increased number of graduate fellowship awards, as they do of current awards, but the growth of PhD production in the United States from the 1960s to the present has not been at these universities. Most of the growth in science and engineering doctorate production has occurred at less-prestigious universities (Freeman et al. 2004), some of which have become world class universities—such as the University of California, San Diego. The reason why the growth of science and engineering PhDs has been concentrated among

newer programs is that many elite universities have reached what they view as optimal sizes and are not eager to expand their enrollments. Thus, the benefits of the proposed new NSF GRFs are likely to be spread widely among research universities.

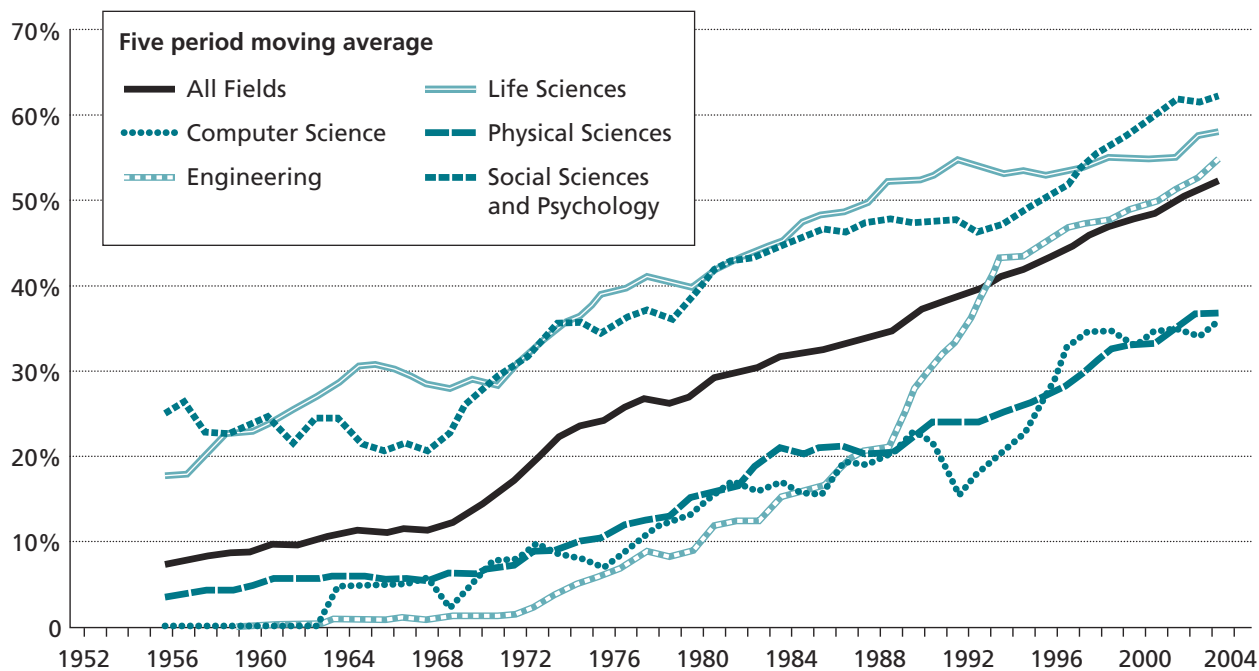
To what extent will an enhanced fellowship program attract more women and minority students?

Exhibit 7 shows the sizable increase in the proportion of NSF GRFs awarded to women from the onset of the program in the 1950s through 2004. The proportion of women winning these fellowships has increased from fewer than 10 percent to more than 50 percent. The proportion of underrepresented minority students winning fellowships has also increased (Freeman et al. 2005, Figure 5). Analysis of the responses of female and minority undergraduate science and engineering majors to changes in the NSF graduate fellowship program shows similar behavior to the responses of men: more apply to the program when the rewards are greater or the NSF grants more awards.

This evidence, together with analyses of student career choices that find substantial responses to economic incentives, implies that fellowship poli-

EXHIBIT 7

Percentage of NSF Fellowships Awarded to Women, 1952–2004



Source: Freeman et al. 2005; Harvard University and NBER 2005, Figure 3.1.

cies are likely to have an impact on enrollments in science and engineering.

Costs and benefits

Stipulate that more students will go on in science and engineering if they can gain graduate fellowship support for their studies. With NSF having established high values of awards, the appropriate margin on which to adjust awards is in the number granted. If the country takes seriously the various reports in Exhibit 1, a reasonable target would be to restore the number of NSF awards relative to the number of bachelor’s science and engineering graduates to the post-Sputnik levels. This means increasing the number of NSF GRFs granted per year from about one thousand to about three thousand. Since NSF selects persons with the highest measurable qualifications, such a large increase would risk some decline in the quality of awardees. To counterbalance this, I propose increasing the value of the fellowships. Higher-valued fellowships will attract more highly able candidates, from which NSF can select the best.

Exhibit 8 summarizes the costs of the proposed fellowship policy. Currently, the NSF gives about one thousand awards, each of which provides \$30,000 to the student and \$10,500 to the university they attend to help pay for the cost of their education. Since the awards are for three years of graduate training, the total cost to the taxpayer is \$121.5 million a year. Tripling the number of awards without changing their value would increase NSF spending to \$364.5 million. If, in addition, the value of fellowships were increased to \$40,000 and the support to universities increased commensurately to \$14,000, the total annual cost of the program would rise to nearly \$0.5 billion a year.

What would the country get for this expenditure? It would get more top students studying and earning doctorate and master’s degrees in science and engineering. Even if the new fellowships went entirely to students who would go into science and engineering in any case, funding those students would free money for universities and other funders to support additional students in

EXHIBIT 8

Costs and Outcomes from Expanded GRF Program

Current costs of NSF GRF Program: one thousand GRFs of \$30,000 for each fellow and \$10,500 as cost of education allowance to the university, for a total cost of \$40.5 million per cohort. Since awards are for three years, the commitment is \$122 million in a given year (rounded).

Proposed Change 1. Increasing the number of awards

From 1,000 to 3,000 per year at \$30,000 per award and \$10,500 to university

Year 1 of program	\$81 million additional cost over current program
Year 2 of program	\$162 million additional cost over current program
Year 3 of program	\$243 million additional cost over current program (steady state cost)

Proposed Change 2. Increasing the number of awards and increasing the value of awards, to keep the quality high

From 1,000 to 3,000 awards per year at \$40,000 per award and \$15,000 to university

Year 1 of program	\$125 million additional cost over current program
Year 2 of program	\$250 million additional cost over current program
Year 3 of program	\$375 million additional cost over current program (steady state cost)

Outcomes:

- Increase in the number of top students getting science and engineering degrees, producing an increase of about 13 percent or more in U.S.-born science and engineering PhDs per year.
- Greater ability to meet the labor demands from prospective increased R&D spending and the retirement of baby-boom scientists and engineers without raising salaries.
- Additional supplies that strengthen the scientific and technology intensive parts of the economy and help maintain comparative advantage in high tech.
- Increase in the supply of citizen scientists and engineers available for defense and national security projects.

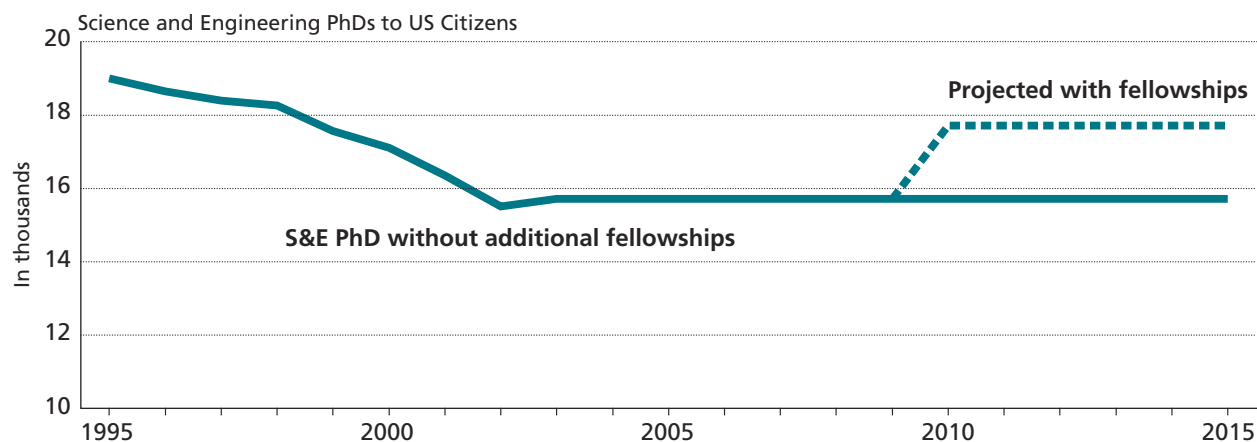
science and engineering. In this case, graduate enrollments and master’s or doctorate degrees would increase by approximately the additional two thousand awards. In 2004, 15,721 U.S. citizens earned science and engineering PhDs. This reflects a decline in the number of U.S. citizens earning science and engineering PhDs from 18,997 in 1995 (NSF 2006b, Table 3). An increase of two thousand PhDs would be a 13 percent increment on the current rate (see Exhibit 9). If, as some of the estimates suggest, a 10 percent increase in the NSF budget would boost graduate enrollments by 7 to 15 percent, then the proposed quadrupling of the budget would imply even larger increases. Even with an expanded number of NSF awards, most students who applied for the awards would

not win one. Nevertheless, many young people would be thinking seriously about scientific careers as a result of their application and might seek other support.

The benefit to the country is not, however, an increased supply of U.S. citizen scientists or engineers, but rather the economic and security gains that they might bring. While no one can be sure of the particular areas where an increased number of scientists and engineers might make their greatest contribution, our recent history is filled with examples where young innovative researchers have made major contributions to economic progress: The Internet. The biotech industry. The PC. The mathematics of cryptography that underpins Inter-

EXHIBIT 9

The Expected Impact of Increasing NSF GRFs on Numbers of PhDs Graduating in Science and Engineering, 2005–2015



Source: NSF 2004b, Table 3.

net commerce. The buzz today is about nanotechnology, though no one is sure in what areas (if any) nano will pay off. Given the potential dangers from global warming and climate change, rising costs of energy, terrorist threats of diverse forms, and environmental pollution, there are many places where a larger supply of scientists and engineers could pay off in higher productivity and better lives. But simply producing more graduates will not by itself produce scientific and technological advances nor will it substantially affect the future supply of such workers. There must also be a commensurate increase in R&D spending that raises the demand for scientists and engineers.

The demand side of the equation

Assuming that more and better-paying fellowships induce more people to become scientists and engineers, what will happen to them after they graduate? If R&D spending does not increase more rapidly than in recent years, and if federal spending for basic research languishes, the new doctorate graduates will find that the job market does not live up to their expectations. The increase in U.S.-born

supplies would reduce wages and opportunities for young scientists and engineers, which in turn would reduce the impact of the fellowships on future supplies. The citizen share of the nation's science and engineering workforce would be higher than otherwise, which could help meet some of the national security concerns, but the overall supply would not increase much. Many young scientists would likely leave science in their thirties and forties for other jobs, or decide to pursue their careers in science in other countries, where they might find adequate funding, as MIT has recently reported about two young physicists to whom it had offered employment.¹³ In this case, I would see little value to expanding the number of GRFs.

But both the executive and legislative branches of government have proposed sizeable increases in research spending that should create greater demand for scientists and engineers. The Bush administration's American Competitiveness Initiative commits \$50 billion to increase funding for research over ten years. NSF spending would double between 2007 and 2016 from \$5.6 billion to \$11.2 billion (OMB

13. In 2006, the MIT physics department reported that two young researchers turned down MIT job offers to work in Europe, where they were more able to get funding (Sarah Shipley Hiles, "Young Scientists Hit the Hardest as U.S. Funding Falls," *Boston Globe*, January 23, 2006).

2006). In addition, the Initiative promises \$86 billion for R&D tax incentives, which would further increase demand. A bipartisan group of senators committed to science and innovation has called for doubling the NSF budget by 2011 in the National Innovation Act of 2005 (U.S. Congress 2005). Such increases are necessary to improve the career prospects of young scientists and to justify a large increase in the number of NSF graduate research fellowships.

Still, the experience in doubling NIH research spending from 1996 through 2002 suggests that increasing research spending by itself does not necessarily improve the career prospects of young scientists. Most of the NIH moneys went to senior scientists, who hired newly minted PhDs from the United States and overseas as post-docs in their laboratories, often on large research projects. The chances of young scientists getting their own grants fell from what it had been in the 1970s. If this happened again, it would reduce the career attractive-

ness of science and engineering and counteract the purposes of the best and brightest fellowship policy. Expanding the NSF fellows program would work best if it were accompanied by structural changes in R&D funding programs, such as special awards for young scientists and engineers and increased fellowship support for post-docs so that they are not completely dependent on principal investigators for research funding. The National Academies' report, "Rising above the Gathering Storm" (National Academies 2005), and some of the other reports given in Exhibit 1, have made some suggestions along these lines. Ideally, the best and brightest fellowships would focus NSF and other agencies on developing research-spending policies to help young investigators advance their careers.

In sum, the policy of providing additional fellowships should be seen as part of a broader set of policies that increase demand for science and engineering workers and offer greater career opportunities to young investigators.

3. Alternatives and Concerns

There are two other policies through which the United States can increase the employment of scientists and engineers, as either complements or substitutes for the proposed increase in fellowship support. The first is to encourage more foreign-born scientists and engineers to immigrate to this country. The second is to strengthen science and math education from kindergarten through grade twelve (K-12) so that the United States has more young people with the interests and talents to go into science and engineering. These policies are almost polar opposites. The first free rides on the interests and talents of persons born overseas and on the lower wages and research facilities available in their native countries; the second seeks to build up domestic supplies over the long run. I discuss each in turn.

Free riding on foreign talent?

At present, the United States can hire as many high-quality scientists and engineers from overseas as it wants. Some of the best international students come to the United States and choose to stay and work here. Many become citizens. The United States also attracts many foreign-trained scientists and engineers as immigrants. Why should the country spend anything to support U.S. students in science and engineering when it can exploit the brain drain and get immigrant talent?

One reason why this strategy—ignoring domestic supplies in favor of relying on a perpetual global brain drain—is undesirable is that the United States is an excellent source of talented science and engineering students, about whose abilities our universities have greater knowledge than about the talents of international students. Another reason is that the

potential to free ride will not go on forever. As other countries improve their university systems and as their economies grow, competition for top students and scientists and engineers will increase, reducing the supplies of immigrant workers to the United States, or raising their price. Thirty years ago, many U.S.-educated PhD science and engineering graduates from Taiwan and Korea remained in the United States. Today, a larger proportion of these graduates return to their native countries. Such a pattern is a natural part of global economic progress. Currently, the United States attracts and retains large numbers of Chinese and Indian students and gains many immigrant specialists from these countries. As China and India develop, though, supplies from those countries will also diminish. The U.S.-born scientists are more likely to remain in the United States as a permanent part of supply.

The country should try to keep the best and brightest foreign talent coming to the United States. It should end the policy of requiring prospective international students to declare that they have no intention of staying and working in the United States when in fact the country wants them to stay. It should increasingly tilt immigration visas toward more highly skilled persons. In some cases, it should grant quick citizenship to immigrant specialists. As long as immigrant scientists are as productive and trustworthy as are native-born scientists in national security-related industries, the country would lose nothing by fast-tracking citizenship to certain immigrants, to maintain the policy on having only citizens work on some national security programs.¹⁴ The 2006 decisions by the Department of Defense and the Department of Commerce to withdraw proposed tight restrictions on immigrant research-

14. Paula Stephan and Sharon Levin find that among individuals making exceptional contributions to science and engineering, foreign-born and foreign-educated individuals are disproportionately represented, presumably due to the selection process. Increased recruitment of foreign-born researchers is likely to reduce average productivity. I know of no evidence that naturalized American citizens are more or less likely to be security risks. The 1999 case of naturalized American Wen Ho Lee suggests that security officials may be overly suspicious of naturalized scientists and engineers.

ers working on sensitive technologies shows that the security-conscious agencies recognize the contribution that even noncitizen scientists and engineers can make to national security (Brainard 2006, Field 2006). Nevertheless, we should not count solely on free riding on foreign supplies as a long-term strategy to maintain world leadership in science and technology.

It is important to recognize, however, that there is a fundamental trade-off between the supply of immigrant labor and of native-born labor in science and engineering, as in any other part of the labor market. At any given level of demand, increased immigration in any particular specialty lowers the wages and opportunities for natives in that area and thus reduces the incentives for domestic talent to invest in that specialty. Conversely, increased domestic supplies will reduce the incentives of immigrants to come in an area. The appropriate strategy should be to seek a balance between the two sources of supply.

Strengthen K-12 science and math education?

The polar opposite way to expand the science and engineering workforce is to invest more in science and math education in elementary and secondary school. For example, there is much to be said for raising teacher pay overall and in science and mathematics in particular. There may be a particularly high payoff to developing special science and math magnet schools in different cities and states, similar to the Bronx High School of Science in New York, the North Carolina School of Science and Mathematics, and comparable schools in other states. But investments in K-12 will take fifteen to twenty-five years to affect supplies, and thus cannot help maintain a strong U.S. science and engineering workforce in the next twenty or so years. Because investments in K-12 will improve the science and math education for many students who are likely to never consider science and engineering careers, moreover, they will invariably be less cost-effective than the proposed fellowship program, which focuses on highly able students who are interested in

science and engineering and can be enticed toward graduate studies in those areas.

Special pleading?

Every industry and group wants the government to spend more on it. Most advocate for themselves in the name of the national interest. The organizations behind the policy papers in Exhibit 1 represent the top U.S. research universities and high-tech firms, the science-engineering parts of the Department of Defense, and the scientific establishment. These are all groups that will benefit directly from increased federal support for science and engineering students and from increased research spending. Much of the rest of the country will benefit indirectly. The cynical and jaded observer of national politics might wonder if this is nothing more than special pleading on behalf of these groups. I disagree.

The big payoff from successful investment in science and engineering will be through greater productivity and continued comparative advantage in high-tech industries that will affect the national economy. Most analysts believe that investments in knowledge have greater social than private returns; this makes it natural to support subsidizing science and engineering students as opposed to, say, subsidizing law or business students. Although estimates of the gap between the social and private returns to basic research, which underlies these beliefs, are uncertain, virtually all estimates, including the most recent ones, indicate that the gaps remain large (Popp 2004). Yes, some will benefit more than others from the proposed expansion of science and engineering fellowships, but the odds are high that most Americans will benefit, which is more than can be said of many other government programs.

Considering the geographic distribution of the award, the benefits of having more trained specialists would flow to many states. Science and engineering doctorates are dispersed across states, and employment in high-tech establishments relative to total employment is even more widely dispersed across states. The areas with the highest concentration of science and engineering doctorates per em-

ployee are Connecticut, Delaware, the District of Columbia, Maryland, Massachusetts, New Mexico, and Virginia. Other states with high science and engineering doctorate shares relative to the national average include California, Colorado, Hawaii, New Jersey, Rhode Island, Vermont, and Washington (NSF 2006a, Table 8–22). Given the mobility of Americans across state lines, the geographic distribution of doctorates and high-tech firms within the country should not be an issue of great concern.

Conclusion

A policy of increasing the number and value of GRFs will attract more Americans into science and engineering without limiting the potential for continued flows of immigrant specialists. It will reverse

the inadvertent signal that the country has given young people against studying science and engineering by allowing the number of the most prestigious national awards, the NSF's graduate research fellowships, to fall relative to the number of science and engineering baccalaureates. It will attract women and minorities to science and engineering. And it will do all this at a relatively modest cost compared to the potential gains.

We should not forget, however, that maintaining our scientific and technological leadership will require not only increased numbers of fellowships, but also increases in government spending on basic research and a shift in the locus of that spending toward young researchers.¹⁵

15. The American Association of Universities (2006) proposes that the federal government increase by five thousand the number of graduate fellowships and traineeships supported by existing programs; to create a one thousand–person graduate fellowship and traineeship program in the Department of Energy's Office of Science; and to expand the Department of Defense National Defense Education Program, in return for student commitment to national service after their studies.

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