

## Do we need more scientists?

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**F**OR much of the past two decades, predictions of an impending shortage of scientists and engineers in America have gained increasingly wide currency. The country is failing to produce scientists and engineers in numbers sufficient to fulfill its economic potential, the argument runs. The supposed causes are weaknesses in elementary, secondary, or higher education, inadequate financing of the fields, declining interest in science and engineering among American students, or some combination of these. Thus it is said that the United States must import students, scientists, and engineers from abroad to fill universities and work in the private sector—though even this talent pool may dry up eventually as more foreign nationals find attractive opportunities elsewhere.

Yet alongside such arguments—sometimes in the very

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same publications in which they appear—one learns of layoffs of tens of thousands of scientists and engineers in the computer, telecommunications, and aerospace industries, of the deep frustration and even anger felt by newly minted Ph.D.s unable to find stable employment in traditional science and engineering career paths, and of senior scientists and engineers who are advising undergraduates against pursuing careers in their own fields. Why the contradictory reports on professions routinely deemed critical to the success of the American economy? Is it possible that there really is no shortage in these fields?

### **A history of gloomy forecasts**

Pronouncements of shortages in American science and engineering have a long history. They date at least to the late 1950s, around the time the USSR launched Sputnik, the first orbiting satellite, prompting concerns that an era of Soviet technological advantage over the United States had emerged. The United States responded with massive public investments in science and engineering education. This led to sharp increases in the numbers pursuing such studies, and a surfeit in the 1970s of entry-level scientists and engineers.

The recent history of shortage forecasts begins in the mid 1980s, when the then-leadership of the National Science Foundation (NSF) and a few top research universities began to predict “looming shortfalls” of scientists and engineers in the next two decades. Their arguments were based upon quite simplistic demographic projections produced by a small policy office reporting to the NSF director—projections that earlier had been sharply criticized by the NSF’s own science and engineering workforce experts.

Only a few years later, it became apparent that the trends actually pointed toward a growing surplus of scientists and engineers. In 1992, the House Committee on Science, Space and Technology’s Subcommittee on Investigations and Oversight conducted a formal investigation and hearing about the shortfall projections, leading to much embarrassment at the NSF. In his opening remarks at the hearing, the subcommittee’s Chairman, Democrat Howard Wolpe of Michi-

gan, declared that the “credibility of the [National Science] Foundation is seriously damaged when it is so careless about its own product.” Sherwood Boehlert, the subcommittee’s ranking Republican and now chair of the full House Science Committee, called the NSF director’s shortfall predictions “the equivalent to shouting ‘Fire’ in a crowded theater.” They were “based on very tenuous data and analysis. In short, a mistake was made,” he said. “Let’s figure out how to avoid similar mistakes, and then move on.”

Boehlert’s advice was not heeded. Only five years later, during the high-tech boom of the late 1990s, an industry association known as the Information Technology Association of America (ITAA) began to produce a series of reports asserting burgeoning gaps and shortages of information-technology workers, based on proprietary surveys of what it termed “job openings.” The first ITAA report claimed that some 190,000 information-technology jobs could not be filled in 1997. The second concluded that there were 346,000 open positions in 1998. The Department of Commerce then produced its own report, which drew heavily upon the findings of the two ITAA reports.

The General Accounting Office (GAO) published a sharply critical assessment of these three related reports in 1998. It concluded that all of their shortfall estimates were questionable due to the studies’ weak methodologies and very low response rates. Unabashed, ITAA returned to the fray in 2000. Its third report asserted that over 843,000 information-technology positions would go unfilled that year due to a shortfall of qualified workers. Despite withering criticism from the GAO, the ITAA reports provided useful political support for the successful lobbying campaign for dramatic expansion—to the current level of 195,000 per year—of the H-1B visa, the temporary-visa program for foreign “specialty workers” that comprise the bulk of foreign science and engineering professionals being admitted to work in the United States.

Remarkably, even the recent economic downturn does not seem to have deterred proponents of the workforce shortage theory. Take NASA administrator Sean O’Keefe, who invoked a shortage argument during testimony before

the House Science Committee in October 2002 on NASA's hiring problems. "Throughout the Federal government, as well as the private sector, the challenge faced by a lack of scientists and engineers is real and is growing by the day," O'Keefe told the committee.

The following month a new organization called Building Engineering and Science Talent (BEST) published a report entitled "The Quiet Crisis: Falling Short in Producing American Scientific and Technical Talent." This "quiet crisis," the report's authors noted, "stems from the gap between the nation's growing need for scientists, engineers, and other technically skilled workers and its production of them.... This 'gap' represents a shortfall in our national scientific and technical capabilities."

Some business leaders and academics are also advancing the shortage thesis despite the economic downturn. Two reports with findings similar to the BEST study subsequently emerged in the spring of 2003. One was a report addressed to the Government-University-Industry Research Roundtable (GUIRR) of the National Academies, and the other was prepared by the Committee for Economic Development (CED), an organization of business and education leaders.

Even some associated with the NSF seem unchastened by the embarrassing failure of the "shortfall" projections of a decade ago. In June 2003, the National Science Board, the NSF's governing body, released for public comment a draft task-force report addressing the "unfolding crisis" in science and engineering. "Current trends of supply and demand for [science and engineering] skills in the workplace indicate problems that may seriously threaten our long-term prosperity, national security, and quality of life," it said.

### **The evidence**

The profound irony of many such claims is the disjuncture between practice in the scientific and engineering professions—in which accurate empirical evidence and careful analyses are essential—and that among promoters of "shortage" claims in the public sphere, where the analytical rigor is often, to be kind, quite weak. Few, if any, of the market indicators signaling shortages exist. Strong upward pressure

on real wages and low unemployment rates relative to other education-intensive professions are two such indicators conspicuously absent from the contemporary marketplace.

A RAND study released earlier this year assembled the available data from its own research, the NSF, the Census Bureau, the Bureau of Labor Statistics (BLS), the National Research Council (NRC), and several scientific associations. What RAND found largely discredits the case being made for labor shortages. First, RAND noted the obsolescence of the available data, the newest of which refers mostly to 1999 or 2000. RAND called this “especially unfortunate” given that “the [science and engineering] workforce situation has arguably changed significantly” since those heady times of the dot-com, information technology, and telecom booms. But more importantly, RAND’s analysis of even data from the boom period showed that “neither earnings patterns nor unemployment patterns indicate [a science and engineering] shortage in the data we were able to find.”

Recent government unemployment data tend to confirm these findings. Data for the first and second quarters of 2003 released by the Bureau of Labor Statistics showed surprisingly high unemployment rates in science and engineering fields. Even the recently “hot” computer and mathematical occupations are experiencing unemployment of 5.4 to 6 percent. For computer programmers, the numbers range from 6.7 to 7.5 percent. All engineering (and architecture) occupations taken together are averaging 4.4 percent unemployment, while the rates for the high-tech fields of electrical and electronic engineering are in the range of 6.4 to 7 percent. Reported unemployment in the life, physical, and social sciences ranges from 2.8 to 4.1 percent. Many of these numbers are remarkably high for such high-skill occupations. Unemployment for the whole of the U.S. workforce averaged about 6 percent over the same period, and highly educated groups such as scientists and engineers normally have substantially *lower* unemployment rates than the national average.

In the natural-science disciplines, which employ far fewer people than engineering, numerous reports by leading scientists have been pointing to increasingly unattractive ca-

reer prospects for newly minted Ph.D.s. As one example among many, a 1998 National Academy of Sciences (NAS) committee on careers in the life sciences—the largest field in the natural sciences—reported that “recent trends in employment opportunities suggest that the attractiveness to young people of careers in life-science research is declining.” More recent data from 2002 showed that key indicators of career problems had continued to deteriorate since then, prompting Shirley Tilghman, the NAS committee’s chair and current president of Princeton University, to tell *Science* magazine that she found the 2002 data “appalling.” She said the data reviewed earlier by the committee looked “bad” at the time, “but compared to today, they actually look pretty good.” The 2003 RAND study concurred. “Altogether, the data ... do not portray the kind of vigorous employment and earnings prospects that would be expected to draw increasing numbers of bright and informed young people into [science and engineering] fields,” RAND concluded.

It is of course quite possible to have “appalling” early career problems in some areas of science and engineering alongside very good career prospects in others. Administrators of federal technical agencies such as NASA do face special problems such as hiring freezes or other on-going personnel or financial constraints. Senior personnel at NASA and other agencies have been offered substantial early retirement incentives while hiring procedures to replace them tend to be cumbersome and slow. In “hot” fields that are new or growing rapidly, like bioinformatics, human resources are inevitably in short supply. And truly exceptional scientists and engineers will always be few in number and vigorously pursued by employers.

Still, in most areas of science and engineering at present, the available data show sufficient numbers or even surpluses of highly qualified candidates with extensive post-graduate education. This is especially the case in the academy, which has become risk-averse about replacing departing tenured faculty with tenure-track junior positions. Instead, many universities in the United States have been filling such open slots with temporary and part-time appointees they find in ample pools of highly educated ap-

plicants. Indeed, advertisements for a single tenure-track assistant professorship often attract hundreds of applications from recent Ph.D.s. Similar circumstances prevail for engineers and scientists in large sectors of the U.S. economy such as telecommunications, computing, and software, sectors in which lurching market collapses and large bankruptcies have greatly weakened demand for their services.

### **What does the future hold?**

Many recent shortage claims point not to current circumstances, but to projections of future demand. What can be said with reasonable assurance about such predictions?

Unfortunately, labor-market projections for scientists and engineers that go more than a few years into the future are notoriously difficult to make. An expert workshop convened by the National Research Council in 2000 reported universal dissatisfaction with past projection efforts, and stated declaratively that “accurate forecasts have not been produced.”

The workshop report commented in particular upon one such study that is often cited by shortage proponents: the Bureau of Labor Statistics’ “Occupational Outlook.” The most recent “outlook,” completed in 2001, projected that over the next decade computer-related fields, including software engineers, computer-network and systems administrators and analysts, would likely be the fastest growing occupations nationwide. But the NRC workshop report noted the limitations inherent in such projections:

The omission of behavioral responses makes the BLS outlook unreliable as a basis for decisions on federal funding designed to respond to anticipated shortages.... The BLS outlook neglects many dimensions in which adjustment may occur, including training and retraining, and especially in response to changes in wages.... No response is built into time trends in relative occupational wages on either the demand side (where employers substitute capital for labor when relative wages rise) or the supply side (where students move toward occupations in which relative wages are rising).

One might add that many science and engineering fields are heavily influenced by federal funding, which makes pro-

jections of future workforce demand dependent upon quite unpredictable political decisions and world events. To their credit, the authors of the BLS Occupational Outlook themselves emphasize the need for caution. “The BLS projections were completed prior to the tragic events of September 11 ... [and] the nature and severity of longer-term impacts [of the terror attacks] remains unclear,” the authors write. “At this time, it is impossible to know how individual industries or occupations may be affected over the next decade.”

Owing to such events and unforeseeable changes in the market, no one can know what the U.S. economy and its science and technology sectors will look like in 2010. It follows that no credible projections of future “shortages” exist on which to base sensible policy responses.

### **Misdirected solutions**

Not only are claims of current or future shortages inconsistent with all available quantitative evidence, but also many of the solutions proposed to deal with the putative “crisis” are profoundly misdirected. The most popular proposed solutions seem to focus mainly on the supply side, urging action to increase the numbers of U.S. students pursuing degrees in science and engineering. Recommendations often include calls for reform of the U.S. elementary and secondary education systems, especially inadequacies in science and mathematics; informational efforts to promote knowledge of such careers among U.S. secondary school students and of the science and math prerequisites required to pursue them at university level; financial and other incentives to increase interest in such fields among U.S. students; and increases in the number of “role models” in science and engineering fields for women and underrepresented minorities. Other commentators, apparently more pessimistic about the abilities of U.S. students, recommend increasing the numbers of students or workers from abroad to meet the needs of the U.S. economy.

This focus on supply to the virtual exclusion of considering demand is not warranted. However desirable many of these proposals may be on other grounds, they are unlikely to be very effective in attracting U.S. students to careers in

science and engineering unless employment in these fields is sufficiently attractive to justify the large personal investments needed to enter them. Surprisingly enough, it is far from common to hear this rather obvious point raised in public discussions of the subject. To put the matter more succinctly, those who are concerned about whether the production of U.S. scientists and engineers is sufficient for national needs must pay serious attention to whether careers in science and engineering are attractive relative to other career opportunities available to American students. And yet little such attention has been forthcoming in recent years.

The qualifications for careers in engineering and especially in science involve considerable personal investments. The direct financial costs of higher education in the sciences can be staggering, depending on the financial circumstances of undergraduates and their families, whether the institution is private or public, whether postbaccalaureate education is required, and whether such education is subsidized.

Engineering and science differ substantially in these characteristics. For engineering, only the baccalaureate is normally required for entry into the profession. Most engineering B.S. degrees are earned at state universities, which are heavily subsidized by state governments. In addition, direct financial aid is often available for those in financial need. In contrast, professional careers in the sciences now commonly require completion of the Ph.D. and increasingly require subsequent postdoctoral work. The direct financial costs of this extensive graduate and postdoctoral work are typically heavily subsidized by both government and universities. Yet even with such subsidies, the personal costs to qualify as a scientist can be quite high—mainly due to the lengthening time required to attain the degree and complete postdoctoral training.

The extreme case is that of the biosciences, which account for half of all Ph.D.s awarded in the natural sciences. Over the past couple of decades, the average period of required postbaccalaureate study has increased dramatically, to between nine and twelve years from about seven to eight years. The Ph.D. itself has stretched out to seven or eight years from about six, while the now-essen-

tial postdoctoral apprenticeship has lengthened to between two and five years from one or two in decades past. In career terms, this means that most young bioscientists cannot begin their careers as full-fledged professionals until they are in their early thirties or older, and those in academic positions usually are not able to secure the stable employment that comes with tenure until their late thirties. Unsurprisingly, the idea of spending nine to twelve years in postbaccalaureate studies before one is qualified for a real job may be unattractive to substantial numbers of would-be young scientists.

There are also concerns about negative impacts on scientific creativity. Wendy Baldwin, until recently the deputy director for extramural research at the National Institutes of Health (NIH), notes concerns arising at NIH over “the long-held observation that a lot of people who do stunning work do it early in their careers.” Bruce Alberts, in his 2003 President’s Address to the National Academy of Sciences, described as “incredible” the fact that even though NIH funding has doubled in only the past five years, the average age of first-time grant recipients has continued increasing. “Many of my colleagues and I were awarded our first independent funding when we were under 30 years old ... [now] almost no one finds it possible to start an independent scientific career under the age of 35,” Alberts told the academy. Nobel laureate and co-discoverer of DNA structure James Watson agrees. As he put it in characteristically pithy terms in a 1992 interview, “I think you’re unlikely to make an impact unless you get into a really important lab at a young age.... People used to be kings when they were nineteen, generals. Now you’re supposed to wait until you’re relatively senile.”

It’s not hard to see why this also portends ill for science careers at a personal level. Delaying career initiation until one’s thirties poses inherent conflicts with marriage and family life. Many who might be attracted to careers in science are justifiably concerned that such a career choice comes at too high a personal cost.

The problem has not gone unnoticed. Many scientific societies have decried the trend toward longer degrees and postdoctoral apprenticeships, and U.S. universities have

created more than 70 new two-year graduate science degrees designed for those who wish to pursue scientific careers outside of the academy. (Start-up costs of many of these have been supported by Sloan Foundation grants.) These new degrees, called "Professional Science Master's degrees," have been attracting interest among U.S. science majors who might otherwise choose paths leading to business or law school.

### **Opportunity costs**

Some senior scientists stress that no one should pursue a science career to get rich, which is a point well taken. Yet it would be unwise simply to ignore how alternative career paths compare in strictly economic terms. The nine-to-twelve year period that a would-be bioscientist now must spend in a student role or low-paid postdoctoral position means that a substantial fraction of lifetime income that would otherwise be earned must be foregone. This is what economists term "opportunity costs," and these are by no means insignificant. A 2001 study conducted by a team of leading economists and biologists for the American Society for Cell Biology found that bioscientists experience a "huge lifetime economic disadvantage" on the order of \$400,000 in earnings discounted at 3 percent compared to Ph.D. fields such as engineering, and about \$1 million in lifetime earnings compared with medicine. When expected lifetime earnings of bioscientists are compared with those of M.B.A. recipients from the same university, the study's conservative estimates indicate a lifetime earnings differential of \$1 million exclusive of stock options. When stock options are included, the differential doubles to \$2 million.

In smaller scientific fields such as physics and chemistry, where Ph.D. programs are shorter and lengthy postdoctoral work less universal, the differentials are smaller but still substantial. Given the direct financial costs and opportunity costs, careers in science and engineering must offer significant attractions relative to other career paths available to American students. College graduates with demonstrated talent and interest in science and

mathematics can choose to go to medical school, law school, or business school; they can pursue other professional education; or they can enter the workforce without graduate degrees.

The options available to most foreign students—at least for those from poorer countries—are completely different. Most do not have the option to study at U.S. medical, law, or business schools (due to the high costs and lack of subsidies) nor can they easily enter the U.S. workforce directly. In contrast, science Ph.D. programs at many American universities actively recruit and subsidize graduate students and postdoctoral fellows from China, India, and elsewhere, from which positions many are able to move on to employment in the United States.

There are, of course, many significant noneconomic rewards associated with careers in science and engineering: the intellectual challenge of research and discovery; the life of the mind in which fundamental puzzles of nature and the cosmos can be addressed; the potential to develop exciting and useful new technologies. For some, these attractions make science and engineering careers worthy of real sacrifices—they are “callings” rather than careers, analogous to those of religious or artistic vocations. Happily, a number of talented students will decide, based on personal values and commitments, to pursue graduate degrees and careers in science or engineering, even with full knowledge that the career paths may be unattractive in relative terms. Yet it is also true that others with strong scientific and mathematical talents will decide that a better course for their lives would be to go directly into the workforce rather than to follow additional scientific studies, or instead to pursue professional degrees in business, law, or other fields.

### **The politics of shortages**

Public discourse about these issues is mired in paradox. There are energetic claims of “shortages” of engineers, while unemployment rates are high and mid-career engineers face increasing job instability. There are reprises of earlier “shortage” claims about scientists, while under-

graduates demonstrating high potential in science and math increasingly seem to be attracted to other careers. Some emphasize the need for K-12 reform, even though very large numbers of entering college freshmen intend to major in science or engineering but later choose otherwise. The NIH research budget has doubled within only a few years, but the average age at which scientists win their first research grants is rising. Why are shortage claims so persistent despite so much evidence to the contrary?

On this issue, where one stands depends upon where one sits. Most of the assertions of current or impending shortages, gaps, or shortfalls have originated from four sources: university administrators and associations; government agencies that finance basic and applied research; corporate employers of scientists and engineers and their associations; and immigration lawyers and their associations.

The economist Eric Weinstein has uncovered documentary evidence suggesting that the real intent of some of those involved in the 1980s "shortfall" alarms from NSF may have been to limit wage increases for Ph.D. scientists. Whether or not such motivations underlay that episode, we can certainly appreciate the various incentives that may currently spur some to endorse such claims. Universities want to fill their classrooms with undergraduates who pay their fees and finance their research with external funding, and to do so recruit graduate students and postdoctoral fellows to teach undergraduates and to staff their research laboratories. Government science-funding agencies may find rising wages problematic insofar as they result in increased costs for research. Meanwhile, companies want to hire employees with appropriate skills and backgrounds at remuneration rates that allow them to compete with other firms that recruit lower-wage employees from less affluent countries. If company recruiters find large numbers of foreign students in U.S. graduate science and engineering programs, they feel they should be able to hire such noncitizens without large costs or lengthy delays. Finally, immigration lawyers want to increase demand for their billable services, and especially demand from the more lucrative clients such as would-be employers of skilled foreign workers.

None of these groups is seeking to do harm to anyone. Each finds itself operating in response to incentives that are not entirely of its own making. But a broad commonality of interests exists among these disparate groups in propagating the idea of a “shortage” of native-born scientists and engineers. Moreover, claims of shortages in these fields are attractive because they have proven to be effective tools to gain support from American politicians and corporate leaders, few of whom would claim to be experts on labor markets. As noted earlier, the dubious reports from the ITAA were used successfully to convince the Congress to triple the size of the H-1B visa program in 2000. In late 2002, a leading lobbyist for the National Association of Manufacturers, responding to criticism that shortage claims cannot be supported by credible evidence, put the matter succinctly: “We can’t drop our best selling point to corporations,” he explained.

Such a short-term view is naturally attractive to lobbyists because it works politically. But it may turn out to be a serious error over a longer period of time. Claims of impending shortages can easily become self-fulfilling prophecies if, as in the past, government responds by subsidizing education or increasing visas for foreign workers without seriously considering the effects such actions may have upon the attractiveness and sustainability of career paths for such professionals. Action along these lines could create an even larger surfeit of scientists and engineers—one that drives down the number of Americans willing to enter these professions and, paradoxically, creates the very problem it seeks to address.

Instead of raising the false flag of shortages, those concerned about the future of science and engineering in the United States should encourage objective appraisals of current career paths, as well as innovations in higher and continuing education designed for more agile adjustments to inevitable changes in these dynamic fields. The overarching goal should be to find ways to make these careers attractive relative to the alternatives, for this is the only sustainable way to ensure a supply commensurate with the United States’ science and engineering needs.