Introduction

In this increasingly globalized world, respected and influential voices warn urgently that the United States is *falling behind* in a global "race for talent" that will determine the country's future prosperity, power, and security. Expressions of such concerns have become common, even conventional, and are embraced with little question by many who have leadership roles in politics, business, media, and education. The gist of this perspective and its key assumptions might be fairly summarized as follows:

> The "second wave" of globalization now under way differs significantly from the "first wave" of about a century ago.[1] Now a nation's economic prosperity is no longer closely related to its physical capital, natural resources, and economic system, but instead is driven by its "human capital." It is the education, skill, creativity, and entrepreneurship of a country's population that will determine whether it will prosper or fall behind in the twenty-first century.
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> The dominant economic role now being played by science and technology means that the core of any nation's human capital consists of the size and creativity of its science and engineering workforce. Hence it is critical for the future of the United States (and indeed of all nations) both to educate domestically *and* to attract from abroad the largest feasible numbers of the "best and brightest" of scientists and engineers. These resources of critical human capital will, in turn, propel the economic growth and prosperity of the nation. Countries that fall behind in science and technology will stagnate economically as others charge forward. Moreover, leading-edge capabilities in science and engineering also have become central to every nation's international and domestic security.
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> In short, scientists and engineers form the vanguard of each country's future "competitiveness" and security in a globalized world.

For some, the subject is more than an issue of competitive advantage among nations in economic or security terms. Indeed, it is a matter of global human survival, expressed in terms approximating the following:

> Humanity as a whole has much to gain from collective investments in human capital in science and engineering. Research in basic biomedical science is the wellspring of major advances against diseases such as cancer, HIV, malaria, and new epidemics. The creativity of scientists and engineers in biomedical fields enables reduced mortality and healthier lives for all of humanity, lower expenditures on healthcare, and more productive workforces worldwide. Scientists and engineers in other fields are of equal importance to the future of humanity, advancing understanding and capabilities in chemistry, physics, energy, and earth sciences that contribute to the global good by enhancing collective understanding of Earth's environment and of effective means for mitigating damage to it.

Guided by such perspectives, many corporate, political, and opinion leaders in the United States have been sounding persistent alarms about current or future "shortages" in the nation's human capital in science and engineering, and more generally to unfavorable trends relative to those in other countries. If their concerns can be encapsulated in a single sentence, it might read as follows:

> The United States, long a leader in the number and quality of its scientists and engineers, has been *falling behind* its international competitors, and is thereby risking serious deterioration in its future prosperity and security.

These recent alarming assessments of the state of U.S. education and research in science and engineering turn out to be quite inconsistent with a very substantial body of research literature produced by independent scholars. Nonetheless, the U.S. political system during the past decade clearly has been highly responsive to claims of "shortages" or "shortfalls" of scientists and engineers, and has taken actions designed to increase the number of scientists and engineers in the U.S. workforce.

This political responsiveness to such assertions of alarm is by no means a new phenomenon. Quite the contrary: concern about "shortages" has a long and fascinating history that goes back at least to World War II. It is a story that lies at the heart of many of the central domestic and international developments, both political and economic, of that tumultuous period. Perversely, past shortage claims, some of which are eerily similar to those being heard today, have led to repeated three-stage cycles of *alarm*, *boom*, and *bust* that have buffeted and destabilized the nation's science and engineering workforce.

In stage 1 of such cycles, the *alarm* has been sounded about the United States "falling behind" in the supply of scientists and/or engineers. In stage 2, the U.S. political system has responded to these alarms with measures that generated rapid expansion in the supply of scientists and engineers. This stage 2 *boom* has then generally (though not always) been followed by stage 3 of the cycle—a *bust* in which expanded numbers of enthusiastic young scientists and engineers, some of whom had devoted many years to advanced education, unexpectedly have found themselves facing chilly labor markets and unattractive career prospects. Finally the cycle has come full circle, as knowledge of the unhappy career experiences of recent graduates cascaded down to talented younger generations of U.S. students who have chosen to pursue other career paths, thereby stimulating a new round of alarms about impending shortages.

This is hardly a happy or uplifting history. But it is a history from which much could be learned to inform competing claims that are readily apparent in current controversies about the prospects for U.S. science and engineering.

In Brief, the Three Core Findings of This Book

The evidence assembled in this book leads inescapably to three core findings:

- First, that the alarms about widespread shortages or shortfalls in the number of U.S. scientists and engineers are quite inconsistent with nearly all available evidence;
- Second, that similar claims of the past were politically successful but resulted in a series of booms and busts that did harm to the U.S. science and engineering enterprise and made careers in these fields increasingly unattractive; and
- Third, that the clear signs of malaise in the U.S. science and engineering workforce are structural in origin and cannot be cured simply by providing additional funding. To the contrary, recent efforts of this kind have proved to be destabilizing, and advocates should be careful what they wish for.

The book is organized as follows. In chapter 1, we review several recent politically influential reports, all of which emphasized the critical need for legislation and public expenditures to increase the number of scientists and engineers entering the U.S. workforce. The discussion assesses the data and analyses underlying these reports and the overlap among the constituencies that produced them.

In chapter 2, we discuss a half-century of experience with earlier influential reports that urged similar actions in prior decades. The chapter discusses no fewer than five earlier rounds of such concerns that go back to the late 1940s. Each cycle lasted for between 10 and 20 years, and generally followed the same three-stage pattern of "alarm/boom/bust."

> *Round 1* began in the decade immediately following World War II. The focus by the U.S. government in this period was on large increases in the number of physicists, seen as a strategic human resource essential to Cold War competition with the Soviet Union. By the mid-1950s, the number of recent PhDs in physics had grown very rapidly, but unexpectedly those newly emerging graduates were beginning to experience difficult career prospects. In this case a full-blown bust seems likely to have ensued had it not been for the launching of Sputnik 1 in October 1957 that initiated Round 2.
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> *Round 2*, driven by political shock over the Sputnik launches, produced even larger increases in the U.S. science and engineering workforce. By the late 1960s, however, political enthusiasm had waned sharply for federal funding of science and engineering, producing an ensuing bust of serious magnitude in the 1970s.
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> *Round 3* was driven by several federal initiatives—the "war on cancer" that had begun in the 1970s, the 1980s defense buildup under President Reagan, and anxious reports from federal agencies during the 1980s. A 1983 federal commission report described "A Nation at Risk" because of a failing public education system, and a few years later other federal reports sounded alerts about "looming shortfalls" of scientists and engineers. Again increased government funding was provided to expand the number of scientists and engineers. By the late 1980s, however, an economic recession and the collapse of the Soviet Union led to declines in spending on science and engineering and reversal of Reagan's defense buildup, all contributing to an ensuing bust in the early 1990s.
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> *Rounds 4 and 5*, discussed in part 2 of chapter 2, took place after the end of the Cold War and so lacked the national security elements of the earlier three rounds. Rounds 4 and 5 had different origins, but overlapped in time—Round 4 ran roughly from 1995 to 2005, while Round 5 covered the years 1998–2008.
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> The origins of *Round 4* lay in powerful and concurrent booms in several high-tech industries (especially information technology, Internet, telecommunications, and biotech), along with a brief episode of large-scale expenditures to "fix" critical software that many warned might fail due to the impending end of the twentieth century, and hence known as the "Year 2000," "Y2K," or "Millennium

bug" problem.[2] These concurrent booms were followed by concurrent busts in all of these industry sectors beginning around 2001. Round 4 also initiated a new strategy that persists to the present day. Coupled with the waning of national security concerns driven by the Cold War, the new availability of large pools of scientists and engineers in low-income countries such as China and India led U.S. employers to advocate successfully for expanded access to large numbers of foreign workers admitted on temporary visas.

Round 5 affected only biomedical research, driven by a successful lobbying effort warning of inadequate federal funding for such research. In response, the federal government sharply increased biomedical research funding by (literally) doubling the budget of the National Institutes of Health over a five-year period from 1998 to 2003. By the end of this period, though, political enthusiasm for further increases had waned as budget constraints emerged and members of Congress in key positions changed. Subsequent NIH budgets were essentially flat, but even in the absence of large cuts these flat budgets produced a sudden bust variously described as a "hard landing" or a true "funding crisis." This bust was later moderated temporarily by a massive infusion of short-term funds in 2009 and 2010, as part of the unexpected economic stimulus package to counteract the economic emergency that began in 2008, only to return to renewed alarms about insufficient federal funding for biomedical research.

In chapter 3, we explore the question of why these repeated cycles of *alarm/boom/bust* have occurred, and assess whether in the end they have mattered. The producers of the studies and reports related to the earlier cycles—which came to widely differing conclusions—were many and various: government agencies such as the National Science Foundation, Department of Commerce, and the Government Accountability Office; nonprofit analytic organizations such as RAND, National Research Council, and Urban Institute; employer organizations such as the Information Technology Association of America and the Business Roundtable; corporations seeking political support for their views; advocacy groups producing their own advocacy "research"; as well as independent academic researchers in a number of universities. For the most influential of these reports, we offer detailed case studies describing the origins, personnel, funding, and promotional efforts underlying each.

In chapter 4, we consider the influential roles played by interest groups and their lobbyists in these cycles. Which such groups have been most unified or most divided, most influential or unsuccessful in their efforts? To what extent have interest groups effectively used credible empirical evidence and research, or to what extent used "advocacy research" of little credibility other than in the political domain?

In chapter 5, we explore the unique characteristics of labor markets for scientists and engineers. How do these characteristics affect public perceptions, and to what extent have the successive cycles of *alarm/boom/bust* affected the attractiveness of careers in these fields? Public discussion has been dominated by persistent but contradictory claims of "shortages" and "surpluses" of scientists and engineers. These emanated from employers and their organizations, higher education, think tanks and independent experts on U.S. labor markets, government agencies, and the media—in many cases these groups have been talking past one another.

In chapter 6 we describe in some detail the distinctive structures that "produce" most of the country's scientists and engineers, along with increasing fractions of those from other countries. These structures, most of which have evolved since World War II, include the world-class array of U.S. research universities, vast governmental funding agencies such as the National Institutes of Health and the National Science Foundation, and the intersections between these structures with the remarkably complex U.S. legal system that is supposed to regulate migration of permanent immigrants, temporary workers, and international students.

Chapter 7 focuses on the U.S. science and engineering workforce in international comparison, addressing in particular some of the recent trends and patterns that have evoked expressions of both concern and confidence in the United States about "competitiveness."

In chapter 8, we conclude with an overall assessment of the U.S. system that has evolved as the joint driver of both basic research and higher education in science and engineering. To what extent have the outputs of this system been successful? Have they been significant positive forces in the economic development and prosperity of the United States? Have some features of this system evolved in ways that are counterproductive? If so, how might the current structure be incrementally modified or tweaked both to maximize the positive and minimize the negative? We consider whether the repeated alarms sounded over the past six decades may be the only way to gain high-level political attention to the important policy issues surrounding science and engineering. Finally, we also discuss whether changes to this system are feasible, or in the alternative more likely to be effectively blocked by those whose interests would lead them to resist.