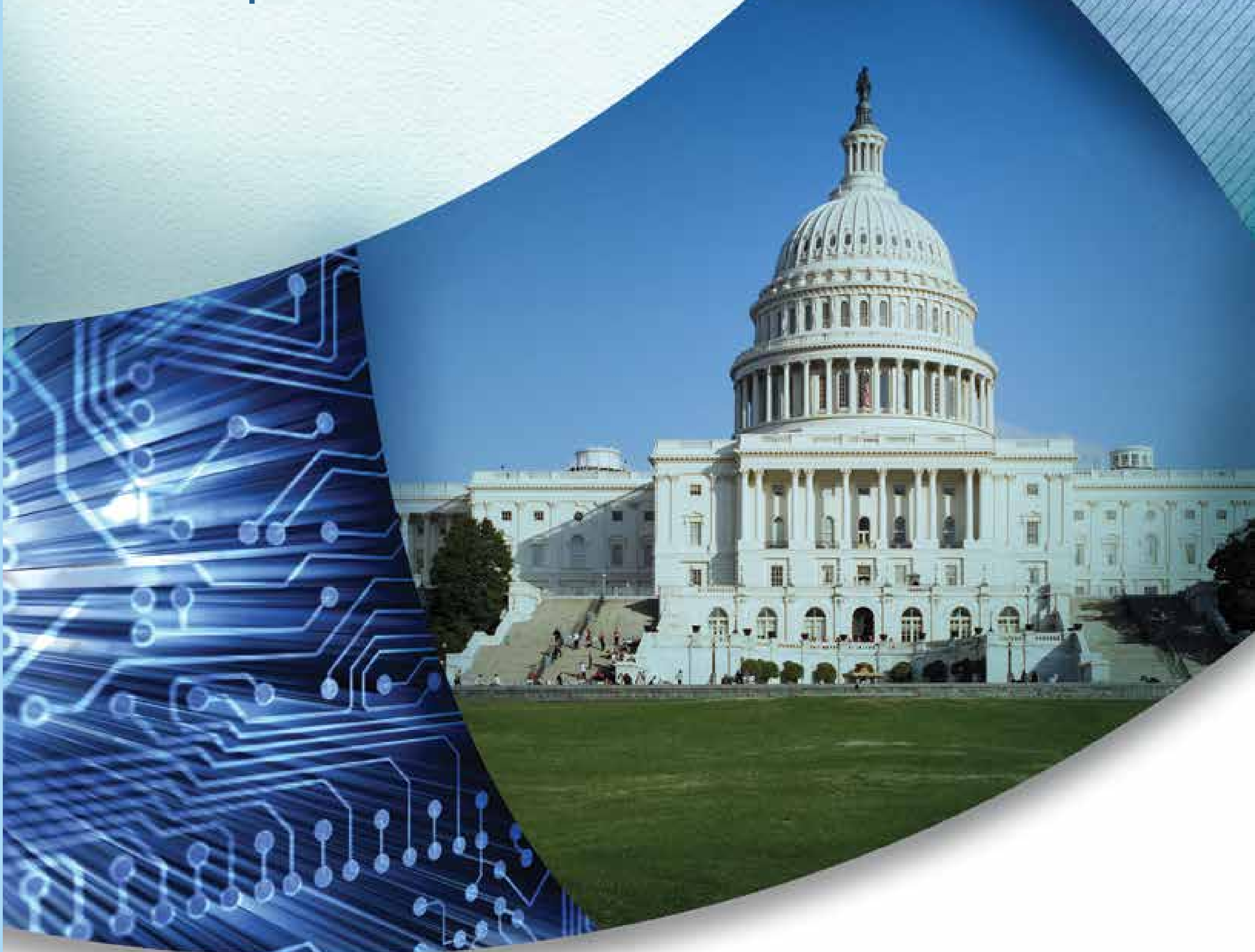
Talent, Immigration, and U.S. Economic Competitiveness



GORDON H. HANSON & MATTHEW J. SLAUGHTER | MAY 2013

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About the Authors

Gordon H. Hanson is the Pacific Economic Cooperation Chair in International Economic Relations at UC San Diego (UCSD), where he is director of the Center on Emerging and Pacific Economies and founding co-director of the Policy Design and Evaluation Lab. At UCSD, he has faculty positions in the School of International Relations and Pacific Studies and the Department of Economics. Professor Hanson is also a Research Associate at the National Bureau of Economic Research.

Matthew J. Slaughter is Associate Dean for Faculty and Signal Companies' Professor of Management at the Tuck School of Business at Dartmouth. He is also a Research Associate at the National Bureau of Economic Research, an adjunct Senior Fellow at the Council on Foreign Relations, and a member of the Congressional Budget Office's Panel of Economic Advisers. From 2005 to 2007, he served as a Member of the President's Council of Economic Advisers.

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Executive Summary

For generations, highly skilled labor in science, technology, engineering, and mathematics (STEM) has been a catalyst for innovation, job creation, and rising standards of living in America. These innovative STEM workers have long been not just native-born Americans but immigrants, as well. Immigration has played a vital role in helping American companies meet their growing demand for skilled labor—demand that, without immigration, would be growing well ahead of supply, forcing companies and the country to endure a talent crunch.

This white paper delivers three central messages.

MESSAGE #1: Talent—especially the talent of highly educated STEM workers—drives much of America's innovation and economic growth. In the increasingly global economy, America's need for talent has become even more acute. Despite the nation's historic innovation prowess, concern is rising among leaders that our economic strength is waning.

- Of the rise in real U.S. output per person over the 20th century, over 80% was accounted for by innovation (as proxied by rising educational attainment and research and development) and technological progress. Innovation requires STEM talent.
- Workers in STEM occupations are much more educated than are workers in other occupations. Compared with workers in non-STEM jobs, today workers in STEM occupations are over 2.2 times more likely to have a bachelor's degree, 2.7 times more likely to have a master's degree, and 5.3 times more likely to have a doctorate.
- There are more than 4.9 million STEM workers in America: 1.5 million engineers, 1.4 million software developers and computer programmers, and 1.3 million computer and information analysts, database administrators, and network architects. Almost all the jobs in the latter two categories are quite new to the U.S. economy. Innovation goes hand in hand with the creation of new demand for STEM labor.
- The World Economic Forum's 2012 ranking of countries' "Global Competitiveness" has the United States at #7, down from #2 in 2004, and also at #7 in the "Innovation" category. For 2012, the World Intellectual Property Organization ranks the United States at #10 in its Global Innovation Index—down from #1 in 2009. Absent measures to strengthen America's innovation capabilities, the nation's ranking will continue to slide.
- Among the 65 countries that participated in the Organisation for Economic Co-operation and Development's (OECD) most recent examinations of 15 year-olds, U.S. students ranked 15th in reading, 23rd in science, and 31st in mathematics. While there are long-run plans to improve America's STEM education and training, in the near term, U.S.-born students cannot meet the nation's need for STEM skills.

MESSAGE #2: Immigration plays a critical role in helping America meet its steadily growing demand for talent—especially for highly skilled STEM workers. Immigrants have long made substantial contributions to American innovation, both at the highest levels and throughout the economy at all stages of discovering and developing new ideas. Over time, America's reliance on talented immigrants has been rising, not falling. America attracts immigrants who achieve very high levels of education and who are strongly inclined toward training in STEM disciplines.

- While immigrants comprise 12% of all U.S. residents, they comprise 27% of recent U.S.-resident Nobel Prize winners in chemistry, medicine, and physics and 25% of recent MacArthur "Genius" Fellows. U.S. immigrants constitute over one-third of current National Academy of Science members in mathematics and engineering, and one-third to one-half of university faculty in top-ranked engineering and computer science programs.
- One quarter of U.S. high-technology firms established since 1995 have had at least one foreign-born founder. These new companies employ 450,000 people and generate more than $50 billion in sales. Immigrants or their children founded 40% of Fortune 500 companies, including firms behind seven of the 10 most valuable global brands.
- Today, foreign-born individuals make up 20% of STEM workers with bachelor's degrees and 40% of those with advanced degrees. Among all U.S. workers both with a STEM doctorate and in a STEM occupation, 60% are immigrants. In the key STEM fields of computer science, computer programming, and software development, over 50% of U.S. workers with a master's degree are immigrants.

MESSAGE #3: Even after the Great Recession, America's need for more talent persists. America's demand for skilled STEM workers continues to grow—and immigrants continue to help meet this demand, both directly and more broadly through their expansive contributions to America's innovation potential. Post-recession, unemployment in STEM occupations has been falling sharply as the STEM labor market rapidly tightens.

- Relative to non-STEM workers of the same age and educational attainment, STEM workers in America today earn a compensation premium of about 25% – a differential that has changed little over the past 30 years despite the substantial increase in the relative size of America's STEM labor force. This STEM wage premium has not disappeared because America's demand for STEM talent has continued to expand.
- Over the past decade, the earnings of STEM workers have risen relative to all other U.S. occupations by 3% to 6%. Since 2000, real wages of main STEM occupations have grown while real wages for nearly all other U.S. occupations have fallen.
- Looking among U.S. STEM workers, there is no evidence that immigrants are paid less than U.S.-born citizens. Using the most comprehensive data available and a number of alternative approaches to controlling for the differences in earnings across workers (such as age, gender, education, industry of employment, and specialized occupation), there is no consistent statistical difference between the earnings of U.S.-born STEM workers and immigrant STEM workers.
- The market for STEM labor is tightening. The unemployment rate for prime-age STEM workers with at least a college degree fell from 4.5% in 2009 to 2.5% in 2012, barely above its 20-year average of 2.45%. In computer occupations (programmers, software developers, computer scientists, computer systems analysts), the unemployment rate has declined even more dramatically—from 5.4% in 2009 to 2.5% in 2012—and is now below its 20-year average of 2.8%.

The Contribution of Talent to American Innovation and Overall Competitiveness

Innovation has long played a central role in driving growth in U.S. output, jobs, and income—and this role may be even more important in the years ahead. Discovering new products and processes boosts output in existing companies and creates entirely new industries. This innovation creates new jobs and higher standards of living for all American workers and their families. Indeed, for many generations, the overwhelming majority of growth in U.S. output, incomes, and overall standards of living has been driven by discovering new ideas that fostered new products and processes of production.

Perhaps most vital to America's innovation success has been the essential factor of talent: the highly skilled knowledge workers who discover and develop the new ideas at the heart of innovation. And among these talented workers, most critical for many innovations are workers in STEM.

THE PAST: THE MASSIVE CONTRIBUTION OF INNOVATION TO AMERICA'S ECONOMY

Since the founding of the American republic, innovation has been a primary driver of growth in U.S. output, jobs, and income. This basic economic fact of knowledge discovery has been well established by academic and policy research in recent decades, and it is widely recognized by leaders in business and in government. For example, here is a statement on the role of innovation in America's economic growth and overall success, from a landmark new study by the U.S. Department of Commerce.

Innovation, the process through which new ideas are generated and put into commercial practice, is a key force behind U.S. economic growth and national competitiveness…Innovation protected by IP rights is key to creating new jobs and new exports. Innovation has a positive pervasive effect on the entire economy, and its benefits flow both upstream and downstream to every sector of the U.S. economy. Intellectual property is not just the final product of workers and companies—every job in some way, produces, supplies, consumes, or relies on innovation, creativity, and commercial distinctiveness.[1]

Innovation has been the foundation of America's economic strength. Over the arc of American economic history, many innovations have been incremental: slight refinements of products and processes that better serve companies' customers. Other innovations are truly disruptive and transformational, creating new industries and bursts of job growth while often simultaneously displacing existing companies, workers, and ways of doing business.

The cumulative economic benefit of innovation—indeed, the cumulative impact on the average standard of living of a country's citizens—is best expressed in terms of productivity: the average value of output of goods and services that a country produces per worker.

The economics of this "essential arithmetic" for why productivity matters is simple. Broadly defined, a country's standard of living rises with the quantity and quality of goods and services its citizens can consume: people achieve economic well-being by consuming goods and services such as food, clothing, and medical care. Purchasing these items, however, requires some means to pay for them. For almost all people, their income is the primary—often the only—means they have to provide for consumption. In turn, people's income derives from producing goods and services, usually by working with others in firms, be they large or small, public or private. Thus, the more and better quality goods and services people produce—that is, the more productive they are—the more income they receive and the more they can consume. Higher productivity means a higher standard of living.

How can a nation raise its productivity? There are two basic means. One is to save and invest to accumulate the other inputs people work with to produce things. The most important other input people need is capital, broadly defined as goods and services that help people make other goods and services—e.g., buildings, machinery, and software.

The second way to raise productivity is to improve the technological know-how for transforming inputs into outputs thanks to innovation. New products and processes allow workers to make new and/or more goods and services. What makes innovation so powerful for productivity is that many ideas are ultimately non-rivalrous—i.e., their use by one company does not preclude their use by another (unlike capital and nearly all other goods and services, which are rivalrous). Thus, the more ideas a country has today, the easier it is to produce additional ideas tomorrow.

So, what does the data say has driven America's rising productivity—and thus average standards of living—over the generations? A large body of academic and policy research has found that the overwhelming majority of America's growth in productivity over the 20th century was driven by innovation and the resulting technological advances.

Robert Solow, in his seminal work that helped lead to his Nobel Prize in economics, calculated that the large majority of U.S. growth during the first half of the 20th century was driven by innovation and technological progress.

- Of the rise in real U.S. GDP per person-hour between 1909 and 1949, "about one-eighth of the total increase is traceable to increased capital per man hour, and the remaining seven-eighths to technical change."[2]
- Looking at the second half of the 20th century, one study found that for growth in U.S. per capita GDP from 1950 to 1993, 80% was accounted for by discovery of innovative ideas fostered by the combination of—to be discussed below—rising educational attainment and R&D effort.[3]

And looking at the recent period of strong U.S. productivity growth that ran for about a decade starting around 1995, the majority of that growth was driven by faster technological innovation in information-technology (IT)—a highly innovation-intensive industry.[4]

- From 1995 to 2005, U.S. labor productivity grew at an average annual rate of 2.9%, up from a 1.5% annual rate in the preceding 10 years (though falling to 1.6% after 2006).
- Post-1995, technical change has accounted for over half of U.S. per capita GDP growth.

Substantial research has found that innovation matters because the social benefits of knowledge often exceed its private benefits; in the jargon of economics, discovery of ideas generates "positive externalities" through several channels (such as worker mobility, and the more general property that ideas, different from other goods and services, are easily shared). A number of studies have found that the social return to R&D exceeds the private return by at least double.[5]

The historical contribution to the U.S. economy of innovation-intensive industries looks strong not just on its own, but in relation to other countries as well. On many measures, today the United States remains the world's largest producer of idea-intensive goods and services.[6]

THE PRESENT: THE CONTRIBUTION OF STEM TALENT TO AMERICAN INNOVATION

What factors account for America's long-standing innovation strength? Many scholars and leaders have identified a constellation of factors working together across a number of areas including laws and regulations, capital markets, and labor markets.[7]

Perhaps most fundamental for innovation success, however, is the supply of talent: the highly skilled knowledge workers who discover and develop the new ideas at the heart of innovation. And among these talented workers, most critical for many innovations are workers in science, STEM. One reason for this is that STEM workers conduct the basic research that inspires applied product and process innovations. In many parts of the U.S. economy, innovation that ultimately ends up on the product shelf begins in the STEM research laboratory. Research on innovation consistently shows this integral role for STEM. Relative to college graduates in other fields, STEM graduates are twice as likely to produce a patent and more likely still to have produced a patent that is licensed or commercialized. They are also more likely to launch startup enterprises in technology fields.[8]

How does the U.S. economy create talent? It does so in part through education. A principal foundation of America's economic success over the 20th century was the dramatic skill upgrading of the American labor force through secondary and tertiary education provided by an open, extensive, competitive system of public and private schools. The result was the world's premier education sector and dramatic growth in talent that is the foundation of innovation.

Today's global preeminence of American higher education is well documented.

- The United States is home to eight of the top 10, 37 of the top 50, and 67 of the top 100 universities in the world.

U.S. educational preeminence in STEM fields is especially pronounced.

- In engineering all of the world's top 10 universities are American, as are nine of the top 10 in life sciences and seven of the top 10 in both natural sciences and mathematics.[9]

The scientists and engineers who graduate from U.S. universities, many of whom go on to work for U.S. companies, are responsible for much of America's innovation. Indeed, higher education of any kind—STEM or not—is required for many STEM jobs in the U.S. economy. Workers in STEM occupations are much more educated than workers in other occupations. Based on data for 2009-2011, Figure 1.1 shows this fact clearly.[10] Compared with workers in non-STEM occupations, workers in STEM jobs are 2.2 times more likely to have a bachelor's degree, 2.7 times more likely to have a master's degree, and 5.3 times more likely to have a doctorate.[11]

Not only do STEM occupations require high levels of education, they also, not surprisingly, tend to require high levels of education in STEM fields, rather than in other non-STEM disciplines.

- From 2009-2011, in STEM occupations the fraction of workers with a degree in STEM fields is very high: 72% for workers with a bachelor's degree, 78% for workers with a master's degree, and 87% for workers with a doctorate.
- STEM education is critical for the large majority of workers in STEM fields. To land a STEM job, workers need the rigorous training that engineering, math, and science afford.

Which industries employ STEM labor? STEM workers are utilized extensively across the U.S. economy. For each of 14 major U.S. industries between 2009–2011, Figure 1.2 reports the share of jobs in each sector that were tied to STEM occupations.

Clear in Figure 1.2 is the high employment of STEM workers in innovation-intensive industries: professional services and management (22%), information (10%), and manufacturing (9%).

FIGURE 1.1

Share of Workers by Education Level for STEM, non-STEM, All occupations (%)

Occupation	Less than high school	High school grad	Some college	BA degree	MA degree	Prof Degree	PhD
Non-STEM	8.9%	25.2%	32.0%	21.7%	8.4%	2.5%	1.2%
STEM	0.3%	3.4%	17.8%	47.9%	23.0%	1.3%	6.4%
All	8.5%	24.2%	31.4%	23.0%	9.1%	2.5%	1.4%

Source: American Community Surveys (ACS), 2009, 2010, 2011

- The salient message of Figure 1.2 is that every one of the 14 major U.S. sectors employs STEM workers.

This breadth of STEM employment throughout the U.S. economy reflects, in part, that the drive for innovation is universal—a drive that, as discussed earlier, has been the foundation of rising U.S. prosperity for generations.

A complementary view on the importance of STEM workers in America is shown in Figure 1.3, which reports the number and major occupations of America's STEM workers in 2012.[12]

FIGURE 1.2:
Employment in STEM occupations

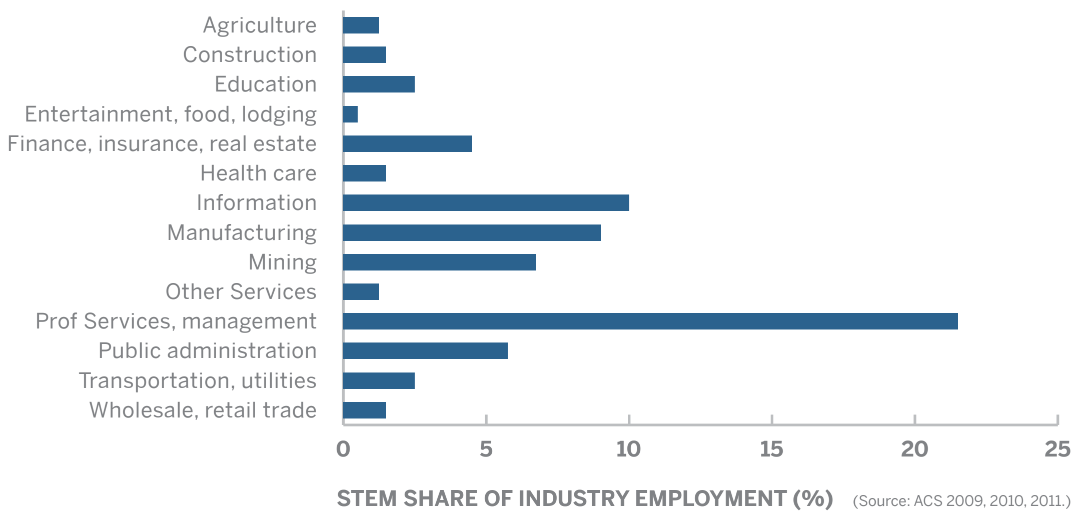


FIGURE 1.3:
Employment and Median Earnings by STEM Occupation

STEM Occupation	Employment	Share of employment (%): STEM occupations	Share of employment (%): All occupations	Median salary
Engineering Occupations	1,530,090	31.1	1.2	86,200
Software Developers and Programmers	1,397,780	28.4	1.1	87,100
Computer and Information Analysts	740,440	15	0.6	80,631
Database Administrators, Network Architects	599,800	12.2	0.5	76,880
Life Scientists, Physical Scientists	534,640	10.9	0.4	71,898
Mathematicians, Computer Scientists	122,880	2.5	0.1	79,686
Total	4,925,630	100.0	3.9	

Source: Bureau of Labor Statistics

For the most recent year of data at the time of writing, 2012, there were over 4.9 million STEM workers in America—3.9% of America's total employment. We disaggregated these 4.9 million into six broad occupation categories, based on the similarity of their endeavors. America has more than 1.5 million engineers, 1.4 million software developers and computer programmers, and more than 1.3 million computer and information analysts, database administrators, and network architects. What is striking about the latter two categories is how new these jobs are to the U.S. economy, thanks to the IT revolution spawning new industries, companies, and activities. Innovation has not just added to overall STEM employment; it has changed the nature of this employment, demanding that American workers acquire fundamentally new skills and master new techniques.

THE FUTURE: SIGNS THAT AMERICA'S INNOVATION STRENGTH IS WANING

Despite America's historic strength of discovery and of transforming innovations into new products, companies, industries, and jobs, concern is rising among leaders in both the private and public sectors that America's innovation strength is waning. Signs of waning strength are apparent in a number of indicators, not just in relative terms in comparison to other countries but even in absolute terms.

Perhaps the most alarming case for America's flagging innovation vitality has been made by the 2007 initial and 2010 follow-up *Gathering Storm* reports—alarming because of the breadth of data brought to bear in this pair of National Academies' studies by a distinguished committee comprised of leading academics, university presidents, CEOs of global firms, and Nobel laureates.[13] Similar alarm bells have been recently rung by the White House.[14]

Consider assessments of America's overall innovativeness compared to other countries. A number of studies using a number of methodologies continue to reach the same concerning conclusion: America's innovativeness, though still high, is falling—in many ways rapidly.[15]

- The World Economic Forum's 2012 ranking of countries' "Global Competitiveness" has the United States at #7, down from #2 in 2004.
- For 2012, the World Intellectual Property Organization ranks the United States at #10 in its Global Innovation Index—down from #1 in 2009.
- In 2009, the Information Technology and Innovation Foundation ranked 44 countries and regions on 16 core indicators of innovation capacity. The United States ranked #4. This was down from America's #1 ranking based on 1999 data. When assessing the rates of change in innovation capacity during 2000-2009, the United States ranked #43—ahead of only Italy. On this rate-of-improvement metric, China ranked #1.

Consistent with these studies of weakening U.S. innovativeness are the data on America's slowing productivity growth, visible in the annual growth in output per worker hour in the non-farm business sector (which many regard as the best indicator of the productivity of the U.S. private sector). From the start of consistent U.S. data in 1947 through 2004, this measure of U.S. productivity growth averaged 2.3% per year. Since that time, however, productivity growth has fallen to just 1.5% per year. This post-2004 average was boosted by the unusually high rates of productivity growth in 2009 and 2010 that were driven primarily not by innovation but rather by dramatic worker layoffs in the wake of the Great Recession. Excluding those two unusual years, in the six other years U.S. productivity growth has averaged just 1.0% per year—with just 0.6% growth in 2011 and 0.7% in 2012.

Several leading scholars on economic growth are now forecasting that U.S. innovativeness and productivity growth may be permanently lower in the future. Indeed, one such scholar has recently forecast that, in contrast to the average growth in U.S. GDP per capita of the past 150 years of about 1.9%, "future growth in consumption per capita for the bottom 99% of the income distribution could fall below 0.5% per year for an extended period of decades."[16]

What explains America's darkening innovation outlook? Part of the cause may be America's faltering growth in educational attainment—the source of much of America's talent dedicated to knowledge discovery. Over the 20th century one of America's greatest achievements was the dramatic skill upgrading of the U.S. labor force. This progress, however, has slowed in the past generation, all while educational upgrading is quickening abroad.

Figure 1.4 shows the remarkable educational growth of the American labor force—and its more-recent sobering slowdown.[17] For every year from 1900 through 1980, it plots for all Americans born that year the mean years of schooling attained by that cohort by adulthood (measured as age 25). Thus, the 1900 value of 8.5 indicates that for all Americans born in the country in 1900, by adulthood the average educational attainment of that cohort was 8.5 years of schooling; similarly, for those born in 1940 average attainment was 12 years of schooling.

One remarkable fact of Figure 1.4 is how over the 20th century, subsequent cohorts of Americans became progressively more educated thanks to the spread of both secondary and tertiary education. Today, those in their early twenties (and so born in the late 1970s) average 14 years of schooling. Looking at the overall U.S. workforce rather than year-by-year cohorts shows the same impressive gains: from 1915 to 2012 the mean educational attainment of all U.S. workers rose by nearly six years, from 7.6 years to 13.5 years—a rate of increase of 0.6 years per decade.

But in addition to this century-long progress, Figure 1.4 also shows a troubling fact: the rate of U.S. educational advance has sharply decelerated.

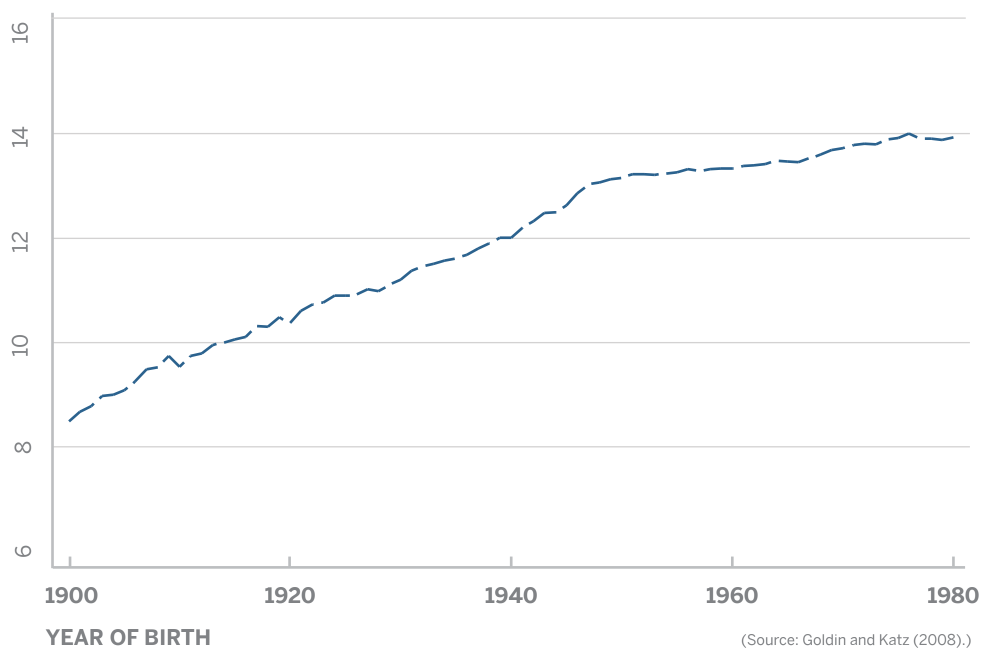
- For cohorts born before 1950, mean years of schooling rose at 0.8 years per decade. For later cohorts, this upgrading slowed, with little change in educational attainment for cohorts born between 1951 and 1965, and much slower growth than pre-1950 after that.

Looking at the overall U.S. workforce, rather than individual cohorts, this slowdown is evident.

- From 1940 to 1980 the mean educational attainment of all U.S. workers rose by 0.9 years per decade (from 9.0 years to 12.5 years)—equivalent to the pre-1950 performance. But from 1980 to 2010 the total increase was barely one year—just 0.4 years per decade.

And while America's slowdown in overall educational attainment is concerning, at least as alarming is its faltering ability to educate children and young adults in STEM. America's governors are sounding this

FIGURE 1.4
Average Years of Schooling for Adults, by Year of Birth



(Source: Goldin and Katz (2008).)

alarm based on the deficiencies they see growing in their local and state schools. A new report by the National Governors Association describes the problem starkly.

The United States has fallen behind in fully realizing the benefits of STEM education. Results...over roughly the past 10 years show little improvement in high school seniors' knowledge of math and science... [Beyond high school,] unfortunately, the growth in post-secondary STEM degrees awarded in the United States over the past decade has been anemic.[18]

This slowdown in America's educational attainment—reflecting the problems plaguing primary and secondary education—threatens America's innovation competitiveness. This is true viewing the U.S. economy in isolation. The median worker in the U.S. labor force today has a high school degree plus little more than one year of post-high school education. A continued near-stagnation of educational attainment could limit the creative dynamism of innovation and entrepreneurship that drove so much of America's economic growth over the 20th century.

But in today's increasingly global economy, America's competitiveness is doubly challenged by its slowdown in skill upgrading because the opposite is happening in so many other countries. While U.S. high school graduation rates have slumped since 1970, mass secondary education was spreading fast around the world.

- Among the 65 countries that participated in the OECD's most recent Program for International Student Assessment examinations of 15 year-olds, U.S. students ranked 15th in reading, 23rd in science, and 31st in mathematics.

These mediocre U.S. results were not driven solely by low scores for challenged U.S. socio-economic groups.

- In comparing scores across the top three quartiles of socio-economic position, U.S. students were outperformed by their counterparts in 15 countries in science and 24 in math. In comparing scores across the third quartile of socio-economic position (i.e., the second highest group), U.S. students were outperformed by 25 countries in science and 31 in math.[19]

A similar pattern has emerged for college-graduation rates, especially among younger Americans. The U.S. rates are now just about average among all OECD countries. And educational upgrading is happening not just in OECD countries but in many lower-income countries as well. It is now well documented, for example, that the U.S. share of global science and engineering graduates is declining at all degree levels thanks to growth in emerging markets.

- In 1975, China produced almost no PhDs in science and engineering; by 2008 China graduated 26,000 such PhDs, compared to just fewer than 25,000 in the United States.[20]

One key reason that America's educational edge is eroding is the globalization of knowledge itself: many foreign universities emulate the structure of U.S. schools—and they increasingly staff their faculty with U.S.-trained scholars.

- In 1975, the share of science and engineering PhDs graduating from U.S. universities was 47% of the total among students from major Asian nations and advanced European economies; in 2004 the share had fallen to just 25%.[21]

Assessing relative supplies of educated workers across countries is not a simple exercise in counting graduation caps. There remain large quality differences across countries, especially for professional and doctorate degrees. On many measures of academic quality, elite American universities remain the best academic institutions in the world.

Even adjusting for these quality differences, however, the trend is clear: America's talent abundance relative to the rest of the world is eroding. Perhaps most significantly, these education trends may threaten America's national security. A 2012 Council on Foreign Relations task force chaired by Joel Klein and Condoleezza Rice articulated this disquieting connection.

The education crisis is a national security crisis... America's educational failures pose five distinct threats to national security: threats to economic growth and competitiveness, U.S. physical safety, intellectual property, U.S. global awareness, and U.S. unity and cohesion.[22]

Were current trends to persist, the pressures of global competition and comparative advantage would continue to reshape the U.S. economy. The world's innovative activities are today both more competitive and more mobile. Gone is the notion that the United States has a perpetual lock on high-profit, ever-expanding innovation.

Even if the United States can maintain its innovation dynamism—along with all the commensurate long-run growth in jobs and incomes—it will do so amidst greater competition among companies and thus, indirectly, among their workers. This competition might eventually shift substantial innovation activity out of America altogether—with some loss of innovation's support to jobs, to income, and to standards of living.

Whether America can maintain its innovation strength in the 21st century will depend critically on an important aspect of talent that Section 2 examines in greater detail: immigration.

The principal message of Section 1 is that innovation has long played a central role in driving growth in U.S. output, jobs, and income. Discovering new products and processes boosts output in existing companies and industries and creates new industries. This discovery has long created higher standards of living for all American workers and their families. In turn, a critical foundation for this innovation strength has been talent—especially talent in STEM fields created through America's educational system. Maintaining innovation's many contributions to the U.S. economy will require smarter public policy now and in the future, given the indicators that America's innovation strength is waning—in part because of its faltering primary and secondary educational system.

1. U.S. Department of Commerce (2012), p. 1.
2. Solow (1957). See also the closely related work in Solow (1956).
3. Jones (2002).
4. See, for example, Feenstra, Mandel, Reinsdorf, and Slaughter (2013).
5. Jones and Williams (1998, p. 1121) estimate "the social return [to R&D] of 30% and a private rate of return of 7 to 14%: optimal R&D spending as a share of GDP is more than two to four times larger than actual spending." Bloom, Schankerman, and Van Reenen (2012) report, "We find that technology spillovers dominate, so that the gross social returns to R&D are at least twice as high as the private returns…We estimate that the (gross) social return to R&D exceeds the private return, which in our baseline specification are calculated at 55% and 21%, respectively. At the aggregate level, this implies under-investment in R&D, with the socially optimal level being over twice as high as the level of observed R&D."
6. See National Science Board (2012).
7. Here is the assessment from a new report of the prestigious National Research Council of the National Academies (2012): "The U.S. innovation system still enjoys many advantages: the world's largest research infrastructure, a number of the world's greatest universities, the deepest capital markets, and a highly dynamic ecosystem for knowing how to turn inventions into products and businesses…The United States still offers one of the world's best environments for commercializing products and launching companies, including strong protection of intellectual property rights, temperate bankruptcy laws, well-developed capital markets, and extensive worker mobility."
8. Hunt and Gauthier-Loiselle (2010) and Zucker and Darby (2009).
9. See world university rankings at www.awru.org.
10. Figures 1.1 and 1.2 are based on data from the American Community Survey (ACS). We define total employment to be total hours worked for individuals in the civilian population aged 25 to 54 (not living in group quarters). Hours worked is calculated as weeks worked last year times usual hours worked per week (weighted by ACS sampling weights). To increase the number of observations and thus reduce the imprecision of calculations, we pool the three most-recent ACS years of 2009, 2010, and 2011.
11. Our definition of STEM occupations follows that of the Department of Commerce (Langdon et al. 2011), except that we exclude the relatively low-skill categories of technicians, computer support staff, and drafters (which include a high fraction of workers who have completed no more than a high school degree). The occupations we classify as STEM are: computer occupations (computer programmers, database administrators, information security analysts, network architects and systems analysts, software developers, web developers), engineers (aerospace, agricultural, biomedical, chemical, civil, computer hardware, computer software, electrical and electronic, geological, industrial and health systems, materials, mining, nuclear, petroleum), life scientists (biological scientists, conservation scientists, medical scientists), physical scientists (astronomers and physicists, atmospheric and space scientists, chemists, computer scientists, environmental scientists, geoscientists, materials scientists, mathematicians, operations research analysts, statisticians), and other STEM occupations (surveyors, cartographers, and photogrammetrists).
12. Figure 1.3 is based on Occupational Employment Statistics produced by the Bureau of Labor Statistics, available at http://www.bls.gov/oes/current/oes_nat.htm.
13. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2010). The introduction to this report stated, "It is widely agreed that addressing America's competitiveness challenge is an undertaking that will require many years if not decades…So where does America stand relative to its position of five years ago when the Gathering Storm report was prepared? The unanimous view of the committee members participating in the preparation of this report is that our nation's outlook has worsened…The only promising avenue, in the view of the Gathering Storm committee and many others, is through innovation. Fortunately, this nation has in the past demonstrated considerable prowess in this regard. Unfortunately, it has increasingly placed shackles on that prowess such that, if not relieved, the nation's ability to provide financially and personally rewarding jobs for its own citizens can be expected to decline at an accelerating pace…The Committee's overall conclusion is that…The Gathering Storm increasingly appears to be a Category 5."
14. The White House (2011): "America cannot rest on its laurels. Unfortunately, there are disturbing signs that America's innovative performance slipped substantially during the past decade. Across a range of innovation metrics…our nation has fallen in global innovation-ranked competitiveness."
15. For the three studies listed below, see World Economic Forum (2012), World Intellectual Property Organization and INSEAD (2012), and Atkinson and Ezell (2012).
16. Gordon (2012). See also, e.g., Cowen (2012). *The Economist* (2012) summarizes much of this recent academic work.
17. All data in this subsection on America's educational attainment are taken from Goldin and Katz (2008), unless otherwise noted.
18. National Governors Association (2011).
19. America Achieves (2013).
20. These figures are taken from *Science and Engineering Indicators, 2012*, by the National Science Foundation (2012).
21. See Adams (2009); Blanchard, Bound, and Turner (2009); and Bound, Turner, and Walsh (2009).
22. Council on Foreign Relations (2012).

Immigration's Contribution to U.S. Talent: Strong Past and Growing Importance Today

Immigration has played a critical role in helping America meet its growing demand for talent—especially for highly skilled STEM workers. Immigrants have long made significant contributions to America's innovation, both in the top tiers of R&D and throughout the economy. Over time, America's reliance on talented immigrants has been steadily rising.

At the highest levels of achievement in a number of professions such as the academy, the arts, and athletics, immigrants have excelled at rates beyond their share of the overall population or labor force. And across America's innovation ecosystem, immigrants help at all stages of discovering and developing new ideas. In business, immigrants tend to be more innovative than native-born Americans on many economic indicators such as starting new companies (especially in high-innovation industries) and patenting. Indeed, over much of the 20th century a cornerstone of America's economic success was its ability to attract large numbers of immigrants and then integrate them into the economy to allow them to contribute to U.S. productivity growth—including through the serendipity of the best and brightest uncovering their potential and reaching the apex of their professions.

Our key findings for this section are that:

- Today, foreign-born individuals make up one-fifth of STEM workers with bachelor's degrees and two-fifths of those with advanced degrees. These shares underscore the essential role that immigration plays in allowing America to meet its demand for the highest talents—in particular for specialized personnel in many areas of STEM.
- People who immigrate to the United States are particularly well suited to STEM jobs both because they tend to achieve higher levels of education and because the education they tend to seek is in STEM fields.

IMMIGRANTS' CONTRIBUTION TO AMERICAN TALENT: INNOVATION AT THE HIGHEST LEVELS

The contribution of immigrants to American talent and creativity has perhaps been most visible at the pinnacles of success. Among the truly outstanding in a number of fields such as academics, the arts, and athletics, immigrants are significantly overrepresented when compared to their presence in the overall U.S. population or labor force. Today, immigrants account for about 12% of U.S. residents and 17% of total U.S. employment. Yet, immigrants account for higher—often much higher—shares of America's most accomplished individuals. Consider their presence among America's highest achievers as indicated by the following accolades and achievements.

- **NOBEL LAUREATES:** "Since 1901, the Nobel Prize has been awarded to men and women from all corners of the globe for outstanding achievements in physics, chemistry, physiology or medicine, literature, and for work in peace."[1] Since 1980, immigrants have been 27% of U.S.-resident Nobel Prize winners in chemistry, medicine, and physics.
- **MEMBERS OF THE U.S. NATIONAL ACADEMY OF SCIENCES (NAS):** "Members are elected to the National Academy of Sciences in recognition of their distinguished and continuing achievements in original research. Membership is a widely accepted

mark of excellence in science and is considered one of the highest honors that a scientist can receive."[2] U.S. immigrants constitute 29% of current NAS members in applied mathematics, 21% in biochemistry, 37% in engineering sciences, and 36% in mathematics.

- TOP-RANKED STEM DEPARTMENTS IN U.S. UNIVERSITIES: In nearly all STEM fields, the three top-ranked departments (in terms of quality of faculty and overall research impact) are consistently the Massachusetts Institute of Technology, Stanford University, and the University of California, Berkeley. Across these three universities, foreign-born academics account for 24% of the faculty in mathematics, 30% of the faculty in computer science, 39% of the faculty in physics, and 44% of the faculty in electrical engineering.
- GOLD MEDALS FROM THE AMERICAN ACADEMY OF ARTS AND LETTERS: Each year since 1950, this Academy awards two gold medals "for distinguished achievement in several different categories of the arts" in rotating categories that include "Belles Lettres and Criticism, and Painting; Biography and Music; Fiction and Sculpture; History and Architecture, including Landscape Architecture; Poetry and Music; and Drama and Graphic Art."[3] Since 1950, foreign-born artists have won 21% of these gold medals.
- MACARTHUR GENIUS AWARDS: "The MacArthur Fellows Program awards unrestricted fellowships to talented individuals who have shown extraordinary originality and dedication in their creative pursuits and a marked capacity for self-direction. There are three criteria for selection of Fellows: exceptional creativity, promise for important future advances based on a track record of significant accomplishment, and potential for the fellowship to facilitate subsequent creative work."[4] Since 2000, 25% of MacArthur Fellows have been U.S. immigrants.
- PROFESSIONAL SPORTS: In recent decades, most premier professional sport leagues in America have become far more global in terms of hiring top athletes from around the world. In Major League Baseball, 28% of players during the 2012 season were foreign born. In the National Basketball Association, a sport long dominated by athletes born in America, 19% of all players in the 2012-2013 season were immigrants. On the PGA Tour, among top-ranked golfers in 2013 who reside in the United States, 27% were immigrants. And in the National Hockey League, 34% of all players in the 2012-2013 season were born outside Canada or the United States.[5]

The success of immigrants in the United States is due in part to America's attractiveness to top performers. U.S. industries and institutions lure the world's most talented because high compensation, a large domestic economy, and easy access to global markets deliver rich rewards to those with outstanding ability. At least as important, America allows individuals—native and foreign-born alike—to rise to the top of their professions as they blossom through various meritocratic methods of talent identification, development, and sorting. For example, technology entrepreneurs have access to a deep and competitive market for venture capital. If a promising young innovator has a brilliant idea but no funds, there are abundant opportunities to make a pitch to prospective investors. In many other economies, and in the emerging world in particular, venture capital is far less developed. In a similar vein, American universities seek out the most promising students from around the world to populate their undergraduate and graduate programs. Those who excel in their studies and go on to seek careers in U.S. academia are drawn by a competitive environment that rewards objective measures of success (publishing top research, winning major grants), rather than connections to university insiders or other arbitrary criteria, which are often cited as the basis for academic-career advancement in Europe.[6]

The celebrity status of elite immigrants makes their presence in many fields easy to recognize: former Secretary of State Madeleine Albright, Google CEO Sergey Brin, Oscar winner Penelope Cruz, NBA champion Tim Duncan, Nobel laureate Albert Einstein, PepsiCo CEO Indra Nyooi, MLB MVP Albert Pujols, Grammy-winning singer Rihanna. Equally significant for the U.S. economy is the less visible contribution of talented immigrant STEM workers all along the innovation production chain, to which we next turn.

IMMIGRANTS' CONTRIBUTION TO AMERICAN TALENT: THROUGHOUT THE INNOVATION ECOSYSTEM

Throughout America's innovation ecosystem, immigrants have long contributed to the discovery and development of new ideas. Research spanning many generations and many empirical approaches has repeatedly documented this broader contribution of immigrants to American talent along a number of dimensions of innovation, both in the STEM realm itself and in the contributions of STEM to broader productivity and economic growth.

In business, immigrants tend to be more innovative than U.S.-born Americans on indicators such as launching new companies—especially in high-innovation industries—and patenting.

- One recent study found that 25% of all U.S. high-technology firms established between 1995 and 2005 had at least one foreign-born founder. In 2005, these new companies employed 450,000 people and generated more than $50 billion in sales.[7]
- Looking over a longer horizon, immigrants or their children founded 40% of Fortune 500 companies, including firms behind seven of the 10 most valuable brands in the world.[8]

U.S. regions that attract larger numbers of talented immigrants are more successful at innovation.

- One study of U.S. states from 1940 to 2000 found that those that attracted more college-educated immigrants created more patents than other states. A rising share of state population made up by college-educated immigrants was associated with an increase in patents produced at the state level (in per capita terms) by approximately 13%.

Other research has found a similar positive association between immigration and employment growth across U.S. regional economies.[9] Similar innovation results hold for U.S. cities. In the 1990s and 2000s, U.S. metro areas that were more attractive to H-1B workers (largely because of the companies that populate the tech sectors in these cities) saw larger increases in the production of patents during time periods when the supply of H-1B visas was expanding. America's H-1B visa program admits immigrants with at least a bachelor's degree to work temporarily in high-talent occupations.[10]

Other research finds that having access to foreign-born talent enhances the productivity of U.S. workers. In an analysis of the changing composition of U.S. graduate programs, one recent study finds that U.S. graduate-school departments in STEM that have a higher share of Ph.D. students who are foreign born generate both more publications in top peer-reviewed academic journals and more citations on these publications (where citations are a standard metric of the importance of a journal article). This positive association between the presence of immigrant graduate students and academic innovation—more and higher-quality publications—may reflect benefits of intellectual diversity and breadth that high-talent immigrants tend to bring to U.S. research environments.[11] Given the connection between STEM research and new-business creation, these foreign graduate students have likely contributed to private sector job growth, as well.[12]

Past immigration into America has expanded the country's innovative capacity and knowledge frontier. Perhaps the most dramatic example of high-skilled immigration comes from the 1930s arrival of Jewish scientists and other intellectuals fleeing Germany during Hitler's rise.

- In chemistry and related fields, Jewish émigrés from Germany in the 1930s increased the production of U.S. patents by 30% in the ensuing three decades.[13]

Research has repeatedly found that the policy mechanism determining how immigrants are admitted to the U.S. influences the innovation and economic performance of these individuals.

- Among college graduates, immigrants who first entered the country on a student or temporary work visa tend to outperform U.S.-born workers in terms of earning higher wages, patenting at higher rates, and commercializing patents at even higher rates.

The large majority of college-educated immigrants entering America on a temporary-work visa do so under the H-1B program. Immigrants who arrived as legal permanent residents (i.e., on green cards) tend to perform similarly to native-borns.[14]

America's innovation success has long depended on talented immigrants at all levels; yes, on the superstars, but also on the many less-decorated but nevertheless highly skilled professionals who are indispensable in making breakthroughs possible and in bringing these breakthroughs to market. For every Nobel laureate scientist there are scores of talented colleagues who helped transmit the Nobel-worthy insights throughout science and to broader society.

THE RISING SHARE OF IMMIGRANTS IN AMERICA'S STEM LABOR FORCE

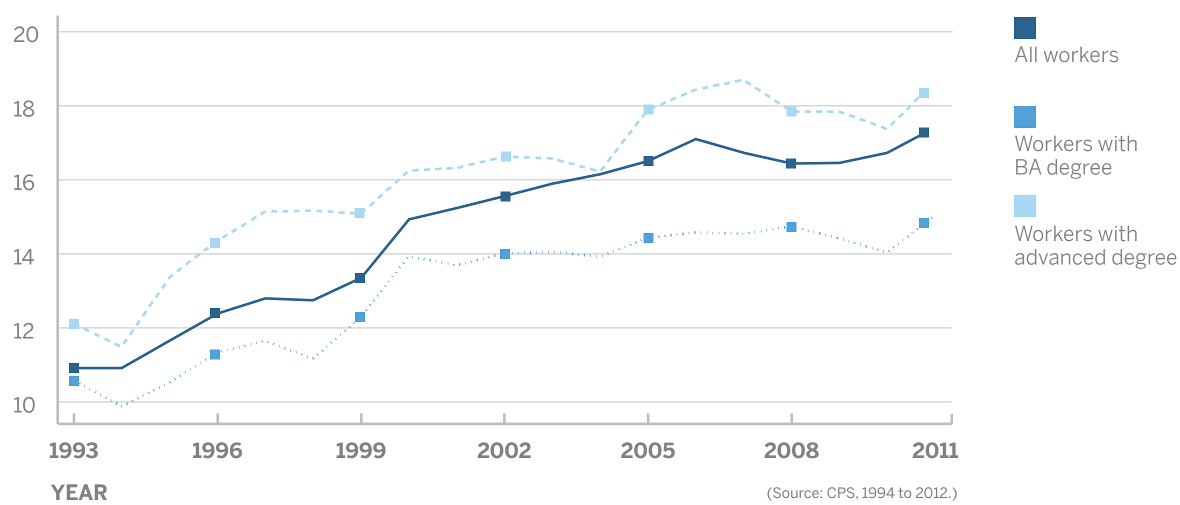
The body of research discussed above documented immigrants' contributions to American innovation for different types of innovation and different types of immigrants. Over time, the magnitude of these immigrant contributions has been growing because immigrants' share of America's STEM labor force has been growing. In recent decades, adding highly educated immigrants to the U.S. economy has been synonymous with expanding the STEM labor force.

To see the rising immigrant share of STEM employment, start with Figure 2.1. For every year since 1993, Figure 2.1 reports the share of American employment accounted for by three segments of the U.S. labor force: all workers (solid line), all workers whose highest degree is a bachelor's (dotted line), and all workers with an advanced degree (dashed line), which includes master's, professional (e.g., JD, MBA, MD), and doctorate degrees.[15]

The solid line shows the steadily rising presence of immigrants in the overall U.S. labor force. Their share of U.S. employment rose from about 11% in 1993 to over 17% in 2011. The rising importance of immigrants to U.S. employment is especially pronounced among the highest-educated: as the dashed line shows, immigrants' share of advanced-degree workers has long been higher. This share rose from 12% in 1993 to over 18% in 2011. Immigrants are less represented among workers with just a bachelor's degree (dotted line), with just a 15% share in 2011.

The predominance of immigrants among the highest-educated reflects a number of factors. One is the tendency, discussed earlier in Section 2, for America to attract highly motivated, highly talented immigrants. A second factor is signaling: to gain entry to the United States immigrants need to communicate to U.S. employers or universities their abilities, while competing against native-born U.S. residents whose backgrounds are typically more familiar to U.S. business recruiters or university admission officers. A high level of schooling is one way for immigrants to broadcast their ability and gain the recognition they need to qualify for skill-based entry visas (e.g., a student visa or H-1B temporary employment visa).

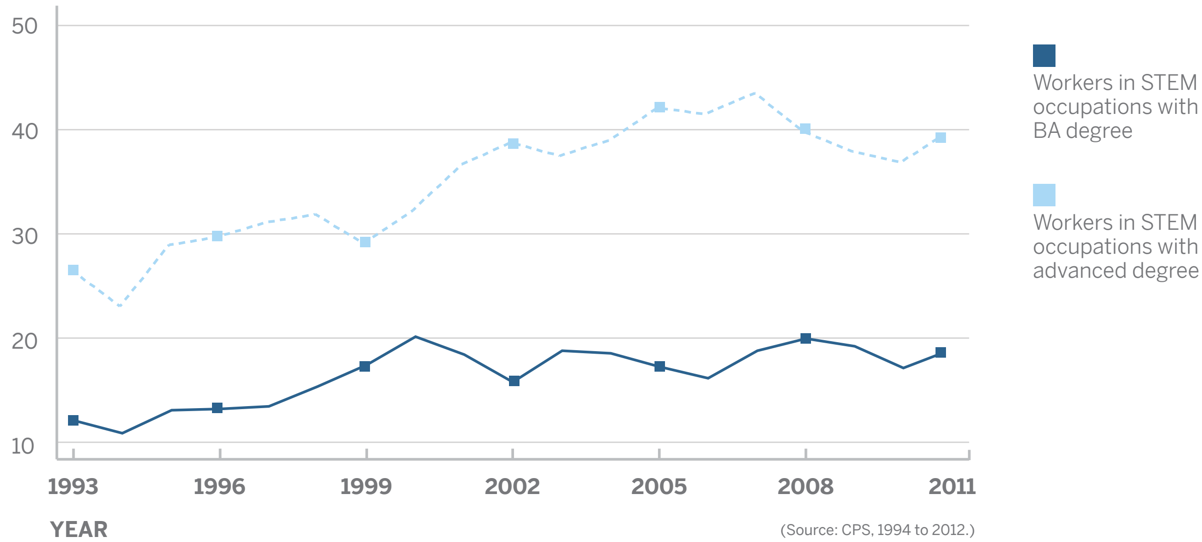
FIGURE 2.1
Foreign born share of US employment (%)



(Source: CPS, 1994 to 2012.)

FIGURE 2.2

Foreign born share of employment, STEM jobs (%)



As important as immigrants have become to the overall U.S. labor force, their contribution to the STEM labor force is even more pronounced. Figure 2.2 reports the foreign-born share of U.S. employment in America's STEM occupations (i.e., as defined in Section 1) for two education categories: workers with a bachelor's degree or the equivalent (solid line) and workers with an advanced degree (dashed line).[16] Of workers with an advanced degree, having a master's is the largest category—professional and doctorate degrees are smaller categories within this group.

The pronounced STEM reliance on immigration is visible in the rising shares of Figure 2.2.

- For workers in STEM occupations with a bachelor's degree, the immigrant share rose from 12% in 1993 to 20% in 2011. For workers in STEM occupations with an advanced degree, the immigrant share rose from 27% in 1993 to a remarkable 40% in 2011.

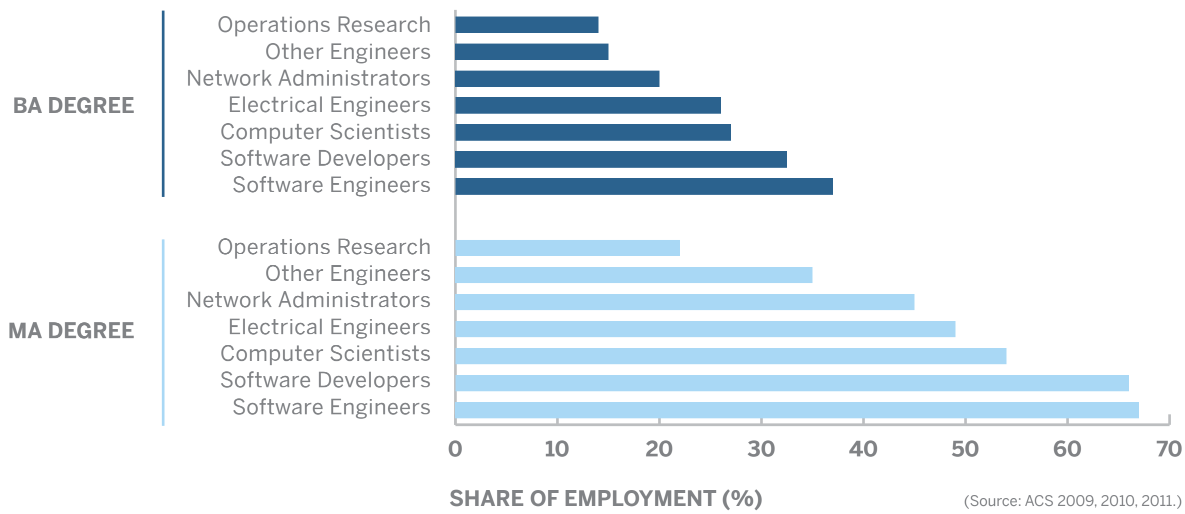
It is notable that most of the growth in the foreign-born share of STEM employment occurred during the late 1990s and very early 2000s, when the U.S. tech sector boomed. Congress accommodated this boom by raising the annual supply of H-1B visas (to 115,000 in 1998, up from the previous cap of 65,000, and further still to 195,000 in 2001). Also notable is that there has been no net growth in the foreign-born share of STEM employment since 2004 when Congress reduced the supply of H-1B visas back to its original annual level (of 65,000).

For some STEM occupations, the immigrant shares are even larger than those shown above. Figure 2.3 presents the foreign-born share of employment in STEM occupations for workers with a bachelor's degree or master's degree, each averaged over the period 2009 to 2011.[17]

- Among bachelor's degree holders, the foreign-born share is 25% for electrical and electronic engineers, 31% for computer programmers and software developers, and 35% for computer software engineers.

What brings the overall average down to the 20% level shown in Figure 2.2 is the lower foreign-born share among the category of other engineers (i.e., engineers other than those related to the computer software or electrical and electronic fields), which is the largest employment category among STEM occupations. Immigrant presence in the labor force is therefore most pronounced in fields most closely tied to IT—computer hardware and software—but it is nevertheless important across the entire economy's STEM occupations.

FIGURE 2.3
Foreign born worker share



In Figure 2.3, we see that among workers in STEM occupations with a master's degree the foreign born share is higher still, especially for computer-related professions:

- For master's degree holders, the foreign-born employment share is 45% for network administrators, 50% for electrical and electronic engineers, 51% for computer scientists, 63% for software engineers, and 65% for programmers and software developers.

Figure 2.3 shows evidence that strongly reinforces the message of Figure 2.2: the presence of immigrant workers in STEM occupations increases with the level of education. Immigrant presence rises further still when we examine doctoral-degree holders.

- Data from the National Science Foundation shows that the foreign born now account for an incredible 55% of those receiving PhDs in STEM fields from U.S. universities.[18]

What do these patterns mean for industry employment of immigrant STEM labor? Recall from Section 1 that all major U.S. industries rely to some extent on STEM workers. This fact combined with Figure 2.3 means that all major U.S. industries rely on immigrant STEM workers. Figure 2.4 documents this important finding. Across the years 2009-2011, for each of 14 major U.S. industries it reports the share of each industry's STEM workers who are foreign born.[19]

The message of Figure 2.4 is that immigrants constitute a substantial share of STEM workers in all major U.S. industries, rather than being concentrated in just high-tech sectors. The foreign-born share of STEM workers is high in industries most intensive in STEM occupations, such as professional services and manufacturing. Yet, the foreign-born share of STEM workers is also high in industries less intensive, but still important, in STEM, such as health care, mining, transportation, and trade.

FIGURE 2.4
Share of Immigrants in STEM Employment by Industry

Industry	Share
Agriculture	6.8%
Construction	16.3%
Education	32.5%
Entertainment, food, lodging	18.4%
Finance, insurance, real estate	29.6%
Health care	28.6%
Information	27.3%
Manufacturing	24.9%
Mining	19.3%
Other services	21.7%
Prof services, management	29.1%
Public administration	12.9%
Transportation, utilities	18.8%
Wholesale, retail trade	21.8%

Source: ACS, 2009, 2010, 2011.

WHY IMMIGRANTS ARE WELL SUITED TO AMERICA'S STEM LABOR FORCE

What characteristics of immigrants account for their large and rising shares of America's STEM labor force? An important clue comes from Section 1, which showed that innovation talent is essential for so much STEM activity in America—and that education has long created this talent. One reason that immigrants are well suited to America's STEM labor force is they are more likely, relative to native-born workers, to have obtained degrees in STEM fields. Not every single worker in a STEM occupation has pursued STEM education. However, most have, and STEM-educated workers are often best suited to the tasks of STEM occupations.

FIGURE 2.5

Share of U.S. Workers with a STEM Degree, by Highest Degree Obtained

	Natives	Immigrants
BA	19.1%	32.8%
MA	20.4%	49.7%
Prof	32.2%	47.0%
PhD	42.0%	68.6%

Source: ACS, 2009, 2010, 2011

For the most-recent years of data available, 2009-2011, Figure 2.5 compares the field of study of U.S.-born and U.S. immigrant workers by highest degree obtained.[20] For each nativity-education group, Figure 2.5 reports what share of the graduates hold a degree in a STEM field. For example, the upper-left cell entry of 19.1% means that of all native-born workers in America who hold a bachelor's degree, 19.1% earned a degree in STEM.

The message of Figure 2.5 is that at every level of educational attainment, immigrant workers are much more likely to have obtained STEM degrees than are native-born American workers.

- Among those with a bachelor's, immigrants are nearly 14 percentage points more likely to have a STEM degree. This differential is even larger for holders of master's degrees—over 29 percentage points—and doctorate degrees as well—nearly 27 percentage points.

Why are immigrants more likely than U.S.-born workers to have studied STEM? Reasons may include home-country educational systems that are strongest in STEM disciplines (e.g., the Institutes of Technology in India and the long-standing emphasis on engineering at top universities in China, Korea, and Taiwan). Regardless of the underlying causes, immigrants study STEM more than U.S.-born workers do, which stands them in good stead for obtaining U.S. STEM jobs. Of course, education reform in America might increase the number of U.S.-born students who pursue STEM degrees. Even with such welcome reform, it is clear from Figure 2.5 that today and in at least the near future, immigrants study STEM more intensively.

The second reason that immigrants are well suited to America's STEM labor force is that, within STEM fields, immigrants are much more likely than native-born Americans to obtain advanced degrees rather than just a bachelor's. For native and immigrant workers who hold a STEM degree (again for 2009-2011), Figure 2.6 disaggregates each group across their highest degree.

FIGURE 2.6

U.S. Workers with a STEM Degree, Shares by Education Level

	BA	MA	Prof	PhD
Natives	59.5%	24.0%	10.2%	6.3%
Immigrants	43.7%	33.6%	9.1%	13.5%

Source: ACS, 2009, 2010, 2011

Figure 2.6 reveals that within STEM education, a larger share of immigrants obtains advanced degrees than do natives. Comparing foreign and U.S.-born workers:

- 59.5% of STEM-educated native-born workers stop with the bachelor's degree—but only 43.7% of STEM-educated immigrants stop at that level,
- 33.6% of STEM-educated immigrants have a master's degree—versus just 24.0% of STEM-educated native-born Americans, and
- 13.5% of STEM-educated immigrants have a doctorate degree—versus just 6.3% of STEM-educated natives.

One reason that STEM immigrants have higher degree levels may be to signal their quality to prospective U.S. employers or schools, thereby offsetting uncertainty that may be less present with U.S.-born candidates.

To summarize: immigrants are more likely to pursue degrees in STEM fields (Figure 2.5), and immigrants are more likely to pursue advanced degrees within STEM fields (Figure 2.6). These two factors together explain why immigrants are especially well suited to STEM occupations—and the related demand for innovation talent—in the U.S. labor force.

The dual impact of these factors means that the share of immigrants among workers both with a STEM degree and working in a STEM occupation is high and sharply rising with education.

- While 22.0% of U.S. workers with a bachelor's degree in a STEM field are foreign born, 34.9% of STEM master's-degree workers and 45.3% of STEM doctorate workers are.
- Similarly, while 20.6% of workers in STEM occupations with a bachelor's degree are foreign born, 41.1% of workers in STEM occupations with a master's degree are foreign born—and 57.8% of workers in STEM occupations with a doctorate are foreign born.
- Among all U.S. workers both with a STEM doctorate and in a STEM occupation, a remarkable 59.8% are immigrants.

The conclusion is clear: immigrants are especially well suited to STEM jobs both because the foreign born who gain entry to the United States tend to achieve higher levels of education and because the education they tend to seek is in STEM subjects.

FOR IMMIGRANTS' CONTRIBUTIONS TO U.S. TALENT, WHEN AND WHY THEY ENTER AMERICA MATTERS

Immigrants succeed economically in the United States in large part because of their high education levels. Foreign-born workers in the United States may first enter the country legally in three main ways: (1) on student visas, (2) on temporary work visas (of which H-1B visas are the most important group for entrants who have at least a bachelor's degree), or (3) on legal permanent resident visas (green cards).

Different visas admit immigrants based on different criteria. Immigrants who enter the United States on student visas must have first gained admission to a U.S. college or university; similarly, immigrants who enter on temporary work visas must have obtained a job offer from an employer. Student and work visas thus select for admission based largely on some feature of talent, whether academic or professional.

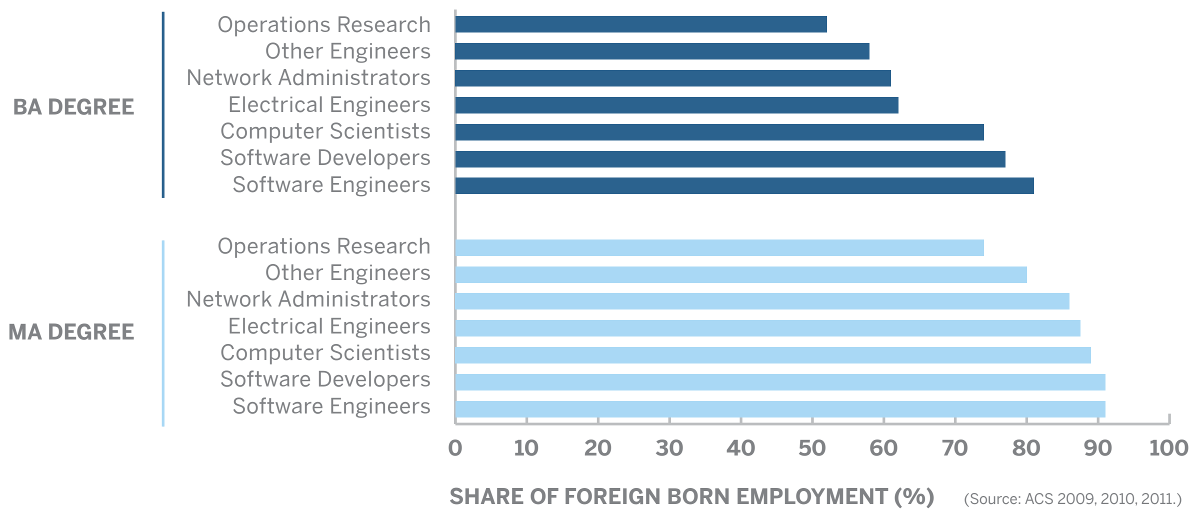
No publicly available and nationally representative data tracks immigrants by their visa status and history.[21] However, immigrants' age of arrival is often tracked. Many student or work visas that select on talent are awarded to first-time immigrants at or after about age 18 (i.e., at or after the typical age at which one begins the freshman year of college). In contrast, many green-card visas that do not select on talent are awarded to first-time immigrants earlier than 18 (e.g., individuals entering as children accompanying older family members). We use arrival in America at age 18 or later as a proxy for arriving on a student or temporary work visa.

Younger-arrival versus older-arrival immigrants have markedly different education outcomes.

- Immigrants arriving after age 18—i.e., those who more likely arrived on a talent-based visa—are much more likely at all levels of educational attainment to either work in a STEM occupation or to hold a STEM degree.
- This finding strongly suggests that student visas and temporary work visas attract immigrants with STEM interests and aspirations. The importance of recently arrived immigrants for STEM degrees is even more pronounced when we examine the STEM occupations that are most reliant on foreign-born labor. Figure 2.7 plots the share of foreign-born workers who arrived at age 18 or later for the major STEM occupations, broken out by highest educational degree obtained.

FIGURE 2.7

Share of Foreign-Born Workers Who Arrived At or After Age 18



(Source: ACS 2009, 2010, 2011.)

STEM occupations that employ foreign-born workers overwhelmingly employ those who arrive after age 18. In Figure 2.7, among bachelor's-degree holders those arriving at age 18 or older account for over 60% immigrants in electrical and electronic engineers, network administrators, computer scientists, software developers, computer programmers, and software engineers.

This pattern is even more pronounced among master's degree holders. Immigrants arriving at age 18 or older account for over 80% of foreign-born employment in four of the seven categories in Figure 2.7. Again, we cannot say for sure the visa type on which these individuals entered the United States. But the pattern of post-age 18 entry suggests that student and work visas are a major channel for STEM-oriented immigrants.

The central message of Section 2 is that immigrants have long made enormous contributions to U.S. talent and innovation. At the highest levels of achievement in a number of professions such as academia, the arts, and athletics, immigrants have excelled at rates beyond their share of the overall population and labor force. And throughout America's innovation ecosystem, immigrants help at all stages of discovering and developing new ideas. Today, the foreign-born share of STEM workers with bachelor's degrees is about 20%, and for those with advanced degrees the respective share is about 40%. These high and rising shares underscore the essential role that immigration plays in allowing America to meet its demand for the highest talents—especially for highly trained personnel in many areas of STEM. Relative to U.S. workers, immigrants are especially well suited to STEM jobs both because they tend to achieve higher levels of education and because the education they tend to seek is in STEM fields. High-tech and low-tech industries alike depend on immigrants to meet their STEM need, needs that are likely to persist for the foreseeable future.

1. See: http://www.nobelprize.org/nobel_prizes/lists/.
2. See: http://www.nasonline.org/about-nas/membership/.
3. See http://www.artsandletters.org/awards2_all.php.
4. See: http://www.macfound.org/programs/fellows/strategy/.
5. These percentages were calculated from data located at the following sites:
http://espn.go.com/mlb, www.pgatour.com
www.nba.com/2012/news/10/30/international-players-on-opening-night-rosters/index.html
www.quanthockey.com/nhl/nationality-totals/nhl-players-career-stats.html
6. Lissoni, Mairesse, Montobbio, and Pezzoni (2011).
7. Wadhwa, Saxenian, Rissing and Gereffi (2007).
8. Partnership for a New American Economy (2011).
9. See Peri (2012).
10. These findings are, respectively, from Hunt and Gauthier-Loiselle (2010), Peri (2012), and Kerr and Lincoln (2010).
11. This study is Stuen, Mobarak, and Maskus (2012).
12. See Zucker and Darby (2009).
13. See Moser, Voena, and Waldinger (2012).
14. These results come from Hunt (2009).
15. In Figure 2.1, the immigrant employment shares were calculated from various years of the Current Population Survey (CPS). Employment is defined as total weeks worked times the usual hours worked per week, weighted by CPS sampling weights. The sample is limited to individuals whose usual hours worked per work is 35 or greater. Our approach has the advantage of accounting for the total stock of labor employed, rather than simply bodies in the labor force.
16. In Figure 2.2, we calculated employment shares similarly to Figure 2.1. The definition of STEM occupations (based in this cased on CPS occupation categories rather than ACS categories) includes engineers, computer scientists, operations and systems researchers, mathematicians/statisticians, chemists, physicists, atmospheric scientists, geologists, agricultural and forestry scientists, biological and medical scientists, cartographers and mapping scientists, computer software developments, and programmers of numerically controlled machine tools. We do not include the low-education occupations of computer support staff, technicians, or drafters.
17. Figure 2.3 (and also Figure 2.7) shows all STEM occupations except life scientists and physical scientists, the vast majority of whom have doctoral training and so are absent among bachelor's and master's degree holders. The sample is the same as in Figures 1.1 and 1.2: using the ACS, we define total employment to be total hours worked for individuals in the civilian population aged 25 to 54 (not living in group quarters). Hours worked is calculated as weeks worked last year times usual hours worked per week (weighted by ACS sampling weights).
18. See Grogger and Hanson (2013).
19. Figure 2.4 (and also Figures 2.5 and 2.6) covers all STEM occupations based on job categories in the ACS (as described in Section 1). Employment is again total hours worked (weeks worked last year times usual hours worked per week) for individuals in the civilian population aged 25 to 54 (not living in group quarters), weighted by ACS sampling weights.
20. The recent ACS also has the advantage of reporting the degree field for an individual's highest academic degree earned (which is not recorded in the CPS or in the ACS before 2009).
21. Two data sources that do track individual visa status and history are the National Science Foundation's (NSF) Survey of Recent College Graduates (http://www.nsf.gov/statistics/srvyrecentgrads/) and Survey of Doctorate Recipients (http://www.nsf.gov/statistics/srvydoctoratework/). Samples sizes for these surveys are small, restricted by degree field and education level, and limited to individuals who obtained their degrees in the United States (as opposed to abroad), which limit their usefulness. Further, these data sets are proprietary to the NSF and require special permission to use in their complete form.

Supply and Demand of STEM Talent in America: Immigrants Continue to Help Meet Growing Demand

Even after the Great Recession, America's need for talent persists. America's demand for highly skilled workers continues to grow, and immigrants continue to help meet this demand—both directly and more broadly through their expansive contributions to America's innovation potential. Decades of data document the continuous increase in U.S. demand for talented knowledge workers: despite ongoing increases in their supply relative to the overall labor force, their high earnings relative to the overall labor force have persisted or even increased.

Ongoing growth in the search for talent holds not just for broad measures of ability—such as college workers versus high school workers—but also for STEM college graduates relative to other college graduates, and even for STEM advanced-degree holders relative to other advanced-degree holders. This fractal aspect of America's talent demand reflects the contributions to productivity of the most capable employees. Innovative companies throughout the U.S. economy continue to search for top-notch labor to help boost their potential for breakthroughs. Such striving to expand the technology frontier sustains the intensity of America's talent search.

Our two key findings of this section are that:

- The Great Recession did not suppress America's need for STEM labor. Relative to non-STEM workers of the same age and education, STEM workers earn a compensation premium of 25%—a differential that has changed little in the past 30 years. Relative to all U.S. occupations, STEM earnings are rising: since 2000, real wages in STEM jobs have grown, while real wages for nearly all other U.S. occupations have fallen. Unemployment rates in STEM occupations today have fallen to or below historic levels.
- Looking among U.S. STEM workers, immigrants are not paid less than natives. Using the most comprehensive data available and a number of alternative approaches to controlling for the standard differences in earnings across workers (such as age, educational attainment, gender, and industry of employment), the average earnings of U.S.-born STEM workers and immigrant STEM workers are the same in almost all cases.

THE SUPPLY OF AND DEMAND FOR TALENT IN AMERICA

Section 1 of this report documented and analyzed America's rising supply of talented workers—especially STEM talent—and Section 2 similarly documented and analyzed the important and expanding role of immigrants in this supply of skill for America. Foreign-born STEM workers have contributed mightily to U.S. innovation and therefore to its overall economic growth.

The link from the supply of STEM talent to dynamism and growth is not automatic, however. Simply endowing an economy with more scientists and engineers does not magically create innovation. What has long grown in America along with the supply of talent is the country's demand for talent—demand from universities and colleges, demand from the government, and—in the aggregate, most important of all—demand from companies in the private sector.

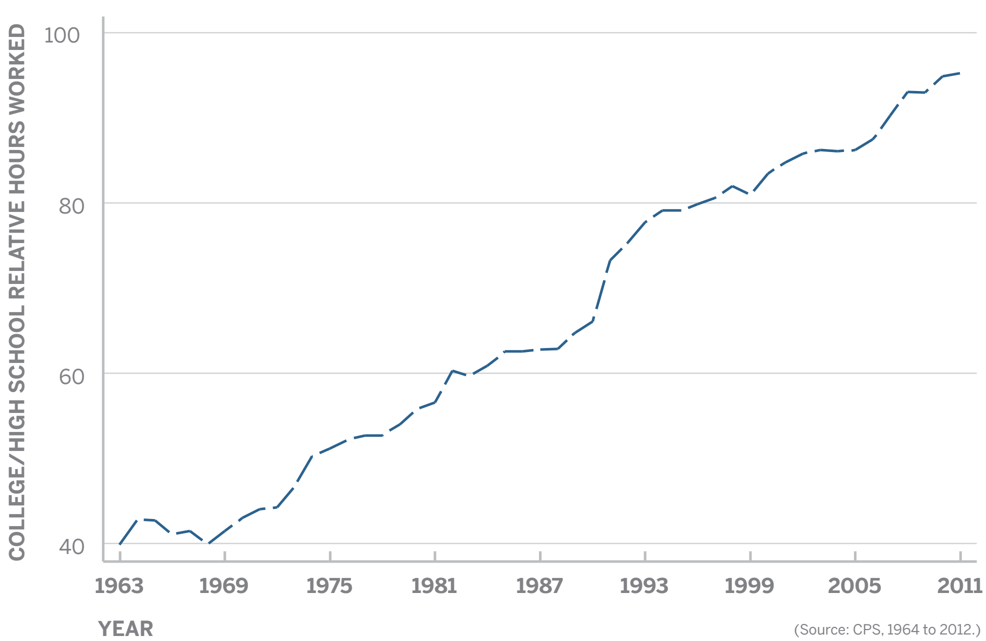
As education and immigration were expanding America's supply of talent over the 20th century and into the 21st, a set of forces were expanding America's demand for talent. One such force is foreign trade and investment.[1] The opportunity to sell new products into expanding foreign markets spurs innovation in global companies.[2] A second important force is innovation and technological change itself. Rather than enlarging proportionately companies' demand for basic and talented workers alike, many advances stimulate companies' need for talent far more than their need for basic skills.[3] Think of the computer and Internet spawning entire new categories of STEM occupations as companies developed demand for new skills such as computer programming, software development, and building and managing computer networks.[4]

Many policymakers are rightly concerned about whether America's policies toward immigration and education are adequately meeting the country's evolving demand for skilled labor. The measurement challenge, of course, is that the demand for talent—like the demand for workers of other skill types, or more generally of many other goods and services—cannot be directly observed. What can be observed is the supply of skills—per much of the discussion of Sections 1 and 2. And, what can also be observed is the "price" for these skills—i.e., the wage and salary income earned by talented workers over and above that earned by the average worker. Examining together America's relative supply and relative price of talent opens a window into how America's demand for talent is evolving.

Start with a broad measure of America's talent: all workers with at least a college degree. For every year from 1963 through 2011, the most recent year of available data on annual earnings, Figure 3.1 shows America's supply of college-educated workers (i.e., workers with a college degree or advanced degree) relative to its supply of high school educated workers (i.e., all workers with a high school degree or the equivalent [e.g., GED] but no college degree). This measure of relative supply is presented as an index in order to facilitate comparisons over time. A value of 100 indicates equal effective supplies of college and high school educated labor.[5]

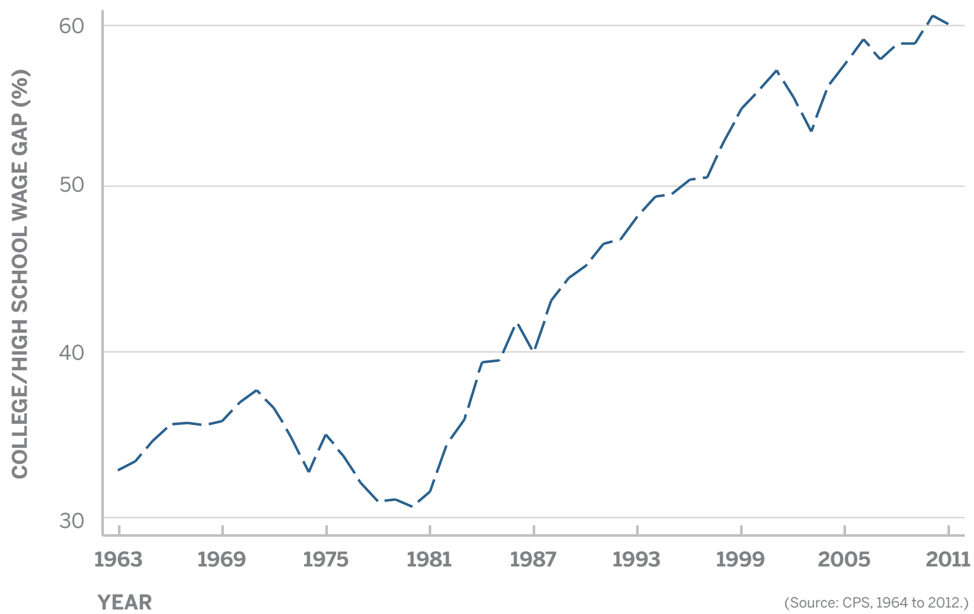
For nearly two generations, America's supply of college graduates relative to high school graduates has been rising. Indeed, this rising relative supply underpins the rising average educational attainment of American workers discussed in Section 1.

FIGURE 3.1
College/high school relative labor supply index



(Source: CPS, 1964 to 2012.)

FIGURE 3.2
College/high school wage difference



- Figure 3.1 shows that whereas in the mid-1960s the effective labor supply of college graduates was about 40% that of high school graduates, today the two are close to par.

The pace of growth, however, has not been even. The increasing relative supply of college-educated labor was most rapid from 1963 to 1993. Since 1993, the surge in the supply of college graduates has eased. This is flattening of educational attainment discussed in Section 1: over time, America has generated ever-more college educated labor, but at a progressively slower pace.

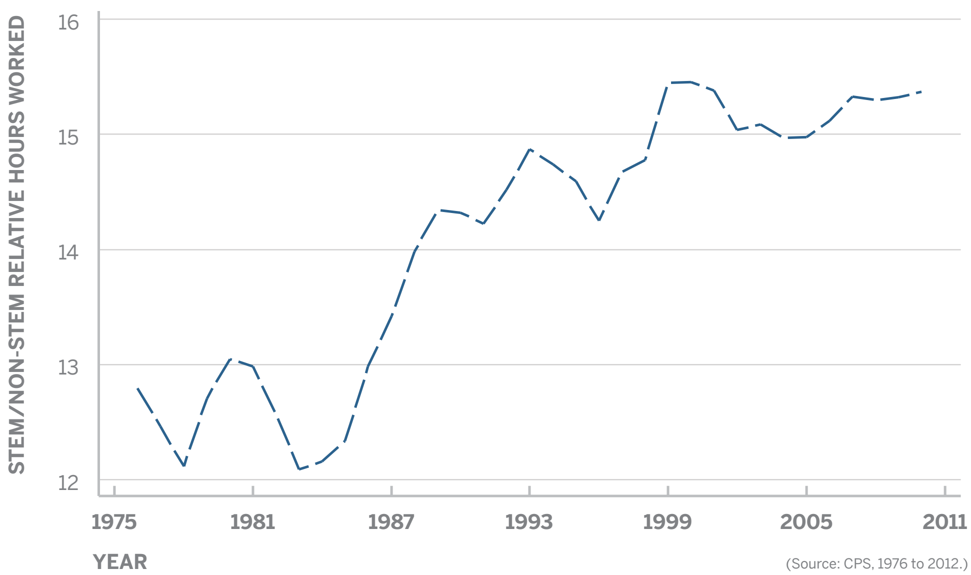
We next document the relative earnings that go with the relative supply of Figure 3.1. For every year from 1963 through 2011, Figure 3.2 shows America's annual earnings of college-educated workers relative to the annual earnings of high school educated workers—in terms of the gap by which the typical college-graduate wage exceeds that of the typical high school graduate.[6]

What do Figures 3.1 and 3.2 say about America's demand for college graduates relative to high school graduates? Consider the 1970s, when college relative wages were falling (Figure 3.2). Given that the relative supply of college graduates was rising strongly during that time (Figure 3.1), we can infer that during the 1970s the relative demand for college graduates was falling, or was constant, or was rising but by less than was their supply. Indeed, during this decade many leaders in business, government, and the academy worried about "the overeducated American."[7]

What about the 30 years from 1981 to 2011? Unlike in the 1970s, now the relative wages of college graduates were rising almost continually—even though college graduates' relative supply was also expanding almost continually as well. The only way that college graduates could be earning more even as their ranks were swelling was for companies' demand for them to have been expanding, too—and, in the aggregate, expanding by more than did the relative supply. In turn, America's demand for talent was expanding thanks to forces such as the IT revolution and the accession into the global economy of fast-growth countries like China and India.

A large body of academic research has documented the increase in the relative demand for more

FIGURE 3.3
Workers with BA degree



educated, more skilled workers in the United States from the 1980s onward.[8] This growth in demand has been a major force behind the expansion of U.S. income equality in recent decades. Scholars have also documented how the nature of labor-demand growth has evolved over time.[9] These nuances, however, do not alter the basic fact about the U.S. labor market over the last thirty years: both the supply and earnings of more skilled labor have risen steadily when compared relative to the supply and earnings of less skilled labor. Figures 3.1 and 3.2 show that:

- America's expanding supply of talent, measured broadly in terms of college graduates, was in the past 30 years exceeded by an expanding demand for talent.
- This growth in demand was so strong that the relative earnings of college graduates were rising, not falling throughout the period. Demand for talent was necessary for America's supply of skill to translate into productive innovations, with the resulting growth in jobs and income spreading throughout the U.S. economy (as described in Section 1).

THE SUPPLY OF AND DEMAND FOR STEM TALENT IN AMERICA

The same supply, earnings, and demand analysis can examine the evolution of STEM talent in America in recent decades—especially to understand questions U.S. leaders have about whether policies towards immigration are adequate for the country's labor force needs.

Start with a broad measure of America's STEM talent: workers with a bachelor's degree in a STEM occupation relative to workers with a bachelor's degree in all other occupations.[10] For every year from 1975 through 2011, Figure 3.3 shows this measure of America's relative supply of STEM workers,[11] again presented as an index to facilitate comparisons over time.

Figure 3.3 shows that in the early 1980s, America's relative supply of STEM talent began to grow, coincident with several landmark innovations marking the beginning of the IT revolution:

- Microsoft shipped MS-DOS version 1.0 in 1981.
- Apple's Macintosh computer launched in 1984.
- Intel introduced the 80386 microprocessor in 1985.

Booming growth in STEM employment, relative to non-STEM, followed thereafter.

- Employment of STEM workers with a bachelor's degree relative to employment of non-STEM workers with a bachelor's degree has increased by about 30% since 1984.

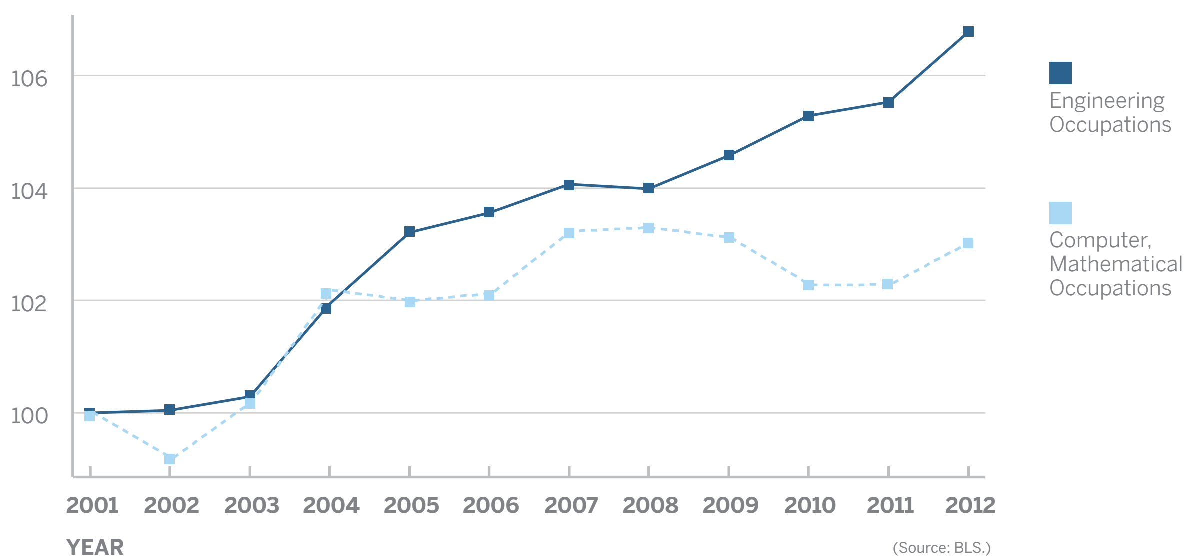
Comparing STEM workers with advanced degrees (master's, professional, doctorate degree) to similarly educated non-STEM workers, the pattern is substantially the same. The similarly constructed figure shows a 30% increase in the relative supply of STEM workers, now measured as those with advanced degrees working in STEM occupations relative to those with advanced degrees in non-STEM occupations.[12] From Section 2, expanding immigration accounts for an important part of the rising supply of STEM talent. The shift in highly educated employment towards STEM jobs is therefore partly a consequence of U.S. openness to skilled foreign labor.

As America's relative supply of STEM talent has expanded, what has happened to STEM earnings? If the only change in the labor market was an increase in the supply of U.S. workers seeking STEM jobs, then the logical outcome would be lower wages in STEM occupations when compared to non-STEM occupations. But if, instead, the employment shift toward STEM was driven by robust growth in demand for STEM skills, then STEM occupations could have expanded with constant or even rising wages for STEM workers.

Figure 3.4 gives a simple first answer. It reports since 2001 the median hourly wage for two large STEM occupations (computer and mathematical occupations—which include computer programmers and software developers—and engineering) relative to the median hourly wage for all U.S. occupations, where each of these two wage ratios is set to equal 100 in 2001.[13]

- The key message of Figure 3.4 is that relative to all other U.S. occupations, the earnings of STEM workers have risen over the past decade by 3% to 6%. The inflation-adjusted wages of major STEM occupations grew over the last decade while real wages for most other U.S. occupations fell.
- Rising earnings for U.S. STEM workers even with the country's expanded STEM labor supply reveals that American relative demand for STEM talent has been expanding.

FIGURE 3.4
Median hourly wage relative to all occupations



(Source: BLS.)

The measurement of relative incomes can be sharpened by controlling for the worker characteristics—e.g., educational attainment and years in the labor force—that tend to influence earnings for individuals and thus for large groupings of workers like those in Figure 3.4. So, for the Current Population Survey—i.e., one of the largest U.S. government data sets designed to measure labor-force outcomes—we measured for each year how much more STEM-occupation workers earn than do comparable workers in non-STEM occupations, controlling for characteristics including years of schooling, age, gender, race, and geography. For each year since 1967, Figure 3.5 reports the estimated percentage premium earned by a U.S. worker in a STEM occupation above that of a comparable worker in a non-STEM occupation.[14] We show the estimated percentage itself, along with the interval above and below it, within which statistical analysis indicates the "true" percentage lies with 95% confidence.

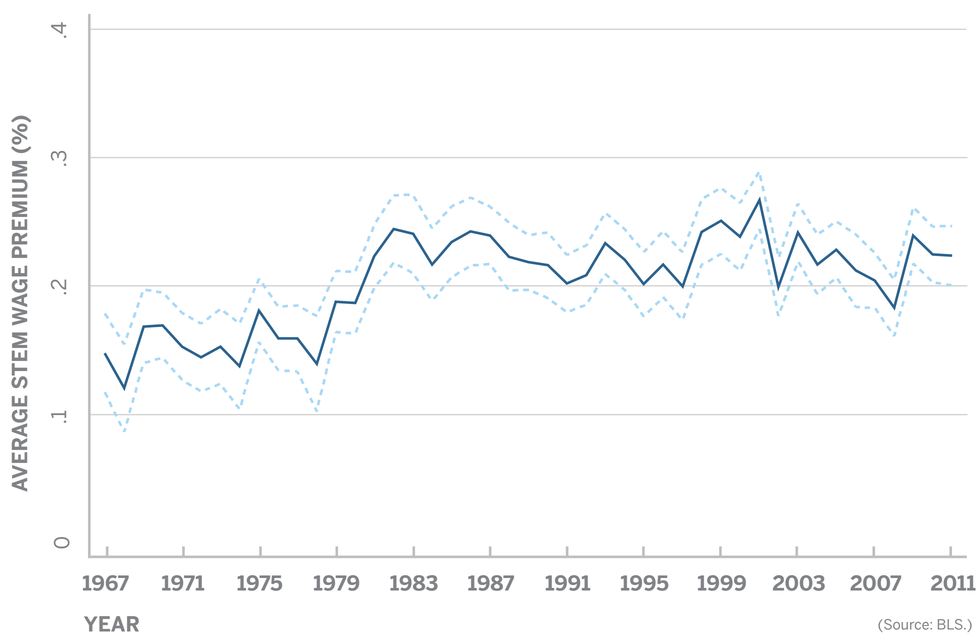
Figure 3.5 documents that for nearly two generations, STEM workers in America have earned a large compensation premium—over the past 30 years, of about 25%—that has changed little. From the late 1960s to the late 1970s, this premium was about 15%. It then increased to around 25% by the early 1980s, at the same time the IT revolution was getting underway. Each year since, it has persisted at about that level with minor fluctuations. Now, recall from Figure 3.3 that America's relative supply of STEM talent has been continually increasing. America's steadily expanding supply of STEM talent could occur without reducing the STEM earnings premium only with a steady expansion of America's demand for STEM talent as well.

This is a central message of this entire report:

Even with substantial growth in the size of America's STEM labor force thanks to the forces of education and immigration, America's STEM wage premium has been sustained by the expansion in America's demand for STEM talent.

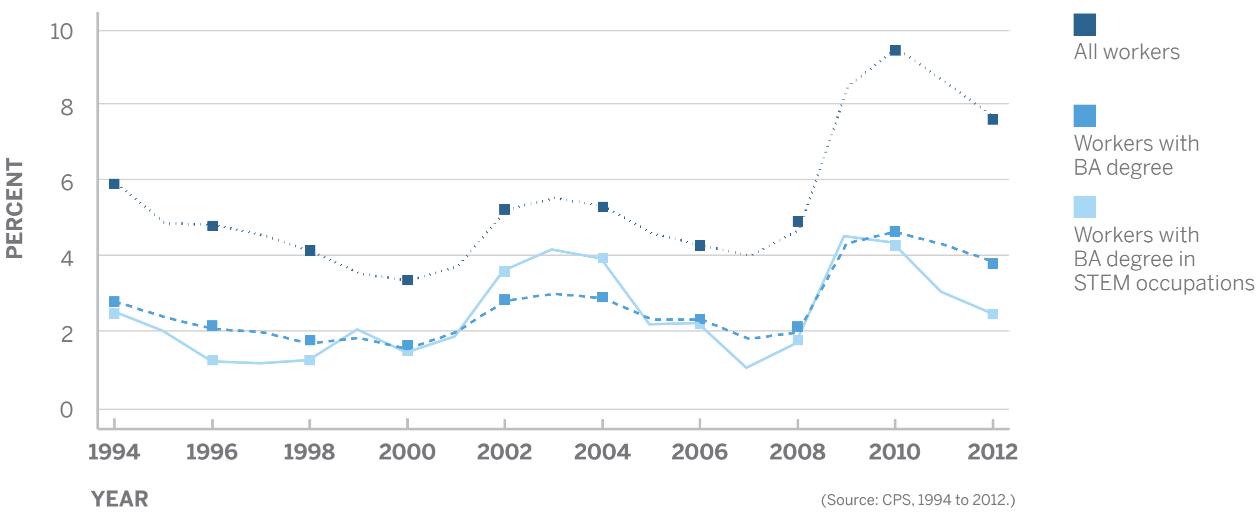
Figure 3.5 also suggests periods of fluctuations in this evolving demand that match with broader economic forces during those periods. For example, the rise in the wage premium in the late 1990s coincides with the IT boom—and with such strong

FIGURE 3.5
Estimated log wage premium for STEM occupations



(Source: BLS.)

FIGURE 3.6
Unemployment rates, workers aged 25+



(Source: CPS, 1994 to 2012.)

demand from U.S. companies for STEM talent that the U.S. Congress, as mentioned in Section 2, agreed to temporarily triple the annual number of H-1B visas granted (from 65,000 to 195,000). The wage premium dipped during the 2001 and 2008 recessions, as one might expect given the IT-concentration of the 2001 downturn and the general severity of the 2008 downturn amidst the world financial crisis. But these dips were short lived, and even in the aftermath of the Great Recession the U.S. earnings premium for STEM talent rose after 2008 back to about 25%.

As clear evidence of this rebound in demand for STEM talent, here in 2013 America's demand for H-1B visas is again very strong—so strong that within one week after U.S. Citizenship and Immigration Services began accepting new H-1B petitions on April 1, 2013, it announced that substantially more than the full-year limit of 85,000—approximately 124,000—had already been filed. Any petitions received after close of business April 5, 2013, were rejected, and USCIS then allocated the fiscal 2014 H-1B visas via lottery.[15] This most-recent H-1B visa lottery reprises the similar lotteries due to similarly strong demand in the pre-crisis years of 2007 and 2008.

What combination of supply-and-demand forces account for America's persistently large compensation premium for STEM talent? There are several possible explanations that available data cannot fully disentangle. That said, the explanation that we find most plausible is that STEM occupations tend to attract relatively high-talent applicants (e.g., because it is difficult to master the math and science needed to excel at so many STEM jobs, and difficult to develop or teach the creative imagination essential for innovation discovery) who go on to be high productivity workers on the job.[16] STEM workers in America tend to be more productive than non-STEM workers and thus tend to earn a premium. This premium has persisted for decades, despite the expanding supply of STEM talent, because of America's continuing expansion of demand for STEM skills. Innovative companies throughout the U.S. economy continue to need an ever growing pool of talent to help boost their output of innovative goods and services.

Additional evidence that post-crisis America's demand for STEM talent remains strong today can be seen in the low unemployment rates for STEM workers. Figure 3.6 reports the monthly unemployment rate from 1994 through 2012 for three groups of U.S. prime-age (25 to 54 years old) workers: all workers (dotted line), all workers with at least a bachelor's degree (dashed line), and all STEM workers with at least a bachelor's degree (solid line).[17]

They key message of Figure 3.6 is that in STEM occupations unemployment is falling sharply, consistent with substantial labor-market tightening.

- The unemployment rate for STEM occupations fell from 4.5% in 2009 to 2.5% in 2012, barely above its 20-year average of 2.45%.
- In computer occupations—software developers, computer scientists, computer systems analysts—the unemployment rate has declined even more dramatically—from 5.4% in 2009 to 2.5% in 2012—and is now below its 20-year average of 2.8%. Today in mid-2013, the STEM unemployment rate very likely has fallen below its long-run average.

ARE IMMIGRANT STEM WORKERS PAID LESS THAN NATIVE-BORN STEM WORKERS? NO.

Even though demand for STEM talent has been expanding in America for decades, perhaps one of the most contentious issues in the U.S. policy discussion of STEM labor is the concern that immigrant STEM workers earn less than do native STEM workers—and thus that immigration holds down the income and economic prospects of U.S.-born STEM job holders.

To evaluate this concern, it is essential to think about data averages, not data anecdotes. Recall from Section 1 that today there are more than 4.9 million Americans working in STEM occupations.

- It is simply implausible to suppose that every single immigrant STEM worker earns more than every single native STEM worker—or vice versa.
- For the millions of America's STEM workers, both U.S. and foreign-born, there is a distribution of earnings (and other outcomes) across which there is substantial overlap.

So, we now examine central tendencies in the data.

When looking across large numbers of foreign and native-born workers in STEM occupations, how do their earnings compare? With millions of STEM employees that differ in myriad ways such as education, experience on the job, and industry of employment, carefully evaluating native and immigrant wages requires two important ingredients: (i) sufficiently well-constructed measures of earnings for a sufficiently large and nationally representative sample of workers, and (ii) sufficiently rich measures of workers characteristics that must be properly controlled for to consider whether nationality per se matters for worker earnings. Many existing studies that try to compare the earnings of U.S.-born and immigrant STEM workers have serious limitations because they fail to include one or both of these important ingredients.[18]

Our wage analysis pools the three most-recent years—2009, 2010, and 2011—of the American Community Survey (ACS) produced by the U.S. Bureau of the Census. We use the ACS because it carefully measures not just worker income but also a sufficiently rich set of demographic characteristics that we can control for wage determinants using the most current and most sophisticated techniques of research in peer-reviewed economics. As is standard practice, we combine three ACS years because each individual year's sample is too small to compare with sufficient statistical confidence native and U.S.-born earnings of STEM occupations conditional on key worker characteristics. We also limit the sample to full-time, non-self-employed workers to compare individuals in comparable positions of employment.[19]

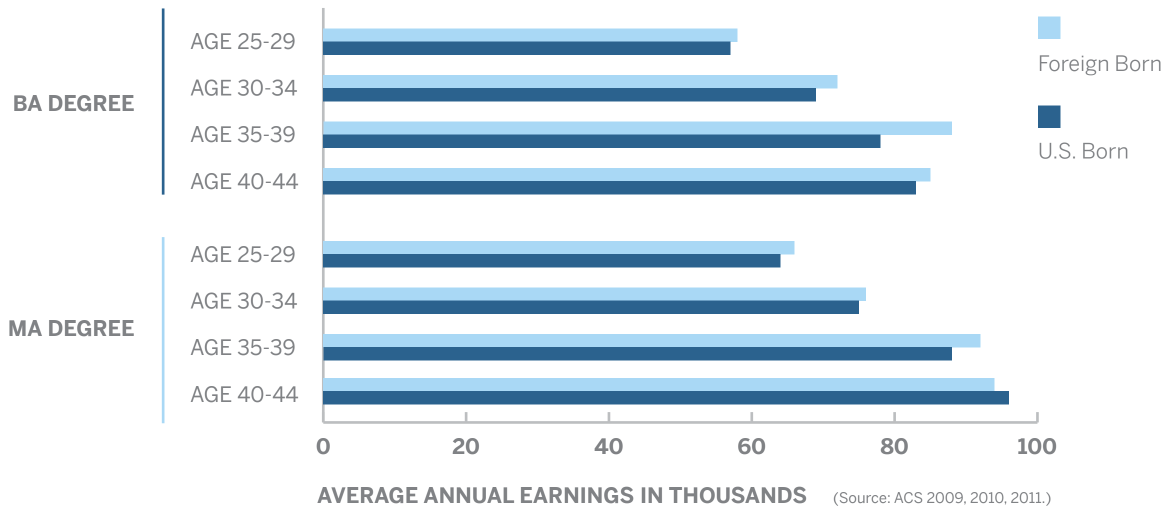
The simple graphic in Figure 3.7 illustrates our central wage-comparison findings.[20] It reports the earnings of U.S.-born and immigrant STEM workers while controlling for two of the most important non-immigration determinants of earnings: education and work experience (as proxied by age). Figure 3.7 pools workers in all STEM occupations in America across 2009, 2010, and 2011, and then reports average annual earnings of U.S.-born and foreign-born workers within eight broad groupings: two educational groups—those with a bachelor's degree and those with a master's degree—and four age groups.

Strikingly, Figure 3.7 provides no systematic evidence that immigrant STEM workers are paid less than U.S.-born STEM workers. This is a second central message of our report:

When comparing immigrant and U.S.-born workers in STEM occupations (where these workers are of similar ages and have similar educational attainment), there is no evidence of a systematic difference in earnings between the two groups.

In seven of the eight age-education groupings in Figure 3.7, immigrants earn slightly higher average annual earnings than their U.S. counterparts, and in one grouping immigrants earn an average of only about 2.5% less than their U.S.-born counterparts.

FIGURE 3.7
Earnings, all STEM occupations



Undoubtedly, one could find instances where immigrants in STEM jobs earn more than native-born workers and instances where the reverse applies. But the central tendency of the data is clear: immigrant and native-born STEM workers have substantially similar wages.[21]

To verify that this initial picture of immigrant-native wage parity holds, we next replicated the basic analysis of Figure 3.7 considering only those immigrants who arrived to the United States at age 18 or older. Recall from Section 2 that the mechanism through which immigrants gain entry to the country may well matter for their average talent. The age of arrival of at least 18 is a proxy for immigrants who arrived on a student visa to study at a U.S. university or on a temporary work visa (the ACS does not ask visa status), and thus for whom talent was likely a more important selection criterion compared to immigrants who arrived when younger on family-based visas. Some critics of current U.S. immigration policy argue that it is recently arriving immigrants on student or work visas who are somehow exploited by U.S. companies by being paid unfairly low wages. We find no evidence consistent with this argument.

- For the same eight comparison groups as in Figure 3.7, now examining only immigrants who arrived to the country no younger than age 18, we find no evidence that immigrant STEM workers are paid less than native STEM workers. In seven of the eight age-education groupings, immigrants earn slightly more than their U.S. counterparts—and in the eighth grouping earn a fraction less than their U.S.-born counterparts.

Could patterns differ for specific occupations? We next replicated the analysis of Figure 3.7 on subsamples of three STEM occupations that are particularly important in terms of size or innovativeness: software developers and computer programmers, computer software engineers, and computer scientists. The pattern is varied—different occupations may have different underlying business conditions and thus higher or lower average earnings than other occupations. But the pattern of wage parity between U.S.-born and immigrant STEM workers persists.

- For the large majority of education-experience groupings across the individual STEM occupations, native-born citizens and immigrants earn nearly identical annual incomes. The groupings with income differences are split between immigrants earning more than natives and vice versa, with no systematic differences between the two.

To look for wage differences in the most complete and sound approach, we last conducted a detailed statistical analysis for all U.S. STEM workers across all three years (i.e., for the full data sample underlying Figure 3.7) that correlates the earnings of each

STEM worker with an exhaustive set of worker characteristics using the most current techniques of research in peer-reviewed economics. The goal of the analysis was to search for any possible pattern of immigrants earning less (or more) than natives. We found no such evidence.

- Across a large number of alternative approaches to controlling for the standard differences in earnings across workers (e.g., age, educational attainment, gender, occupation, and industry of employment), there is no systematic evidence of wage differences between U.S.-born STEM workers and immigrant STEM workers.[22]

We performed further statistical analysis in which we limited the sample to computer occupations (programmers, software developers, web developers). We again found no consistent statistical difference between earnings for immigrant and native-born STEM workers.

EARNINGS OF STEM WORKERS: THE IMPORTANCE OF THE LONG-RUN PERSPECTIVE

Why do immigrant and native STEM workers earn about the same amount in the United States? In a narrow sense, it is because the U.S. labor market efficiently allows similarly talented workers to command similar incomes. In a more-complete sense, comparable U.S.-born and immigrant earnings in STEM occupations reflect the global competitive intensity facing U.S. companies. STEM talent is critical for a number of U.S. industries to thrive in a world whose innovative activities are today both more contested and more mobile. The notion that the United States has a perpetual lock on high-profit, ever-expanding innovation is gone (a conclusion supported by Section 1). Even if the United States can maintain its innovation dynamism, it will do so amidst greater competition among companies and thus, indirectly, among their workers.

The value that U.S. companies see in talented STEM workers is reflected in the high levels of compensation seen in Figure 3.7.

- Average annual earnings in STEM that broadly range from about $50,000 to over $100,000 are substantially above the 2011 full-time annual income for all U.S. occupations of just $45,230 (which for 2012 was essentially unchanged at $44,795).[23]

The earnings parity between immigrant and U.S.-born STEM workers is not to say that over shorter time horizons and for particular niches in the overall STEM labor market, native and foreign-born STEM works do not compete with each other and thus impact each's earnings. For example, a few recent studies have found that greater supplies of foreign-born post-doctoral fellows in the United States may lower the wages for U.S.-born post-doctoral fellows.[24]

Finding that in one segment of the labor market an increase in the supply of workers reduces their short-run wage is not surprising. In almost all markets—labor markets or otherwise—an increase in supply will, in the short run and thus at current demand, reduce prices. Specific to this post-doc result, current U.S. immigration policy induces many immigrant doctorates to take post-doctoral positions. Upon completing their U.S. doctoral studies, immigrants have a finite amount of time by which they must leave the country if they do not secure some form of legal employment. Absent a sufficient supply of work visas such as H-1Bs or green cards that allow these newly minted doctorates to match into the U.S. labor market, the only work option many unmatched doctorates can secure is a post-doc position that satisfies Optional Professional Training and thus allows staying in the country on an original student visa. This limits the mobility of immigrant post-docs across employers, occupations, and industries—and therefore opportunities for wage growth for both natives and immigrants alike.

- The more important time horizon within which to consider the impact of immigrant STEM talent on American jobs and incomes is the long run, not the short run.

Recall from Section 1 that for generations, U.S. jobs have been created and U.S. incomes have risen almost entirely thanks to innovation and its resulting growth in productivity. Immigrants, as Section 2 documented, have long been a key part of the America STEM talent pool that has been the foundation of this innovation and thus of growth in jobs and incomes. For the bigger-picture questions of how will America create jobs and incomes today and in the future, the contributions of immigrants is still large and can, with proper policies, be even larger—independent of any short-term adjustment impacts incurred as talented immigrants integrate into the U.S. economy.

The industry of the two U.S.-born authors of this study, American higher education, offers a fitting example. America maintains the world's most dynamic higher-education system by welcoming foreign scholars and students (hence the high fraction of foreign-born faculty in top STEM university departments documented in Section 2). Today, about one-third of the tenured and tenure-track faculty are foreign born at each of the School of International Relations and Pacific Studies at UC San Diego and at the Tuck School of Business at Dartmouth.

Suppose that tomorrow the "Employ American Economists Act" became a U.S. law and it forbade foreign-born economics professors from working in American higher education. What would happen to our earnings? In the short run, our wages would almost surely rise as American schools scrambled to hire the remaining U.S.-born academics to teach their existing classes.[25]

But in the long run, our every expectation is that our wages would fall. Our research and teaching productivity is enhanced by the opportunity to interact with and learn from the ideas brought by our foreign-born colleagues. (Indeed, five of the past 10 winners of the John Bates Clark Medal, awarded every other year to the top North American economist under age 40 and historically a strong predictor of a future Nobel Prize, has gone to someone who is foreign born.) Also likely to be hurt in the long run would be U.S. students and the overall U.S. economy.

And where would all these foreign-born professors go? It is likely that relatively few would simply stay in the United States to ply their talents in other occupations and industries. Instead, given the rapid expansion of higher education around the world, most would leave for countries whose leaders recognize their job-creation potential and shape policy accordingly. The exodus of these academics from the United States would strengthen university departments abroad and weaken America's ability to attract top undergraduate and graduate students to its programs. Any short-run income gain for U.S. academia would likely be offset by a longer-run loss, as productivity growth among U.S. universities diminished.

America's demand for highly talented workers continues to grow. Immigrants continue to help meet this demand—both directly and more broadly through their expansive contributions to America's innovation potential. Decades of data document the continuous increase in U.S. demand for talented knowledge workers. The Great Recession did not suppress America's need for STEM labor; indeed, in recent years in STEM occupations unemployment has fallen sharply, consistent with substantial labor-market tightening. Relative to non-STEM workers of the same age and educational attainment, STEM workers in America today earn a compensation premium of about 25% – a differential that is largely unchanged over three decades. Relative to all other U.S. occupations, the earnings of STEM workers have risen: since 2000, real wages of main STEM occupations have grown, while real wages for most other U.S. occupations have fallen. Looking among U.S. STEM workers, there is no systematic evidence that immigrants are paid less than native-born workers.

1. Autor, Dorn, and Hanson (2013) and Haskel, Lawrence, Leamer, and Slaughter (2013) are recent studies of how globalization shapes U.S. labor demand.
2. As documented by Bloom, Draca, and Van Reenen (2011).
3. See Autor, Levy, and Murname (2003).
4. Lin (2011) documents how technological advance creates new occupations in the United States.
5. To construct the labor-supply index in Figure 3.1, we used data from the CPS on total hours worked for each person (weeks worked last year times usual hours worked per week or, in earlier data before 1976, hours worked last week), covering all civilian workers and including the self-employed (weighted by CPS sampling weights). Simply counting total hours worked misses the fact that workers with different levels of education and experience have different productivity levels. To incorporate these productivity differences into a measure of labor supply, we first divided workers into labor-market groups broken down by gender, five education categories (less than a high school degree, high school degree or equivalent, some college but no bachelor's degree, bachelor's degree, advanced degree), and eight experience categories (0-4, 5-9, 10-14, 15-19, 20-20, 25-29, 30-34, and 35-39 years of potential labor market experience, following definitions of experience in Jaeger and Page (1996) and Park (1994)). Then, for each gender-education-experience group we calculated average weekly earnings in each year (for full-time, full-year workers, defined to be those working at least 35 hours per week and 40 weeks a year) and divided this average by that for white, male, high school graduates with approximately 10 years of labor-market experience (which group is used as the reference category is unimportant). We take this relative wage to capture a group's relative labor productivity and we average this relative wage across years to create a time-constant labor productivity adjustment factor for each gender-education-experience group. We multiply these adjustment factors by hours worked in each labor-market group and sum across groups for each year separately for high school graduates and for college graduates (weighting by each subgroup's average share of hours worked in the broader education group over the entire sample period to avoid having differential changes in age structure between college and high school graduates affect the measure of labor supply). Finally, in each year we divided total labor supply for the college educated by total labor supply of the high school educated, took the log of this relative labor supply value, and rescaled the log value such that equal values of college and high school labor supply have an index of 100. This method of calculating labor productivity follows Autor, Katz and Kearney (2008).
6. To construct the college-high school wage premium in Figure 3.2, we used data from the CPS for average weekly earnings (annual earnings divided by weeks worked) for full-time, full-year civilian workers (35 or more usual hours per week, 40 or more weeks worked last year). We excluded the self-employed; earnings are defined as wage and salary income (i.e., excluding business income). We weighted each observation by weeks worked last year times the CPS sample weight. To keep constant across years the age composition of workers, we constructed average gender-experience weights across the sample period for each education group and then held these weights constant over time. Similar to the construction of relative supply, discussed above, we used five education categories and ten categories for labor-market experience.
7. This quoted expression borrows from the title of the book by Freeman (1976).
8. Early research is reviewed in Katz and Autor (1999). Recent analyses include Autor, Katz, and Kearney (2008) and Beaudry, Green, and Sand (2013).
9. In the 1980s, demand grew by more at every additional step up the skill ladder—wages for the median worker grew by more than low-wage workers, and wages for the already highly compensated grew by more than at the median. In the 1990s, however, wage growth in the middle of the U.S. labor force sagged, with strong growth in earnings continuing only at the top. Katz and Murphy (1992) is a classic early paper, which developed methodology to measure changes in relative labor demand. See Autor and Dorn (2013) on earnings polarization in the U.S. labor market. In the 2000s, even before the Great Recession, the story evolved further. While earnings growth at the top yet again continued, some college graduates (likely mostly in non-STEM fields, given our evidence later in this Section) were pushed down the occupational ladder, taking jobs less-educated workers typically held in the past. See Beaudry, et al (2013).
10. CPS STEM occupations are defined as in Section 2.
11. To construct the labor-supply index in Figure 3.3, we follow the same procedure as for Figure 3.1, except now we sum up productivity-adjusted hours worked for two educated groups: workers in STEM occupations with a bachelor's degree (but no more) and workers in non-STEM occupations with a bachelor's degree (but no more).
12. To construct this labor-supply index, we again follow the procedure for Figure 3.1. The two groups of workers are workers in STEM occupations with an advanced degree (master's, professional, or doctorate) and workers in non-STEM occupations with an advanced degree.
13. Data for median hourly wages are from Occupation Employment Statistics from the Bureau of Labor Statistics: http://www.bls.gov/oes/current/oes_nat.htm. Computer and mathematical occupations are occupational group 15-0000; engineering occupations are occupational group 17-2000; and all occupations are group 00-0000.
14. To produce Figure 3.5, we limited the sample to full-time, full-year workers (at least 35 usual hours of work per week, at least 40 weeks worked last year) and regressed log weekly wages (deflated for price inflation by the Personal Consumption Expenditure index) on dummies for seven education categories (less than high school, high school, some college, college degree, master's degree, professional degree, PhD), a quartic in potential labor-market experience, dummies for race and gender, dummies for nine Census geographic regions, and a dummy for whether a worker is in a STEM occupation. The STEM wage premia (with 95% confidence bands) are the estimated coefficients on the STEM dummy variables for each year-by-year regression. Estimating the regressions year by year allows returns to education, experience, and other characteristics to vary over time. We used as weights weeks worked last year times the CPS sample weight, such that people who worked more influence the analysis more. Results are essentially the same when we interact education dummies with dummy variables for labor-market experience categories (based on five-year experience bins).
15. See: http://www.uscis.gov/portal/site/uscis/.
16. There are many studies that examine the source of pay differences between industries and occupations (with a classic being Dickens and Katz, 1987). Perhaps the definitive study on the subject (Abowd, Kramarz, and Margolis, 1999) finds that person-level characteristics such as talent (and as opposed to firm or industry characteristics) are the dominant source of pay differences across individuals observed working across a large

number of firms and industries. Other possible explanations for the STEM earnings premium we find less plausible. One is that for the typical U.S. worker, acquiring STEM talent may be more costly in terms of time and/or money, such that the STEM wage premium would be compensating for the higher upfront investment. This investment-cost explanation seems unlikely, in part because the analysis that constructs the STEM premium in Figure 3.5 controls for education and work experience—and because STEM and non-STEM college graduates tend to be educated at the same universities where they pay common tuition rates. Another possible explanation is that companies that heavily employ STEM workers may earn consistently higher profits than do other companies, where companies share some of these higher profits with workers in the form of higher salaries or bonuses. This profit-sharing explanation also seems unlikely, in part because it begs the question of why STEM-intensive companies would be persistently more profitable over decades.

17. These unemployment rates are calculated from the CPS. STEM occupations are defined as in Section 1. We define the employment rate as 100 times the ratio of the number of individuals who report being unemployed to the number of individuals who report being in the labor force, where we weight each of these aggregate counts by CPS sample weights. We limit the sample to those aged 25 to 54 to exclude individuals transitioning into (i.e., under age 25) or out of (i.e., over age 54) the labor force for whom occupation may be poorly defined.

18. See in particular Hira (2010) and Matloff (2013).

19. We focus on younger workers, aged 25 to 44 years old, to capture immigrants who are likely to have arrived in the country relatively recently and to avoid concerns about high ability individuals being promoted out of STEM occupations into higher level management jobs. Eliminating the self-employment is standard practice in economics research on wages. Since the self-employed may take their income as salary or unrealized capital gains, it is difficult to compare their earnings with wage and salary workers.

20. The data used for Figure 3.7 are from the 2009, 2010, and 2011 ACS. We limit the sample to full-time (at least 35 usual hours worked per week), full-year (at least 40 weeks worked last year) civilian workers aged 25-44 employed in a STEM occupation (as defined in Section 1). We exclude the self-employed and report average weekly earnings (annual earnings in the previous year divided by weeks worked in the previous year) based on wage and salary income. Annual income is calculated by multiply average weekly earnings by 48 (such that weeks worked is held constant across groups). We further limit the sample either to individuals with a bachelor's but no higher degree or with a master's but no higher degree. Sample sizes for individuals in STEM occupations with professional or doctorate degrees are quite small, making their use problematic. All figures are weighted by ACS sample weights.

21. It is important to mention that the absence of wage differences between immigrants and U.S.-born workers does not hold when we examine non-STEM occupations. In this case, we see the well-documented pattern that immigrants, and in particular recently arrived immigrants, earn significantly less than native-born workers. Clearly, however, this pattern does not translate to STEM. Borjas (2013) discusses evidence on immigrant-native wages gaps across all occupations.

22. In this analysis, we used the 2009, 2010, and 2011 ACS sample for full-time (at least 35 usual hours per week), full-year (at least 40 weeks last year) individuals employed in STEM occupations, as defined in Section 1. We limited the sample to men, 15 years or less beyond the standard age for their highest degree (age 23 for bachelor's, age 25 for master's) to capture individuals before they were promoted out of jobs emphasizing STEM skills into management positions. Earnings were defined as log inflation adjusted log weekly earnings (wage and salary income last year/ weeks worked last year). Regressions were run separately for individuals with bachelor's degrees (N=26,462) or master's degrees (N=11,980). Independent variables included in the regressions were: a quartic in age, a dummy for race, dummies for nine geographic regions, dummies for survey year, and a dummy for being foreign born. For the regression weights, we used by weeks worked last year times the ACS sample weight. We estimated four specifications: the baseline regression as described, adding dummies for industry, adding dummies for occupation, and adding dummies for industry and occupation. We summarize the coefficient estimates on the dummy variable for being an immigrant:

- The coefficient estimate on being foreign born ranges in value from -0.006 to 0.017 in the bachelor's degree sample, indicating a range of -0.6% below to 1.7% above native-born wages (with only one of the four estimated coefficients statistically significant at the 5% level: the coefficient of 0.017 in the baseline specification); and ranges from -0.039 to 0.015 in the master's sample, indicating a range of -3.9% below to 1.5% above native-born wages (with only one of the four estimated coefficients statistically significant at the 5% level: the coefficient of -0.039 in the industry and occupation dummy specification).
- In additional regressions, we limited the sample to computer occupations (computer programmers, software developers, web developers) and obtained similar results. The coefficient on the immigrant dummy was statistically insignificant and economically very small. We further included two immigrant dummies, one for those arriving before age 18 and a second for those arriving age 18 or later. The results were again similar.
- Finally, we changed the dependent variable to be log hourly earnings (weekly earnings/ usual hours worked per week), using as regression weights weeks worked last year times usual hours worked per week times the ACS sample weight. In these regressions, the foreign dummy variable was positive in all cases and sometimes statistically significant.

23. Earnings data are from the Bureau of Labor Statistics, http://www.bls.gov/oes/current/oes_nat.htm, which reports annual mean wages by occupational group. The nominal value for 2012 is $45,790, which we adjust to 2011 dollars using the ratio of the CPI for the two years (224.9/229.6 = 0.98).

24. See Borjas (2006) and Lan (2011). Borjas (2003) studies the wage impacts of immigration across a broad set of education and labor-market experience groups.

25. Borjas and Doran (2012) examine the impact of the arrival of large numbers of Russian mathematicians on the U.S. academic market for math professors.

Conclusions

For generations, highly talented immigrants in science and engineering have been a catalyst for innovation, job creation, and rising standards of living in America. Immigration has played a vital role in helping American companies—young and old, small and large, U.S. based and foreign-based alike—meet their growing demand for talent to help America expand jobs and incomes for its workers and their families.

Despite the preponderance of evidence of the many net benefits highly skilled immigrants have generated for America, today's policy conversations voice unease about these immigrants. This unease is driven partly by the continued fragility of the U.S. economy and labor market in the wake of the Global Financial Crisis and Great Recession. It is also driven partly by the pre-crisis flagging of America's innovation success. Even before the crisis, concern was rising among leaders in both the private and public sectors that America's creative dynamism is waning.

Past need not be prologue for America's innovation success. In today's increasingly global economy, America's competitiveness is doubly challenged by its innovation and productivity slowdown because the opposite is happening in so many other countries. The world's innovative activities are now both more competitive and more mobile. The notion that the United States has a perpetual lock on high-profit, ever-expanding innovation is gone. Even if the United States can maintain its innovation dynamism—along with all the commensurate benefits of long-run growth in jobs and in incomes—it will do so amidst greater competition among companies and thus, indirectly, among their workers. And, this competition might eventually shift substantial innovation activity out of America altogether—with commensurate loss of support to jobs and to standards of living.

What is unclear is what policies the United States will pursue in response to this challenge of maintaining America's innovation strength by, in part, sustaining an environment in which the world's most talented—by birth and education or by immigration—are welcomed to thrive in America.

So, what will the future bring? A pessimistic future would entail a continued erosion of America's global competitiveness in innovation. This pessimistic future would probably not involve any dramatic crisis. But it would involve a slower-growing, less-dynamic U.S. economy with no rekindling of the growth trajectory that talent and innovation spawned over much of America's 20th century. Along this pessimistic path, 2020 may well arrive with business and government leaders puzzling over why the U.S. labor market and overall economy had still not recovered its pre-crisis health.

This need not be the destiny for the United States. A vigorous, optimistic future is very possible. But creating a healthy and optimistic outcome will require crafting new U.S. policies to welcome the immigrant STEM talent that America has long and increasingly relied on to help drive its innovation and resulting growth. Such policies should be based on empirical facts and patterns like those established in this white paper—not on anxiety, not on assertion, and not on anecdote. We know that America's citizens and its leaders can rise to this challenge.

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