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GUESTWORKERS IN THE HIGH-SKILL U.S. LABOR MARKET

An analysis of supply, employment, and wage trends

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Executive summary

This paper reviews and analyzes the science, technology, engineering, and mathematics (STEM) labor market and workforce and the supply of high-skill temporary foreign workers, who serve as “guestworkers.” It addresses three central issues in the ongoing discussion about the need for high-skill guestworkers in the United States:

- Is there a problem producing enough STEM-educated students at sufficient performance levels to supply the labor market?
- How large is the flow of guestworkers into the STEM workforce and into the information technology (IT) workforce in particular? And what are the characteristics of these workers?
- What are the dynamics of the STEM labor market, and what are the employment and wage trends in the IT labor market?

Analysis of these issues provides the basis for assessing the extent of demand for STEM workers and the impact of guest-worker flows on the STEM and IT workforces.

Our examination of the IT labor market, guestworker flows, and the STEM education pipeline finds consistent and clear trends suggesting that *the United States has more than a sufficient supply of workers available to work in STEM occupations:*

- The flow of U.S. students (citizens and permanent residents) into STEM fields has been strong over the past decade, and the number of U.S. graduates with STEM majors appears to be responsive to changes in employment levels and wages.
- For every two students that U.S. colleges graduate with STEM degrees, only one is hired into a STEM job.
- In computer and information science and in engineering, U.S. colleges graduate 50 percent more students than are hired into those fields each year; of the computer science graduates not entering the IT workforce, 32 percent say it is because IT jobs are unavailable, and 53 percent say they found better job opportunities outside of IT occupations. These responses suggest that the supply of graduates is substantially larger than the demand for them in industry.

Analyzing new data, drawing on a number of our prior analyses, and reviewing other studies of wages and employment in the STEM and IT industries, we find that industry trends are strikingly consistent:

- Over the past decade IT employment has gradually increased, but it only recovered to its 2000–2001 peak level by the end of the decade.
- Wages have remained flat, with real wages hovering around their late 1990s levels.

We also find that, while there were strong increases in the number of computer science graduates and entrants from other fields that supply the IT industry during the late 1990s, after the dot-com bubble burst in 2001 a declining number of both guestworkers and U.S. students entered the IT pipeline. But since then, the number of IT college graduates has recovered modestly, while the number of guestworkers has increased sharply, suggesting a fundamental change in this labor market.

Our review of the data finds that *guestworkers make up a large and increasing portion of the IT labor market:*

- The flow of guestworkers has increased over the past decade and continues to rise (the rate of increase dropped briefly with the economic collapse of 2008, but the flow of guestworkers has since continued its rapid upward pace).
- The annual inflows of guestworkers amount to one-third to one-half the number of all new IT job holders.

It could appear to casual observers that the striking increase in guestworkers might be a response to increased labor demand in the IT field. But employment and wage levels in IT jobs have been weak, trends that are *not* consistent with strong demand. The data also show that there are multiple routes into IT employment, most of which do not require a STEM degree:

- Only about a third of the IT workforce has an IT-related college degree.
- 36 percent of IT workers do not hold a college degree at all.
- Only 24 percent of IT workers have a four-year computer science or math degree.

The data also strongly suggest that *there is a robust supply of domestic workers available for the IT industry:*

- The number of domestic STEM graduates has grown strongly, and many of these graduates could qualify for IT jobs.
- The annual number of computer science graduates doubled between 1998 and 2004, and is currently over 50 percent higher than its 1998 level.

At the same time, current U.S. high-skill immigration policy, which includes the granting of work permits to foreign students and the issuance of a variety of nonimmigrant guestworker visas, provides employers with large numbers of STEM guestworkers, most of whom are in IT occupations.

Until about 2001, when the dot-com bubble burst, the IT labor market performed in the way that economic fundamentals suggest it should, with the supply of IT graduates and workers responding to strong wage increases and reflected in growing employment. Since then, however, the IT field appears to be functioning with two distinct labor market patterns:

- The domestic supply of IT workers exhibits increasing but slow growth in line with market signals.
- The supply of IT guestworkers appears to be growing dramatically, despite stagnant or even declining wages.

The immigration debate is complicated and polarizing, but the implications of the data for enacting high-skill guest-worker policy are clear: *Immigration policies that facilitate large flows of guestworkers will supply labor at wages that are too low to induce significant increases in supply from the domestic workforce.*

Introduction

The strength of the U.S. science, technology, engineering, and mathematics (STEM) workforce and the need to enhance U.S. innovation and productivity are longstanding concerns. A key part of this discussion focuses on whether there is sufficient supply and “quality” in the domestic pool of STEM students and workers, and what might be the most effective policy initiatives to address the range of technology and workforce challenges facing the nation (see, e.g., National Academy of Science 2007). Current immigration bills proposed in Congress include various provisions to increase the supply of guestworkers for STEM employers. Proposals include expanding the current temporary visa programs by increasing the H-1B visa cap and providing permanent residency (green cards) to nonresident foreign students who graduate from a U.S. college in a STEM field.

The rationale for these provisions is that there is a shortage of STEM workers available domestically. The claim is based primarily on numerous industry statements that employers cannot find sufficient numbers of qualified workers in the domestic labor pool (which comprises both immigrants and natives, citizens and lawful permanent residents). In our research we find that there is no lack of domestic graduates or existing domestic STEM workers to fill available STEM jobs. We undertake an analysis of the best available data on the supply of STEM workers from college and in the labor force. We examine the supply of guestworkers and, because of their concentrated use in the information technology (IT) sector, we examine in detail the wage and employment trends in IT industries and occupations.

The central issues examined here are: (1) the size of the domestic pool of STEM students and workers; (2) the size of the pool of new and available guestworkers; and (3) trends in the wages and employment of the IT workforce. We examine the evidence on each of these issues, which are central to an evaluation of STEM workforce supply, demand, and employment outcomes. We address the performance and number of students who have the potential to become STEM workers, and the pursuit of STEM studies by college students and the subsequent entry of these students into the workforce. We then turn to characteristics of the STEM workforce and the comparative number of guestworkers in the STEM and, in particular, IT workforces.

The supply of STEM-potential students

The United States has a large number of STEM-ready students and produces large shares of high-performing students who rank at the top internationally. This fact is often overlooked, perhaps because the overall size of the STEM workforce is small and because focusing on *average* performance in international student rankings is misleading. When we examine the data carefully, we find that test scores of U.S. high school students have been improving, that a remarkably small fraction of all high school graduates will find STEM employment available upon graduating college, and that the United States actually produces a significant share of the world’s high-performing students.

Our analysis of students in the STEM pipeline—the students who have the education, skills, and aptitude for STEM work—draws on extensive research we have conducted on these issues (see Salzman and Lowell 2008; Lowell and Salzman 2007; Lowell, Salzman, Bernstein, and Henderson 2009).

TABLE 1

U.S. trends in student mathematics performance

INCREASES IN NAEP* SCORES SINCE 1973 BY DEMOGRAPHIC GROUP (POINTS)

Age group	White	Black	Hispanic
Age 9	25	34	32
Age 13	16	34	29
Age 17	4	17	16

* National Assessment of Educational Progress

Source: Authors' analysis of National Center for Education Statistics (2009a)

U.S. high school student performance is improving. Academic performance is a widely used indicator of a student's potential for STEM work, and efforts to improve education have long been the focus of a multitude of policies and programs.

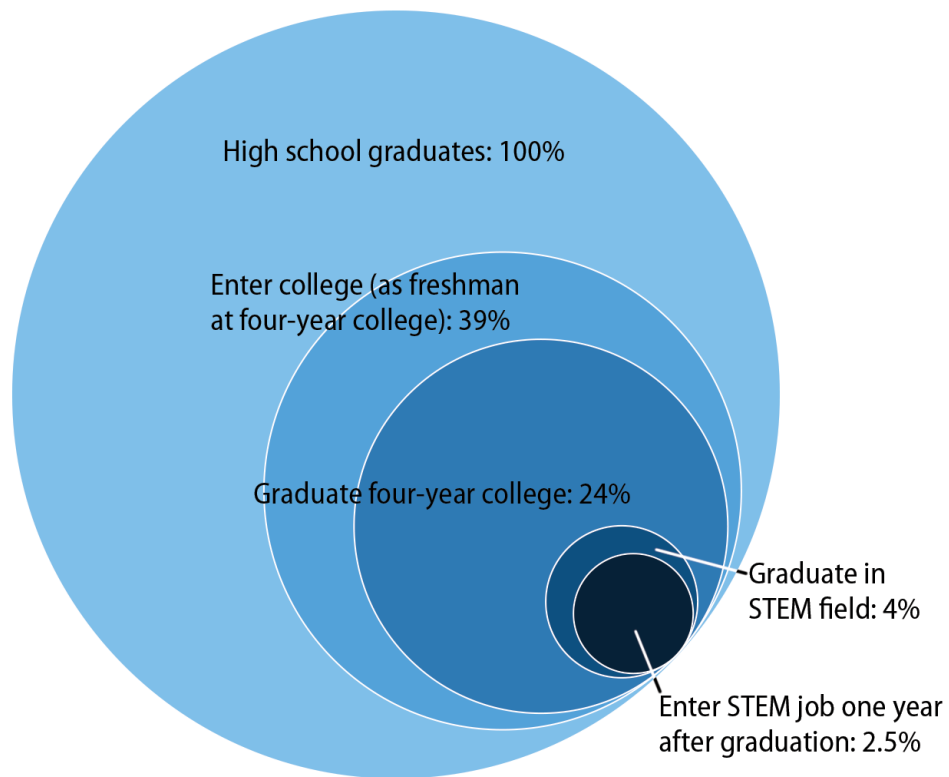
Numerous studies using a wide range of metrics and performance criteria show that the educational performance of U.S. students has improved steadily since the 1970s (see **Table 1** for mathematics performance). The data also show reason for concern about the persistent gap between whites and minority students, who are a growing proportion of the student population, and the lower rates of college completion for many minority groups. Yet, though these disparities are relevant to efforts to increase the diversity of the STEM labor force, it is not clear that they significantly limit the domestic supply of potential STEM workers.

The STEM workforce is small relative to the pool of students. Concern about the pathways into the STEM workforce is relevant to only a small share of the student population. The STEM workforce comprises just 4.4 percent of the total U.S. workforce¹ and it, in turn, is drawn from an even smaller share of the high school- and college-educated populations. Only 4 percent of high school graduates go on to earn a STEM degree in college, and the share that actually takes a STEM job one year after graduation is even lower, just 2.5 percent. **Figure A**, which shows the flow of students from high school into the STEM workforce, makes clear that it is the characteristics and performance of a very small group that is most relevant to the STEM education-to-work pipeline. Conversely, it is misleading to focus on the performance of the average student or even the abilities or characteristics of the overall population.

U.S. employers have access to the world's largest body of STEM students. This small population of STEM students and graduates is drawn disproportionately from the higher-performing segment of the secondary-school population, even though, in college, not all STEM students are top performers and many are average scholastically (see Lowell, Salzman, Bernstein, and Henderson 2009). Without minimizing the problem of educational performance for U.S. students overall, our focus here is on the relatively small number of students who might pursue STEM studies. For example, it is frequently asserted that U.S. students rank in the middle on tests that purportedly compare students internationally, but the United States has generous numbers of students whose test scores place them among the highest of international performers (see Lowell and Salzman 2007; Carnoy and Rothstein 2013).

FIGURE A

Percent of high school graduates going to college, graduating, and then entering a STEM job



Source: Authors' analysis of National Center for Education Statistics (2009b, 2013)

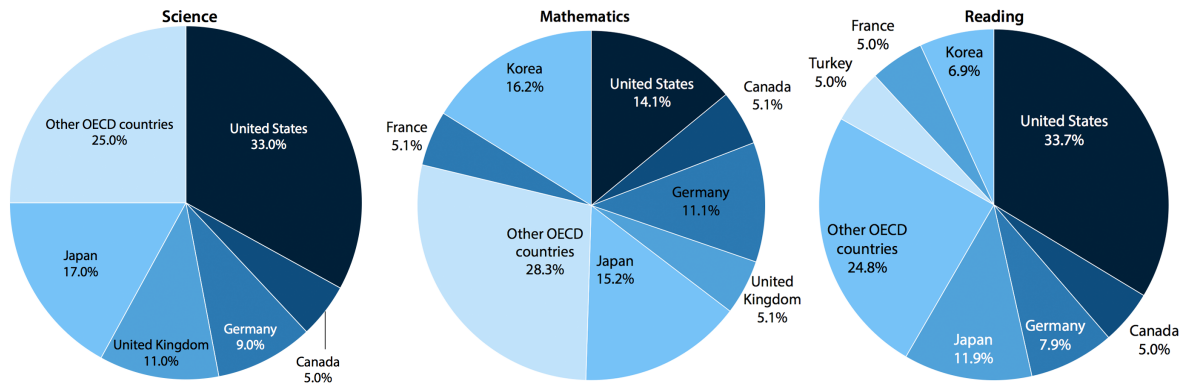
Consider that U.S. students make up one-third of the entire global population of high-performers on tests of science knowledge. In a global economy, firms have a great deal of flexibility in choosing where they will locate and from where they will hire workers. The misguided focus on average scores and the relative rankings of countries actually tells us little about where employers are most likely to find STEM-ready workers. Students in Singapore or Finland, for example, rank high internationally but are few in number; such small countries, with populations of 5 or 6 million, yield a negligible supply of STEM students, particularly high-performing students, to be hired. As measured by international test comparisons of OECD countries (Figure B), the United States has a large share of the OECD's global supply of high-performing students (Salzman and Lowell 2008). More recent analyses find similar performance outcomes for U.S. students (Carnoy and Rothstein 2013).

Staying with STEM, and the supply of college graduates

A common assertion about the future supply of STEM students is that U.S. students lose interest in STEM fields as they progress through college. This is often referred to as the “leaky STEM pipeline,” and indeed many students who begin their college studies in a science or engineering field transfer to a different major by the time they graduate. But conversely, many students who do not begin in a STEM major move into one during their college years. Since college is often a period of exploration and development of interests and abilities, movement in and out of different fields

FIGURE B

Shares of OECD countries' high-performing students



Source: Authors' analysis of Organization for Economic Cooperation and Development (2006)

might be expected. Using longitudinal data to examine the pathways of four-year college students, from freshman year to graduation, we find a significant flow of freshmen out of STEM majors but also a large flow of non-STEM freshmen into STEM majors. The pool of STEM majors actually increases between freshman year and graduation. As shown in **Figure C**, considering all students who enter a four-year college and graduate within six years, more students take on a STEM major than drop a STEM major.

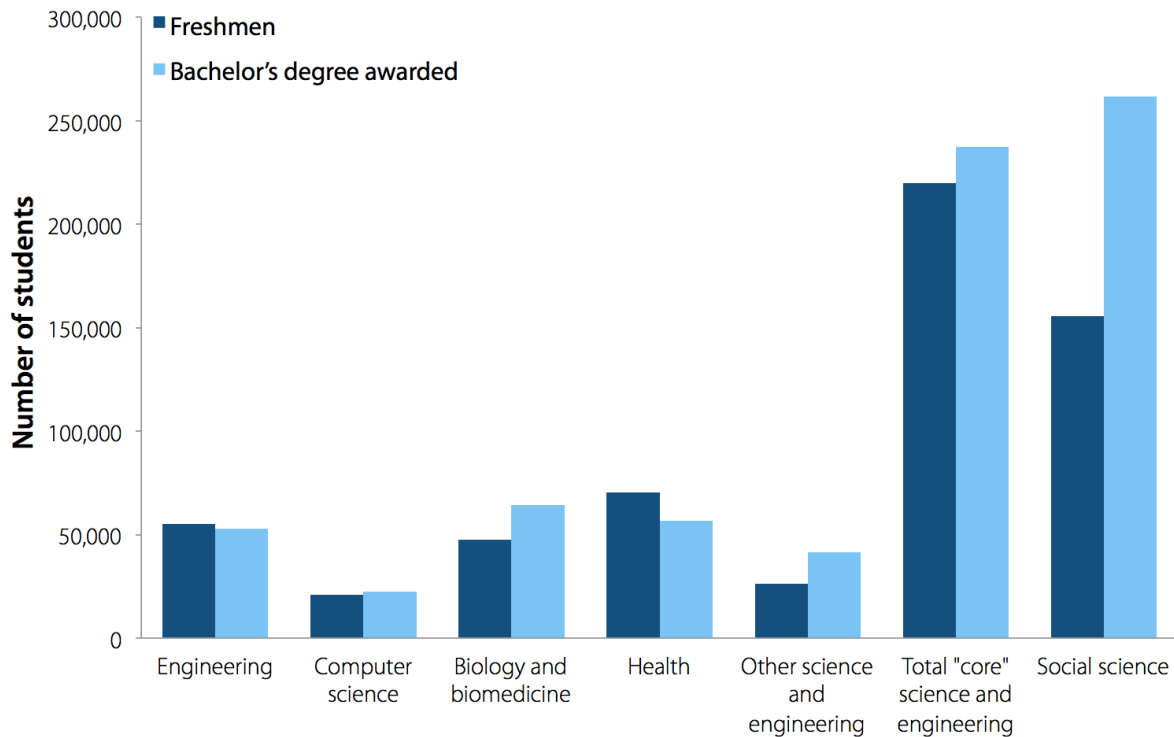
Nevertheless, is this pool of STEM graduates sufficient to supply the job market? **Figure D** shows the percentage of employed STEM graduates who are in STEM jobs one year after graduation. For STEM graduates, the supply exceeds the number hired each year by nearly two to one, depending on the field of study. Even in engineering, U.S. colleges have historically produced about 50 percent more graduates than are hired into engineering jobs each year. Figure D shows that share to be even higher in recent years. In all disciplines (STEM and non-STEM), health is the only field that stands out as having the vast majority of graduates hired into the field (this is especially true in nursing, where about 90 percent of graduates become practicing nurses).²

The overall low transition rates of graduates from a field of study to an occupation in their discipline are consistent for college graduates generally in the liberal arts and humanities. Professional degree programs, however, are intended to be more tightly coupled to specific occupations and industries than other degree programs, and thus we should expect graduates to have higher transition rates from those programs to occupations directly related to their fields of study. Therefore, it is not surprising that a large share of computer science and engineering graduates enter occupations closely related to their degree. What is surprising is that there are still 50 percent more graduates than the number who enter occupations related to their professional degrees.

Further examining the career transitions of these graduates, we look at the reasons why a third of computer science graduates, and nearly half of engineering graduates, do not go into a job directly related to their degree (**Figure E**). For computer science graduates employed one year after graduation (i.e., excluding those unemployed or in graduate school), about half of those who took a job outside of IT say they did so because the career prospects were better elsewhere, and roughly a third because they couldn't find a job in IT. For engineering graduates, it's about an even split,

FIGURE C

Number of science and engineering freshmen and graduates in 2003 college cohort (graduating within six years)



Source: Authors' analysis of National Center for Education Statistics (2009b)

with approximately one-third each saying they did not enter an engineering job either because of career prospects or they couldn't find an engineering job. In short, of those graduates with the most IT-relevant education, a large share report they were unable to find an IT job while others found IT jobs to be paying lower wages or offering less attractive working conditions and career prospects than other, non-STEM jobs.³

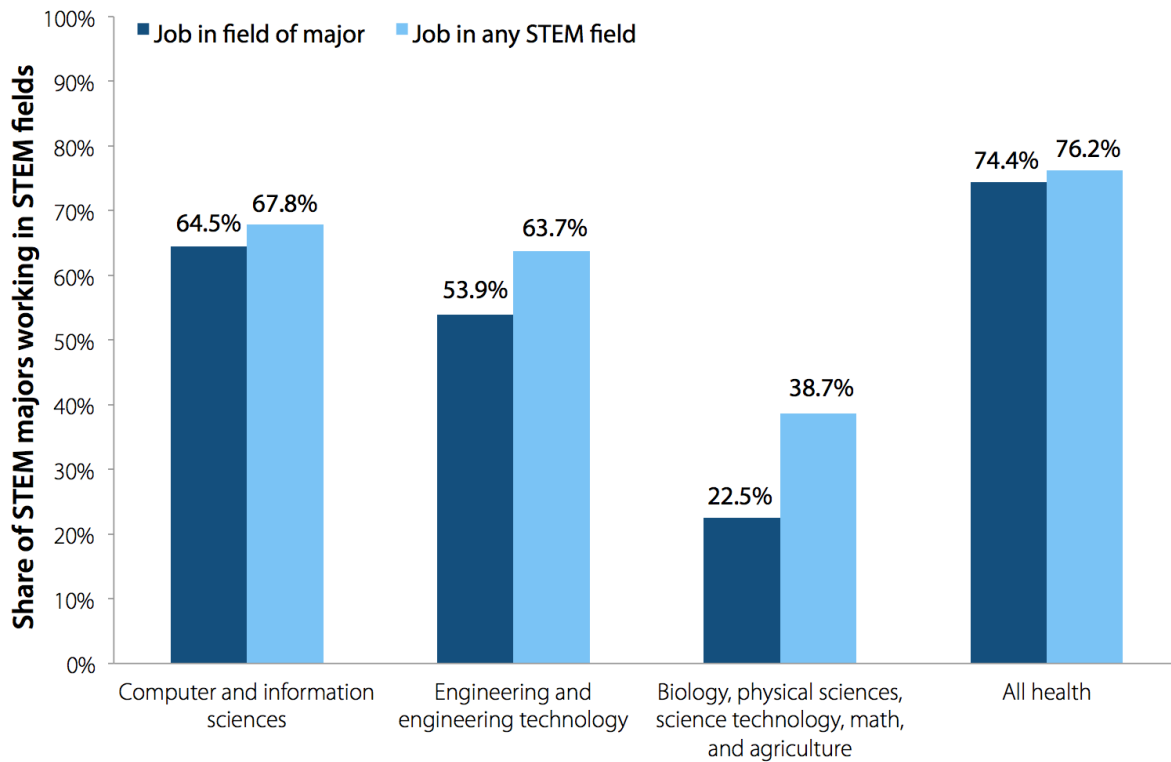
Educational background of the IT workforce

IT workers, who make up 59 percent of the entire STEM workforce, are predominantly drawn from fields *outside of* computer science and mathematics, if they have a college degree at all. Among the IT workforce, 36 percent do not have a four-year college degree; of those who do, only 38 percent have a computer science or math degree, and more than a third (36 percent) do not have a science or technology degree of any kind. Overall, less than a quarter (24 percent) of the IT workforce has at least a bachelor's degree in computer science or math. Of the total IT workforce, two-thirds to three-quarters do not have a technology degree of any type (only 11 percent have an associate degree in any field).⁴

Although computer science graduates are only one segment of the overall IT workforce, at 24 percent, they are the largest segment by degree (as shown in **Figure F**, they are 46 percent of college graduates entering the IT workforce, while nearly a third of graduates entering IT do not have a STEM degree). The trend in computer scientist supply is

FIGURE D

Occupational field of STEM college majors one year after graduation, 2009



Source: Authors' analysis of National Center for Education Statistics (2013)

important as a source of trained graduates for IT employers, particularly for the higher-skilled positions and industries, but it is clear that the IT workforce actually draws from a pool of graduates with a broad range of degrees.

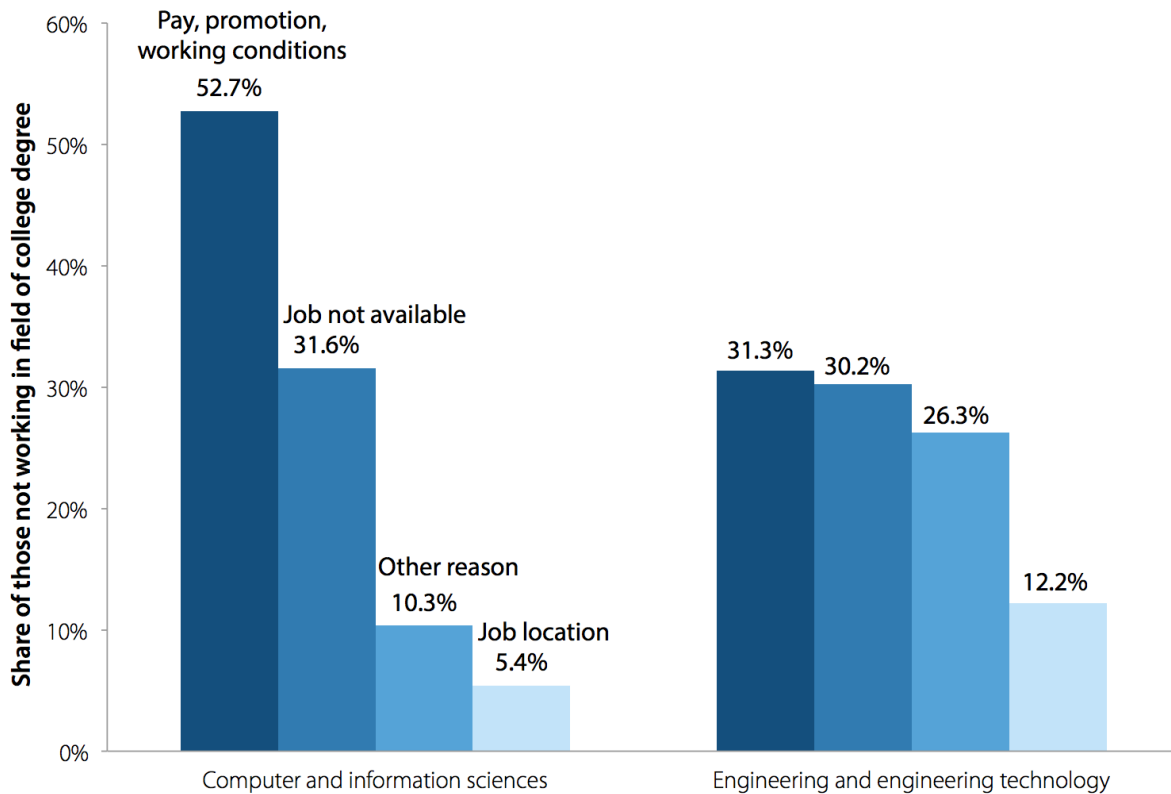
Guestworkers in the U.S. STEM and IT workforces

Technology firms and many pundits and policymakers frequently maintain that the United States restricts the admission of highly skilled foreign workers. It is true that the number of permanent immigrants admitted purely for family reasons exceeds that of employment-based immigrants, and it is also true that the policies that regulate admission are cumbersome and should be reformed. But the United States admits significant numbers of the most highly skilled migrants (Lowell 2010), both on a permanent basis and as temporary guestworkers. We focus on the latter class of migrants here because they receive the greater attention in policy discussions. We turn here to estimates of the supply of these temporary foreign workers relative to new job creation.

The most-discussed visa for these workers is the “specialty occupation” H-1B nonimmigrant visa, and its use is dominated by the IT sector. This visa permits a stay of up to six years. H-1B workers may switch between employers (if the new employer can sponsor their H-1B), but many stay with one employer in order to be sponsored for permanent status. Some firms have a targeted business strategy of circulating offshore workers through positions in the United States and do not sponsor many guestworkers for permanent status (Hira 2010). Under international trade law, the

FIGURE E

Primary reason for not working in field of college degree one year after graduation, 2009



Source: Authors' analysis of National Center for Education Statistics (2013)

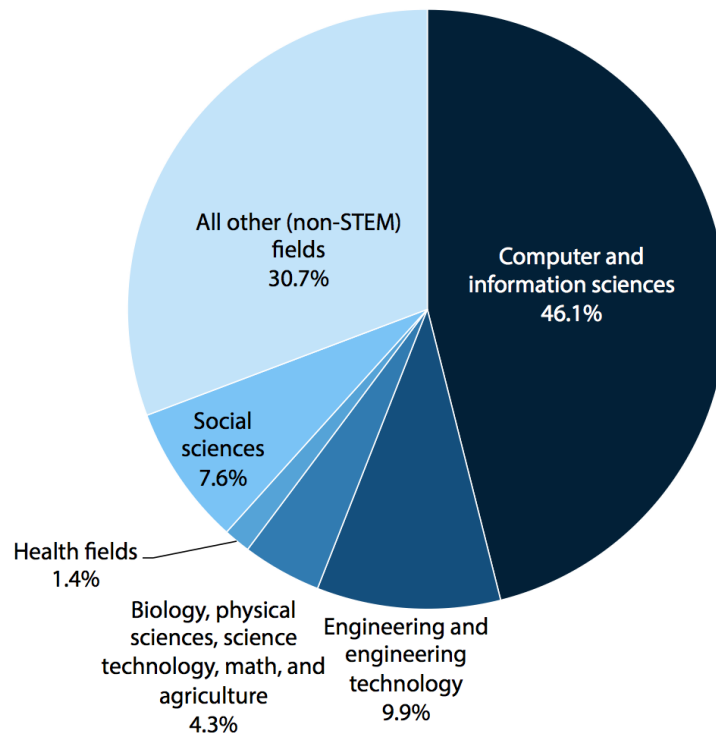
United States may not restrict the annual number of H-1B visas to fewer than 65,000 annually, but U.S. law has been amended to provide an additional 20,000 visas for foreign STEM graduates of U.S. universities, and there is no cap on the number of H-1Bs sponsored by nonprofit employers such as universities.

The next largest visa used by STEM employers is the L-1 visa for intracompany transferees. The L-1 has two categories, the L-1A for executives and managers (it permits work for up to seven years) and the L-1B for employees with “specialized knowledge” (it permits work for up to five years). Spouses and children of L-1 workers may be admitted with an L-2 visa, which grants the L-2 holder work authorization for the same amount of time as the principal L-1 holder. There are no caps on the L visa, and its use has increased over time.

An unknown but substantial proportion of foreign students on F-1 nonimmigrant student visas change status directly to the H-1B visa if sponsored by an employer, while many other foreign students first work after graduation through the Optional Practical Training (OPT) program. The permitted stay to work under the OPT was two years in the past, but it has been changed to 12 months. In 2008, however, the program was extended by 17 months for graduates in STEM fields, meaning that these graduates can work on OPT status for a total of 29 months.⁵

FIGURE F

Majors of college graduates (2003–2004 freshman cohort) in IT jobs one year after graduation, 2009



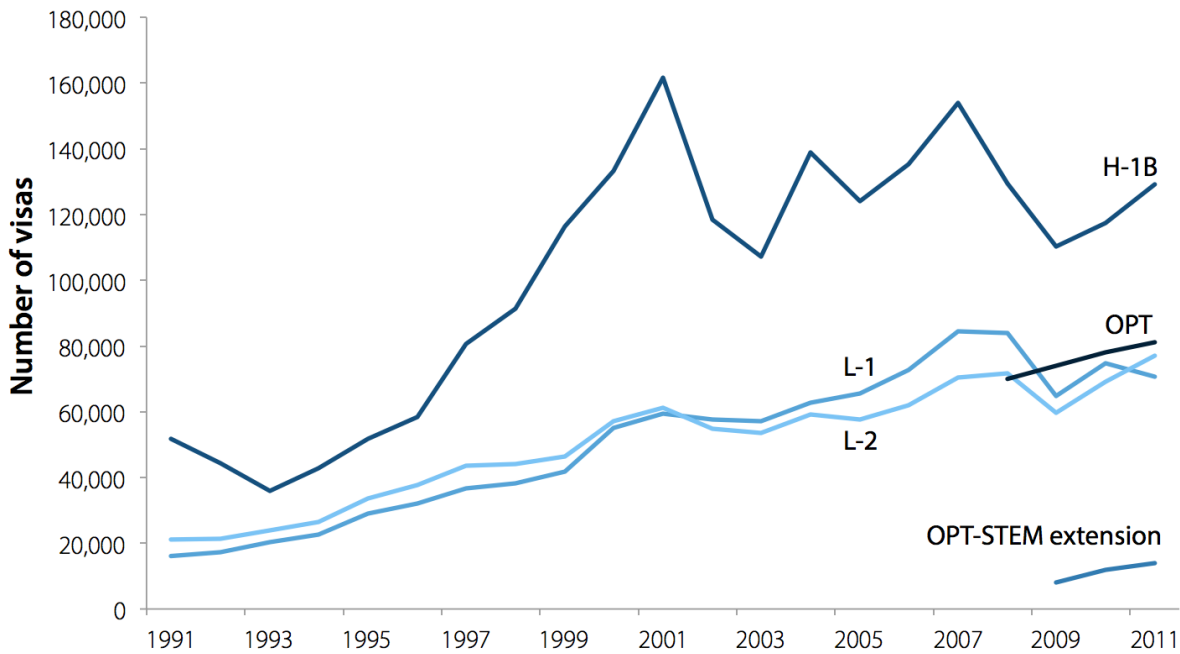
Source: Authors' analysis of National Center for Education Statistics (2013)

Another temporary visa that often supplies workers for IT jobs is the O-1 visa for workers of extraordinary ability (10,590 total O-1 visas were issued in 2012). Less often found in the IT fields are the E visa for traders and investors from nations with which the United States has qualifying treaties, and the J visa for cultural exchange.

In order to estimate the number of guestworkers who are available to work in the IT sector, we need to know the number in each visa category who are eligible to enter an IT job. Data show that the majority of H-1Bs are employed in IT jobs and that large shares of both L-1 visa holders and foreign students working on the OPT visa can be found in IT jobs. Although it is not known the extent to which the L-2 spousal/child visa is used for IT or STEM fields, we include it here because IT recruiters are targeting this group of visa holders in advertisements, and there has been a sharp increase in the number of L-2 visas issued (see **Figure G**). While many of the other temporary visa categories could be used to recruit STEM workers, there are no data on employment for these groups. As explained below, we calculate a range in which the lower bound is based on minimal STEM workers being drawn from the L categories and none being drawn from the other visa categories (though there is likely some flow from these other groups, as there are nearly 400,000 employment-eligible visas issued each year in categories such as J-1, J-2, E-2, and O-1). As such, we can be reasonably certain that ours are conservative estimates, erring on the side of undercounting rather than overcounting the number of guestworkers available to enter the labor force.

FIGURE G

Guestworker visas issued annually, by program or visa category, 1991–2011



Note: Optional Practical Training (OPT) visa numbers for 2009, 2010, and 2011 are estimated based on the 2008 total reported by the Department of Homeland Security. The initial OPT estimates use the OPT-extension ratio to initial OPT in 2008, and the OPT-STEM extension statistics for 2007–2013 are used to estimate 2009, 2010, and 2011 initial OPT visas.

Source: Department of State (2012) and Department of Homeland Security (2008 and unpublished DHS data)

Figure G shows the annual number of visas issued to guestworkers in the relevant visa categories, i.e., the H-1B, the L, and foreign-student OPT workers. The number of workers hired in these visa categories has been growing over time. The H-1B trends reflect the booming demand during the dot-com bubble years and a congressional cap that was raised to 195,000 (it dropped to 65,000 in 2003). The H-1B numbers dropped sharply after 2001, only to rise again up until the recession of 2008. Use by employers of all of the guestworker visa programs declined following the crash of the economy in 2008, but it has been increasing since that time. In fiscal 2011, these guestworker H-1B, L, and OPT visa programs totaled 372,000 workers.

Employers of guestworkers are either IT firms or in non-IT industries but with IT occupations to fill. For the H-1B workers, about half are approved for employment in formally defined IT occupations.⁶ There are no official, detailed statistics on the occupational categories of L-1 visa holders, but a 2006 study by the Department of Homeland Security (DHS) Office of the Inspector General (OIG) concluded that the evidence suggested the L-1 visa was effectively “The Computer Visa.” The study noted that, although “the L-1 visa program is not specifically tailored for the computer or information technology (IT) industries, the positions L-1 applicants are filling are most often related to computers and IT.” In addition, “...nine of the ten firms that petitioned for the most L-1 workers were computer and IT related outsourcing firms that specialize in labor from India...[and] almost 50 percent of the L-1B (specialized knowledge) petitions...named beneficiaries...born in India.” (DHS 2006, 4) Other analysts have also concluded that the L-1 visa

is primarily used for the IT industry and IT occupations, and that the number of all L visas has been steeply increasing since the Inspector General's report in 2006. There are no publicly available data on the number of L-2 visa holders (for spouses of L-1 visa holders) who have been granted employment authorization by DHS or where they are employed. There are also no publicly available occupational or employer data on initial OPT visas (the maximum 12-month work permit provided to all college graduates on an F-1 visa), but we obtained data on the 17-month OPT-STEM extension applicants for 2008 through early 2013. Our analysis found the vast majority (77 percent) were for IT occupations and/or IT firms (the other major group is biomedical and pharmaceutical industries). Because these guestworker programs are clearly used most intensively by the IT industry and for IT occupations, we focus our analysis on the IT workforce to identify the role of guestworkers and potential workforce impacts.

The H-1B and F-1/OPT guestworker visa categories are primarily for workers with at least a bachelor's degree, though the H-1B category does permit use of experience as a degree equivalent.⁷ Except for L-1B visas granted under a "blanket" petition, which are limited to "professional" jobs and thus generally require the worker to possess a college degree, the main L-1 visa categories do not have a college degree requirement; they require only that the worker be coming to fill a managerial/executive position (L-1A) or a position requiring specialized knowledge (L-1B). However, the 2006 DHS OIG report suggested that the L visa is more likely to be used by employers to import workers with a foreign college degree of three years instead of the U.S. standard of four years, than to hire those without a college degree at all. The L-2 spousal/child visa has no education, degree, or skill requirement (but the spouse may work, unlike, say, the spouse of an H-1B visa holder). Given the wide range of educational levels in the IT workforce, there is demand for guestworkers at many different education and skill levels.

Estimating the number of annual guestworker entrants to the IT workforce

The occupational and industry data are available only for the H-1B visa petitions approved by DHS and for the OPT-STEM extension visa, though there are estimates of the industry employment of L-1 guestworkers, as discussed previously. DHS also provides detail on the H-1B population by education and age. We use these figures to develop estimates of the total number of guestworkers entering annually into the IT workforce.⁸

The only common data available for most guestworkers are the State Department's tallies of annual visas issued, but DHS releases data on employer petitions for H-1B workers. A total of 192,990 H-1B petitions were approved in fiscal 2010, of which 76,627 were for "initial employment"; the balance were for renewals. In fiscal 2011, DHS reported there were 105,395 initial employment H-1B petitions approved for which occupation was known; another 1,150 initial employment H-1B petitions were approved but occupation was not known. The State Department, which issues the actual visas, reports significantly more H-1B visas issued than there are DHS petitions. The number of visas issued in a given year may exceed the number of H-1B petitions approved by DHS because a petitioner approved in one year might not apply for, or be issued the actual visa, until the following year. We use the State Department visa statistics because the data are a reliable indicator of the number of eligible guestworkers and can be obtained for other visas. In fiscal 2011, 51,570, or 49 percent of the initial H-1B employment visas, were identified by DHS as "computer-related occupations" (DHS 2012). The percentage of H-1B guestworkers in IT has been reported as significantly greater in the past two years than the 49 percent in IT in previous years, according to industry watchers and knowledgeable experts. Moreover, the DHS statistics undercount the IT workforce because they report only the number of H-1B petitions

approved for work in IT occupations, not the number working for IT employers but in non-IT occupations. Thus, to be conservative we use the DHS estimate although there is evidence that the actual share of new H-1B guestworkers in the IT field is larger than the reported 49 percent and appears to be growing.

There are no detailed statistics on the 70,728 L-1 visas issued in fiscal 2011, but, as noted above, the OIG investigation and knowledgeable experts both estimate that a higher percentage work in the IT industry than is the case for the H-1B population (it has been suggested that the expansion of L visas is disproportionately used by the IT industry). Applying the same distribution of 49 percent as a conservative estimate (i.e., it would tend to undercount rather than overcount the number) would yield 35,280 guestworkers on L-1 visas in IT jobs (in our range estimates, we use 21,000 as the lower bound and 53,000 as the upper bound for L-1 IT guestworkers in fiscal 2011).

The L-2 visa count is 69,233 for fiscal 2010 and 76,949 for fiscal 2011 (in fiscal 2011, the number of L-2 visas was greater than the number of L-1 visas issued). We would expect a lower proportion would be in the IT industry, but since there is some correspondence between the education and occupations of L-1 visa holders and the education and occupations of their spouses and adult children (who are eligible for L-2 visas), the number of L-2 visa holders in IT would be nontrivial. Further, because the IT industry is composed of such a wide range of education levels and backgrounds, the L-2 pool could be used throughout the IT occupational range even if the person was not formally trained in IT. It has also been noted that there has been an increase in recruitment ads targeting L-2 visa holders for the IT industry. We will include 30,000 L-2 visa holders in the upper bound and 10,000 as the lower bound of this segment of the guestworker IT pool.⁹

The number of F-1/OPT guestworkers has been increasing, from approximately 70,000 in 2008 to an estimated 89,000 in 2010.¹⁰ We conducted an analysis of the occupation and industry/employers for all of the 14,499 OPT-STEM extension approved petitions in fiscal 2011. Our analysis included all those employed in an IT occupation and STEM graduates working for an IT company. We found that 77 percent, or 11,103, of OPT-STEM extension guestworkers in fiscal 2011 were in IT. To estimate the *initial* OPT IT guestworker population, we use a range of 35 percent to 65 percent of the total initial OPTs issued (it is lower than the OPT-STEM extension rate since initial OPT visas are also provided to students outside of STEM).

The combined number of annual IT guestworker entrants (of those with work visas eligible for employment) for fiscal 2011 is thus conservatively estimated to range from 134,000 to 228,500. **Table 2** shows the overall number of new guestworker visa holders and the mid-range estimates of the available IT guestworker labor force entrants. We now turn to examine the IT workforce to better understand the employment impact of this flow of guestworkers.

The crucial question is: How significant is the flow of guestworkers into the IT labor market? We first look at this flow as consisting of the pool of eligible IT workforce entrants. Ideally we would want to know how many job openings were filled by guestworkers and how many were filled from the domestic labor pool (again, the domestic labor pool comprises both citizens and permanent residents). Unfortunately, the data on job openings in the IT field are not available; the best data available to address this question measure job tenure of those in IT occupations.¹¹ We examine the number of IT workers who began their jobs in the year 2011 and were still employed in January 2012, and we compare that to the number of guestworkers who were approved for initial work in 2011. While the annual entry of guestworkers could be taking IT jobs that were opening due to turnover, as well as those newly created, we cannot ascertain these two types

TABLE 2

Annual guestworker visa issuances, estimated total and number approved for employment in IT, 2010–2011

Visa program	2010 total	For IT employment	2011 total	For IT employment
<i>H-1B</i>	117,409	57,530	129,134	63,276
<i>L-1</i>	74,719	36,612	70,728	34,657
<i>L-2</i>	69,233	17,308	76,949	19,237
<i>OPT</i>	78,000	31,200	81,206	32,482
<i>OPT-STEM extension</i>	16,739	12,554	14,499	11,103
Total	356,100	155,205	372,516	160,755

Note: OPT visa numbers for 2010 and 2011 are estimated based on the 2008 total reported by DHS. The initial OPT estimates use the OPT-extension ratio to initial OPT in 2008, and the OPT-STEM extension statistics for 2007–2013 are used to estimate 2010 and 2011 initial OPT visas.

Source: Department of State (2012) and Department of Homeland Security (2008 and unpublished DHS data)

of jobs separately. Because these are the only reliable data available on new guestworker entrants, as well as on total new IT jobs, we compare these two measures to gauge the relative supply of guestworkers in the IT sector.¹²

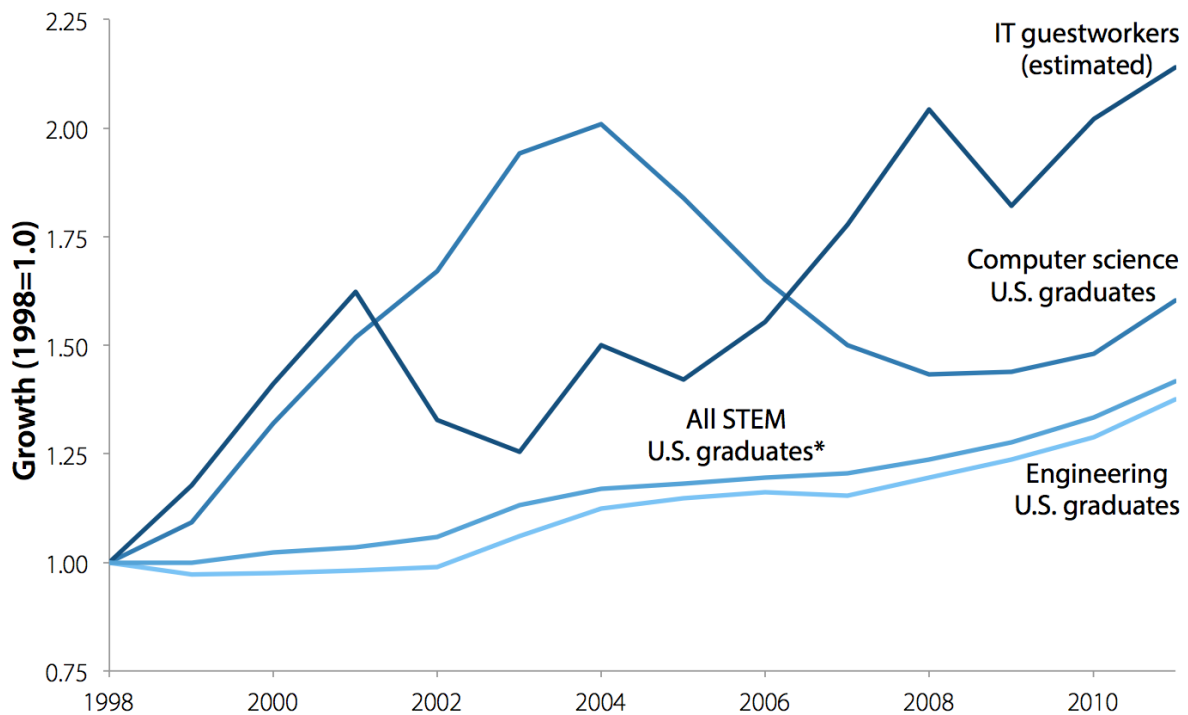
We estimate that during fiscal 2011, 372,516 high-skill guestworkers were issued visas to enter the U.S. labor market, and, of these workers, between 134,000 and 228,500 were available for IT employment. We use the mid-range estimate of 160,755 IT guestworkers for the year fiscal 2011. **Figure H** shows the growth rate in the number of new eligible guestworkers for the IT workforce and of all graduates from U.S. colleges (B.S., M.S., and Ph.D. degrees) in all “core” STEM fields (excluding social sciences), as well as growth rates of graduates in engineering and computer science (engineering and computer science are in the STEM total and shown separately). These graduates are the core segment of newly minted high-skill workers entering the labor market.

Hiring and age/education of the IT workforce

In January 2012, 698,412 workers reported that they started an IT job over the course of 2011. Our estimates of the number of potential new guestworkers in IT fields equal, at the mid-range estimate of 160,755, almost a quarter of all new hires in these occupations. However, as discussed earlier, the IT workforce comprises workers with a wide range of skills and education, while the high-skill guestworker programs are specifically designed to limit this guestworker population to those with particular skills and/or a college degree. In fact, the data on high-skill guestworkers show that nearly all have at least a bachelor’s degree. We thus examine the characteristics of the new guestworkers and jobs held by workers with similar educational backgrounds and age groups. **Table 3** shows that the population of IT workers with a college degree (bachelor’s and above) who started their jobs during 2011 is 483,692. Of these, the 160,755 guestworkers represent approximately a third of all new IT jobs (specifically, we estimate the number of guestworkers to range from a low of 28 percent to a high of 47 percent of the number of all IT jobs in 2011 that were filled by a college graduate hired in that year).

FIGURE H

Growth in numbers of new guestworkers and domestic graduates, 1998–2011



* This includes those graduating from a U.S. college with a bachelor's, master's, or Ph.D. degree who are not on an F1 visa (i.e., citizens and permanent residents) and excludes social science degrees.

Note: Optional Practical Training (OPT) visa numbers for 2009, 2010, and 2011 are estimated based on the 2008 total reported by the Department of Homeland Security. The initial OPT estimates use the OPT-extension ratio to initial OPT in 2008, and the OPT-STEM extension statistics for 2007–2013 are used to estimate 2009, 2010, and 2011 initial OPT visas.

Source: Department of State (2012) and Department of Homeland Security (2008 and unpublished DHS data)

TABLE 3

IT workers in job less than one year, by educational attainment, 2011

	All education levels	Less than bachelor's degree	Bachelor's degree	Master's or higher	Bachelor's and above
<i>Started job in the last year</i>	698,412	214,720	301,858	181,834	483,692
<i>Percent</i>	100.00%	30.70%	43.20%	26.00%	69.30%

Source: Authors' analysis of Current Population Survey Job Tenure Supplements microdata

Similar to the differences in the educational profile, the age distributions of the new guestworker population and the total population of IT workers who started their jobs within the year are dramatically different. **Table 4** shows that a third (34.3 percent) of all workers with at least a bachelor's degree who began their IT jobs in 2011 were under the age of 30; among guestworkers approved for H-1B visas for initial employment in 2011, the under-30 share was 57 percent

TABLE 4

IT workers in job less than one year, by age and educational attainment, 2011

	Bachelor's degree	Master's degree or higher	Bachelor's and above
Started job in 2011			
< 30 years old	120,329	45,564	165,893
30 + years old	181,529	136,270	317,799
All ages	301,858	181,834	483,692
Share of total			
< 30 years old	39.90%	25.10%	34.30%
30 + years old	60.10%	74.90%	65.70%
All ages	62.40%	37.60%	100%

Note: This table includes all IT workers (U.S.-born, foreign-born, and guestworkers).

Source: Authors' analysis of Current Population Survey Job Tenure Supplements microdata

(DHS 2012). An even higher share of F-1/OPT guestworkers are likely to be under the age of 30, since it is a benefit extended to recent college graduates.

A more detailed analysis of the age distributions of U.S. workers beginning their IT jobs during 2011 and H-1B guestworkers approved for initial employment shows striking differences: More than half (52 percent) of new U.S. IT hires were over the age of 35, compared with only 18 percent of H-1B new workers (Table 5).

IT employment and wage trends

A basic tenet of economic theory is that prices are determined by the interaction of market demand and supply. The long-running discussion about the STEM and IT labor markets focuses on whether wages direct workers to occupations that are in high demand, and what kind of impact policy choices concerning high-skill guestworkers might be having on this labor market. In this section we review the wage and employment trends for the IT industry and IT occupations.

Wages and unemployment rates of IT workers generally and computer programmers specifically are shown in Figure I. Beginning in the 1990s, wages and employment rose steeply to a peak during the dot-com boom. (This trend has been reviewed in recent research by Costa 2012, Lazonick 2009, and Matloff 2013 as well as by other researchers.) Through the 1990s and until 2004, we observe the expected relationship between unemployment and wages; in the 1990s unemployment was low and wages grew strongly, both signs of growing demand for IT workers. After the bursting of the dot-com bubble, a period of high unemployment was accompanied by a tapering off of IT wage growth. However, starting around 2004, a different pattern emerges. Although the recovery of the 2000s brought down unemployment and increased employment, wage growth never resumed. These flat wage rates do not appear to reflect a level of unmet demand.

TABLE 5

H-1B and U.S. IT workforce age and tenure distribution, 2011

	H-1B (ALL OCCUPATIONS)		U.S. IT WORKFORCE	
	Initial	Continuing	Started job in last year	Started job more than a year ago
Age group				
< 25	10.7%	0.6%	15.6%	2.1%
25 to 29	46.1%	27.7%	18.7%	10.2%
30 to 34	25.4%	40.8%	14.2%	13.2%
35 to 39	10.1%	19.7%	14.1%	19.2%
40 and older	7.4%	11.3%	37.4%	55.4%
Total	100.0%	100.0%	100.0%	100.0%

Source: Authors' analysis of Current Population Survey Job Tenure Supplements microdata, and Department of Homeland Security (2012)

A more detailed analysis of the IT industry has been undertaken by Lazonick (2009),¹³ who focused on four key information and communication technology areas: semiconductors (SC), software publishing (SP), computer programming (CP), and computer system design (CS), with data up to 2006. Figures J-O update the data to 2010.¹⁴

Figures J and **K** show employment and real wages, respectively, in these four IT areas for the United States as a whole. As charted in Figure J, SP, CP, and CS employment increased rapidly to 2001, dipped in the early 2000s, and then regained its peak levels of 2000–2001 by the end of the decade. SC employment also increased in the late 1990s, but in the 2000s it seems to have been in permanent decline.

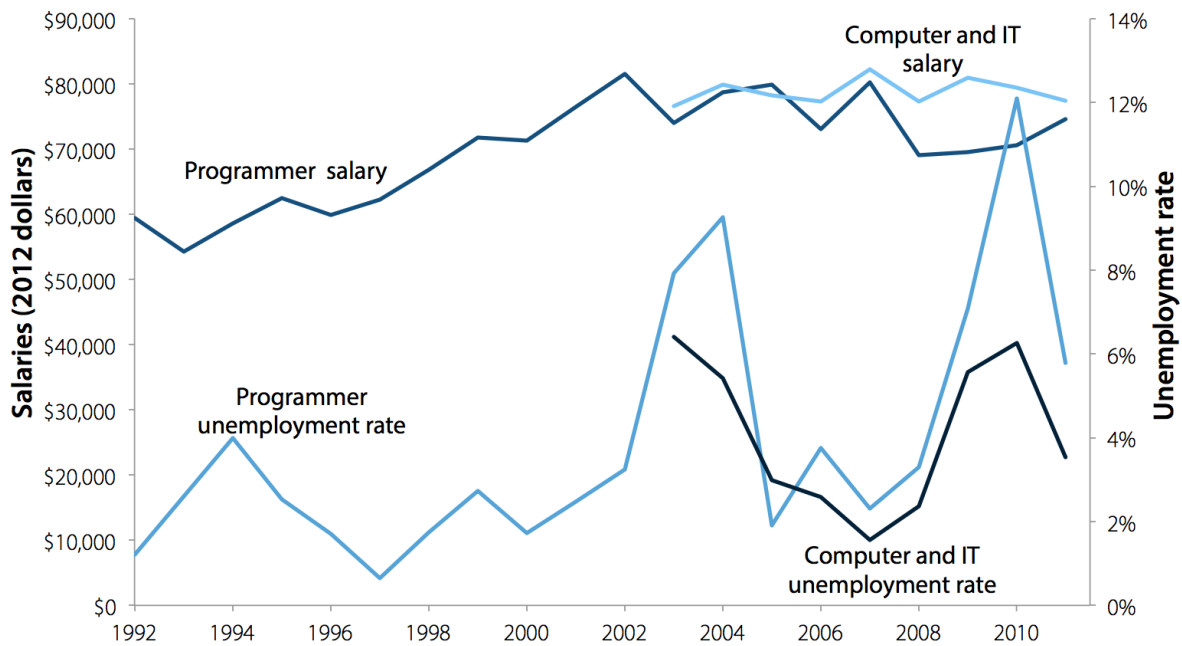
As for earnings, software publishing, which is dominated by large publishing companies that include Microsoft and Oracle, stands out as a high-wage segment (Figure K). The increase in earnings in the late 1990s culminating in the sharp spike in 2000 was largely the result of gains from the exercise of stock options. This spike was particularly pronounced in SP and SC. The movements in earnings in both SC and SP in the 2000s suggest a more moderate influence of stock-based components, but an influence nonetheless.¹⁵

Lazonick's analyses also examine the employment and wage trends in different industry segments and regions, with particular focus on the high-tech regions of Silicon Valley in California, the Route 128 corridor in Massachusetts, and the cities of Dallas and Austin in Texas (**Figures L-O**). The trends for CP and CS in each of these labor markets show similar patterns: steep increases in employment and wages during the dot-com boom, a collapse in 2001, and then gradual increases in employment accompanied by an overall stagnation in wages (with only some regional, occupation-specific, and cyclical fluctuations).¹⁶

There are important differences in trends by region and occupation. Policy discussions about the IT and guestworker labor markets tend to focus on Silicon Valley and big product companies such as Apple. But as the following figures

FIGURE I

Average salaries and unemployment rates for computer and IT occupations, 1992–2011



Note: The list of Computer and IT occupations was expanded considerably for the Current Population Survey in 2002, so that continuous data on the set of occupations currently identified as IT occupations can only go back to 2002. Some major computer and IT categories, such as "programmers," are available before 2002. Data on these workers are included to provide a longer data series for comparison purposes.

Source: Authors' analysis of Current Population Survey Annual Social and Economic Supplement microdata

show, the Silicon Valley pattern in employment and wage levels is not representative of the industry as a whole. For example, the sharp increase in computer system design employment in Silicon Valley in 2010, shown in Figure N, is primarily the result of the dramatic growth of employment at Apple in response to the success of the iPhone and the launch of the iPad.

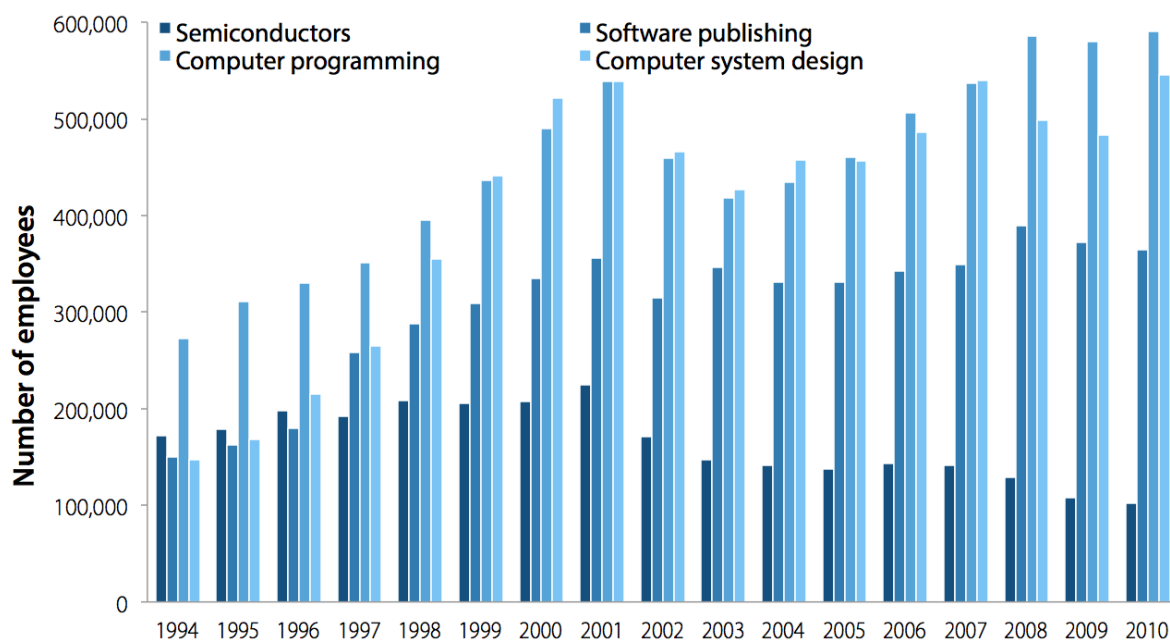
Programmer employment exhibited the strongest growth during the dot-com boom and again before the 2008 recession, but semiconductor employment experienced no recovery (Figure J). Programming is the lower-paid and generally lower-skilled of the occupations, and wages have stagnated over the past decade; in many cases they even fall below the lowest levels reached after the dot-com crash (Figure K).

Even in the dynamic technology regions of Silicon Valley, Route 128, Dallas, and Austin, the local earnings data shown in Figures M and O for workers in computer programming and computer system design reveal no signs of the rising wages that would be expected to occur if employers were hiring in a market that had a limited supply of workers.

Lazonick's (2009) wage data for critical IT labor markets reflect the earnings of IT workers at all experience levels. Another relevant wage indicator to consider in discussions of IT guestworkers is the wage of newly hired IT workers, who are directly competing for jobs with new guestworkers. Information on new hire characteristics by occupation is

FIGURE J

Employment in semiconductor, software publishing, computer programming, and computer system design, 1994–2010



Source: Lazonick (2009), updated by Lazonick using U.S. Census Bureau County Business Patterns data and provided to the authors

not readily available, but new hire earnings by industry are available in the Census Bureau’s Quarterly Workforce Indicators (derived from a longitudinal dataset matching households and firms). Although most industries employ workers in IT occupations, these workers are highly concentrated in the professional, scientific, and technical services industry. In **Figure P**, we examine the earnings of new hires in this industry for the five metropolitan areas identified by Ruiz, Wilson, and Choudhury (2012) as having the highest intensity of H-1B applications (i.e., the highest number of H-1B applications relative to the size of the local workforce). The wage pattern is similar to the patterns shown in Lazonick’s (2009) tables for all IT workers, namely flat earnings, with the exception of Silicon Valley (San Jose-Sunnyvale-Santa Clara), which showed some earnings increases immediately before the crash of 2008.

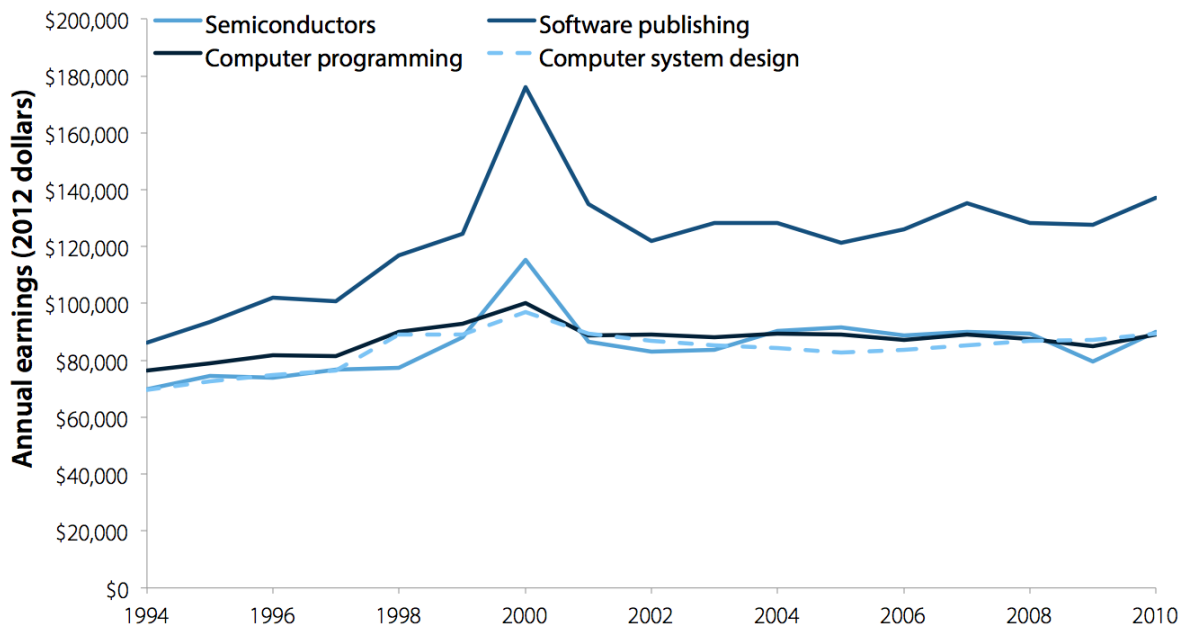
Do economic fundamentals still apply to IT workers?

The trends in the supply and demand characteristics of the STEM labor force, particularly the IT labor market and guestworkers flowing into it, are consistent and clear, even if the interpretation and implications for enacting policy are less obvious.

The flow of students into STEM fields, and the overall education performance of this student population, is consistently strong. Twice as many students in STEM majors graduate from U.S. universities every year than the number that are able to find a job in a STEM occupation. Even in computer and information science and engineering, the college graduate supply is 50 percent greater than the number hired into those fields each year.

FIGURE K

Average annual earnings of U.S. employees in semiconductors, software publishing, computer programming, and computer system design, 1994–2010



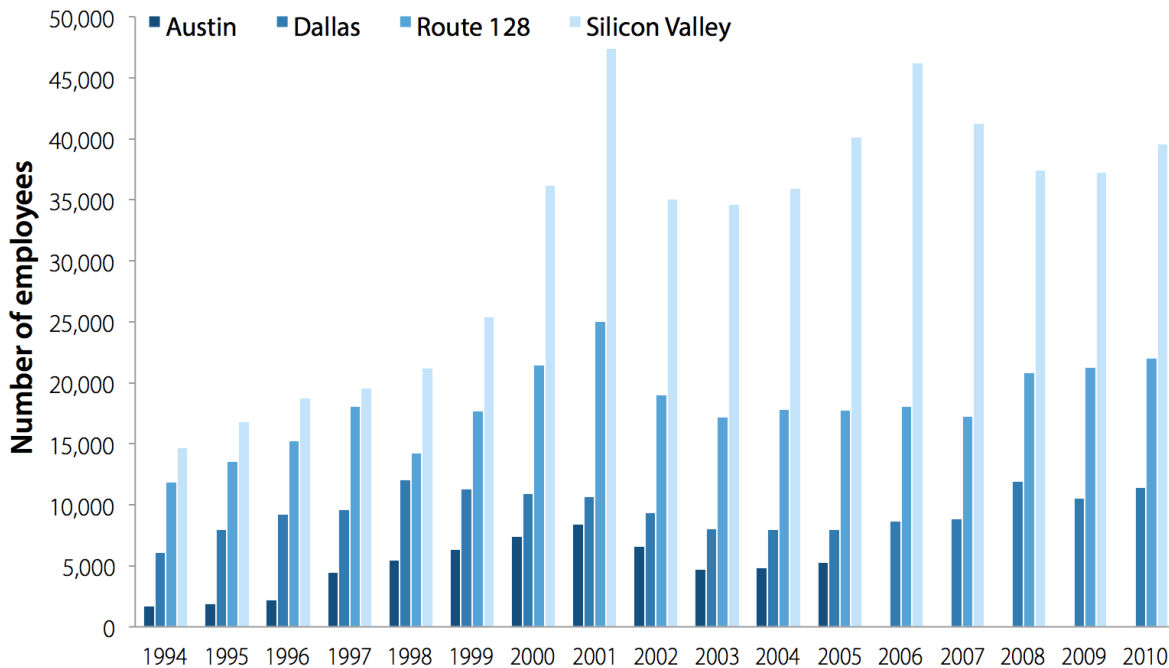
Source: Lazonick (2009), updated by Lazonick using U.S. Census Bureau County Business Patterns data and provided to the authors

Nevertheless, many policy groups and the IT industry in particular claim that it is difficult to find a sufficient supply of domestic workers. Although prior research shows that the college graduate market in general, including STEM fields, does respond to market demand (albeit with a lag, given the time it takes to complete a degree; see Freeman 1976 and Stephan 2012), some claim that the current STEM market does not work as it once did. Advocates of this position argue that because of barriers in preparation, interest, or motivation, students are either unable or unwilling to enter the STEM fields, even when levels of demand are high. The implication is that, for some reason, the IT and engineering labor markets are unresponsive to the usual wage signals, and that the standard market tool of increased wages to obtain the supply of workers needed has been unsuccessful. It then becomes the role of Congress to enact policy changes that can increase the supply of workers through targeted guestworker programs.

In our research and reviews of existing research, we have indeed seen cases where labor market signals suggested that hiring demand outpaced the available supply of workers. From the mid/late-1990s through 2001–2002, there was a sharp increase in demand for IT workers, and salaries rose steeply, climbing 22 percent in the four years from 1998 to 2002. In response, the number of domestic computer science graduates rose dramatically, doubling from 1998 to its peak in 2003–2004 (see **Figure Q**; the peak in graduates will lag the market—about two to three years for B.S. and M.S. graduates and one to two years for A.A., or associate in arts, graduates—because students make their major choices two to three years before graduation and have limited flexibility in quickly changing their degrees). Since that time wages have stagnated, and the number of computer science graduates has fallen from its dot-com bubble peak.

FIGURE L

Full-time computer programming employment in Austin, Dallas, Route 128 corridor, and Silicon Valley, 1994–2010



Note: The Austin series data are only available until 2005 because the County Business Pattern (CBP) data are suppressed for counties/zipcodes in which the dominance of one firm would make it possible to identify the firm whose data is being presented.

Source: Lazonick (2009), updated by Lazonick using U.S. Census Bureau County Business Patterns data and provided to the authors

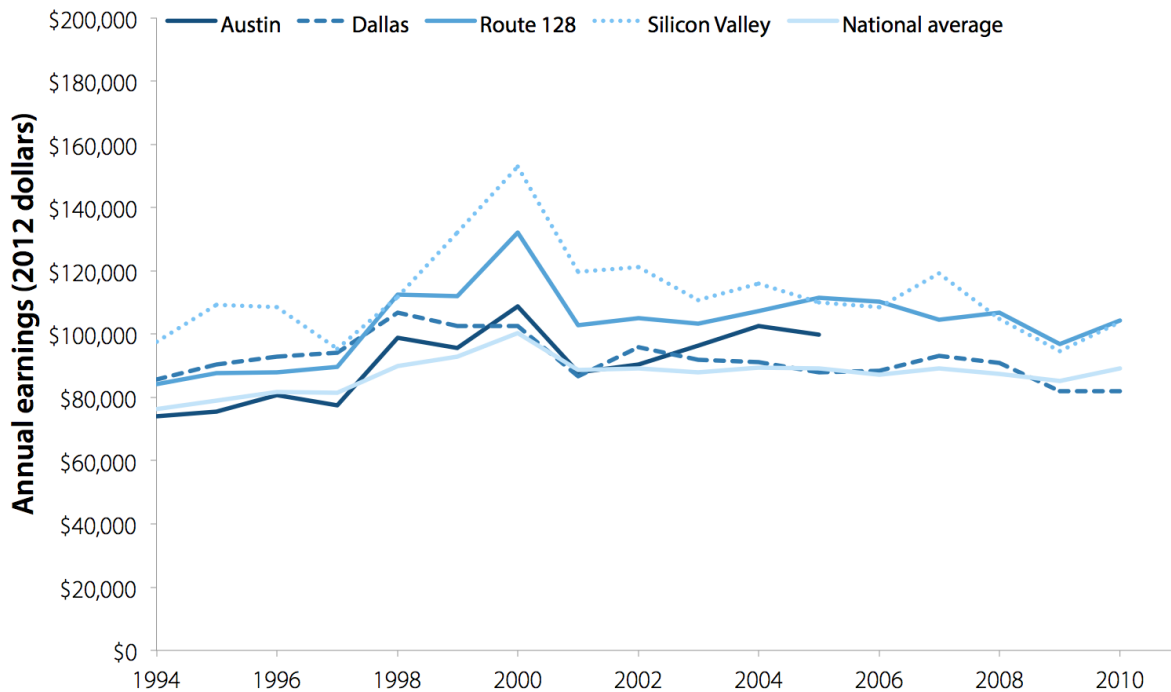
All the evidence indicates a highly responsive labor market during this period, of increasing wages leading to increasing numbers of graduates, and then a decline in wages followed by a decline in numbers of graduates.

A second case we have examined in detail is that of petroleum engineers (Lynn, Salzman, and Kuehn 2011). The case of petroleum engineers serves as a “natural experiment” about labor market dynamics. For a range of reasons (from an aging workforce to increased exploration following several decades of low domestic hiring rates), there was a sharp increase in industry demand in the mid-2000s. The result was a sharp increase in wages offered to new graduates—wages rose 71 percent over five years—and the response was a more than doubling of graduates over the same period. Most interesting is that petroleum engineering had one of the highest proportions of foreign students (at the undergraduate level), yet nearly all of the increase in supply came from the domestic pool of students (domestic students include the native-born, foreign-born citizens, and permanent residents; foreign students are those on temporary F-1 student visas).

Over the decade after the bursting of the dot-com bubble, neither the number of bachelor’s degree computer science graduates nor their wage levels have reached their previous heights. In fact, overall employment, even after the recovery of the IT industry, has stayed well below its peak of 2002–2003. Although the overall number of computer science

FIGURE M

Average annual earnings of full-time computer programming employees in Austin, Dallas, Route 128 corridor, and Silicon Valley, 1994–2010



Note: The Austin series data are only available until 2005 because the County Business Pattern (CBP) data are suppressed for counties/zipcodes in which the dominance of one firm would make it possible to identify the firm whose data is being presented.

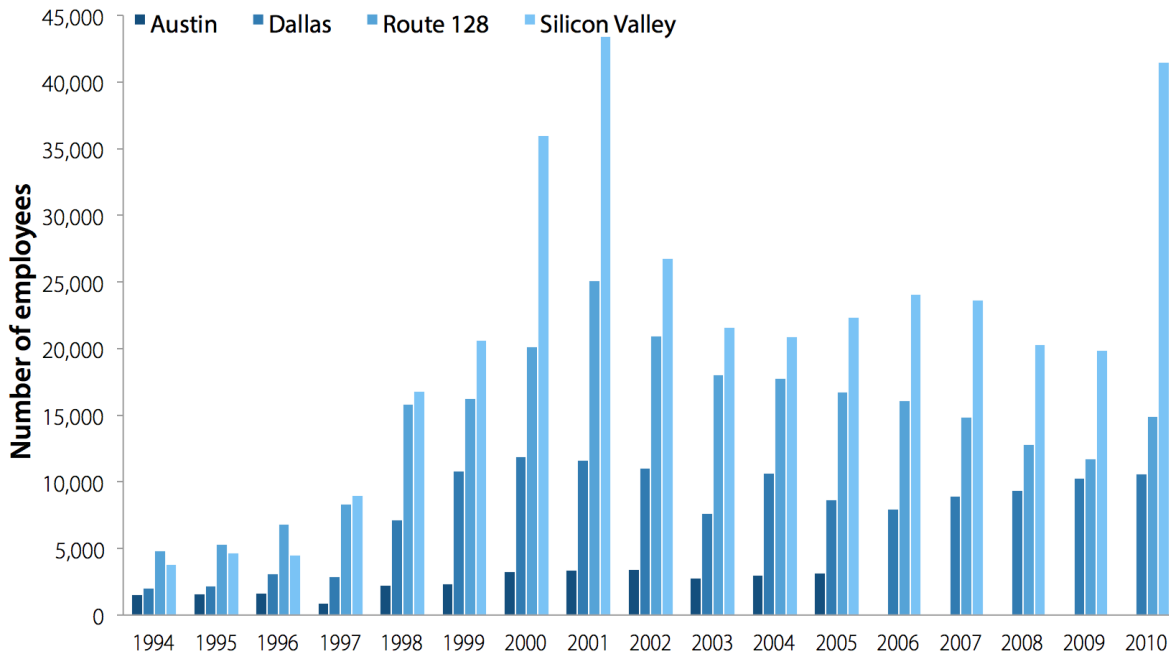
Source: Lazonick (2009), updated by Lazonick using U.S. Census Bureau County Business Patterns data and provided to the authors

graduates has declined since its peak during the dot-com boom, U.S. colleges still graduate 50 percent more each year than enter IT jobs. As noted previously, for those computer science graduates employed but not entering the IT field, about half say they found other occupations to provide better pay and/or working conditions, and roughly a third said there were no IT jobs available. These survey results of students employed one year after graduation are consistent with the findings from field work conducted over the past decade on changes in IT and engineering labor markets (e.g., Lynn and Salzman 2007, 2009, 2010; Salzman and Biswas 2000). Moreover, three-quarters of the IT labor market is composed of workers with degrees other than computer science or without a college degree at all, suggesting that there is a very large domestic pool of potential workers available for the IT industry.

Wage trends over this period are the most striking finding of our analysis and review. As would be expected during a period of high demand for labor, wages increased during the dot-com boom. However, following the crash of 2001, wages declined and have been essentially flat for the decade. As Lazonick (2009) found, in some metropolitan areas employing a high number of IT workers, wages actually declined over this period, falling to late-1990s levels. There is some variation by sector and region (see Figures J–O) but, other than some localized and short-term changes, the overall trends have been fairly consistent throughout the past 10 years. Wage levels remain constant throughout the decade,

FIGURE N

Full-time computer system design employment in Austin, Dallas, Route 128 corridor, and Silicon Valley, 1994–2010



Note: The Austin series data are only available until 2005 because the County Business Pattern (CBP) data are suppressed for counties/zipcodes in which the dominance of one firm would make it possible to identify the firm whose data is being presented.

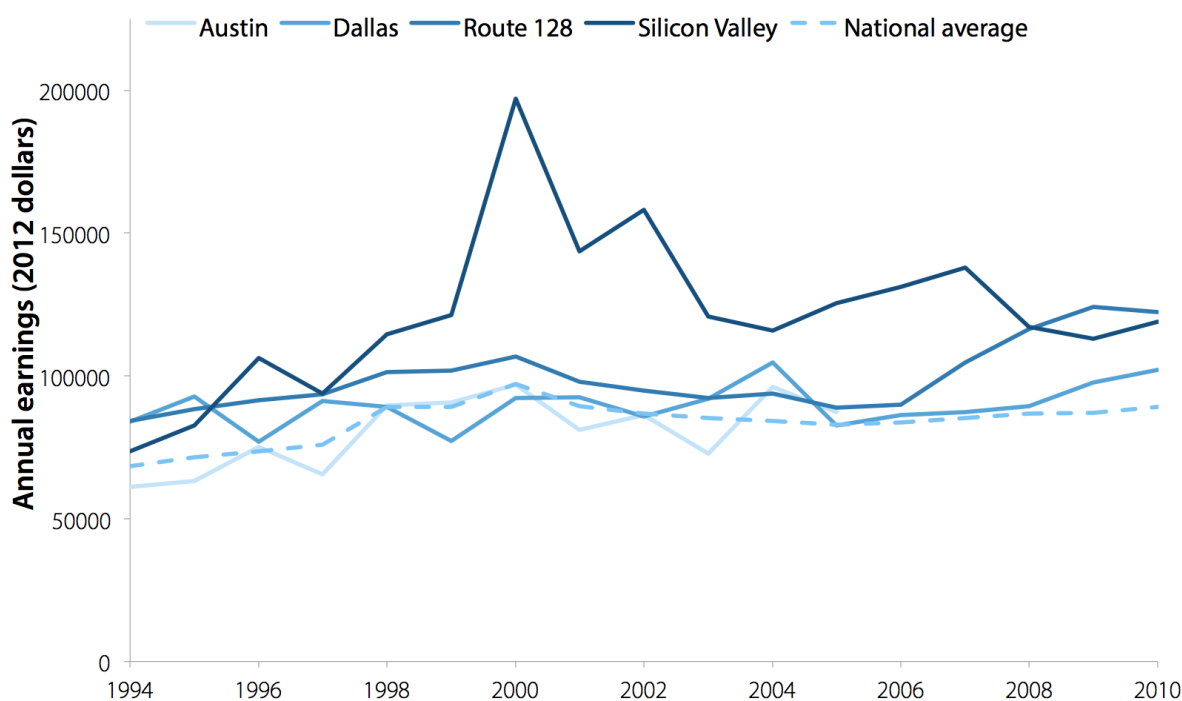
Source: Lazonick (2009), updated by Lazonick using U.S. Census Bureau County Business Patterns data and provided to the authors

declining slightly during periods of high unemployment and never increasing beyond their level of the early 2000s and sometimes sinking as low as the levels of the late 1990s.

The only secular increase, interrupted briefly by the bursting of the dot-com bubble, and even more briefly after the economic collapse of 2008, is in the number of new guestworkers each year (**Figure R**). This increase appears to be limited only by changes in visa policies related to guestworkers in STEM occupations over the years (note the fluctuations in the number of visas issued, illustrated in Figure G), and appears unaffected by changes in the prevailing wage levels in the industry. These trends stand in sharp contrast to those of the domestic supply of STEM students and workers, which appears to be highly responsive to changes in wage levels. Guestworkers appear to make up a significant portion of the IT labor market; as detailed previously, in our estimates they equal between one-third to half of the number of all new IT job holders.

FIGURE O

Average annual earnings of full-time computer system design employees in Austin, Dallas, Route 128 corridor, and Silicon Valley, 1994–2010



Note: The Austin series data are only available until 2005 because the County Business Pattern (CBP) data are suppressed for counties/zipcodes in which the dominance of one firm would make it possible to identify the firm whose data is being presented.

Source: Lazonick (2009), updated by Lazonick using U.S. Census Bureau County Business Patterns data and provided to the authors

Conclusion

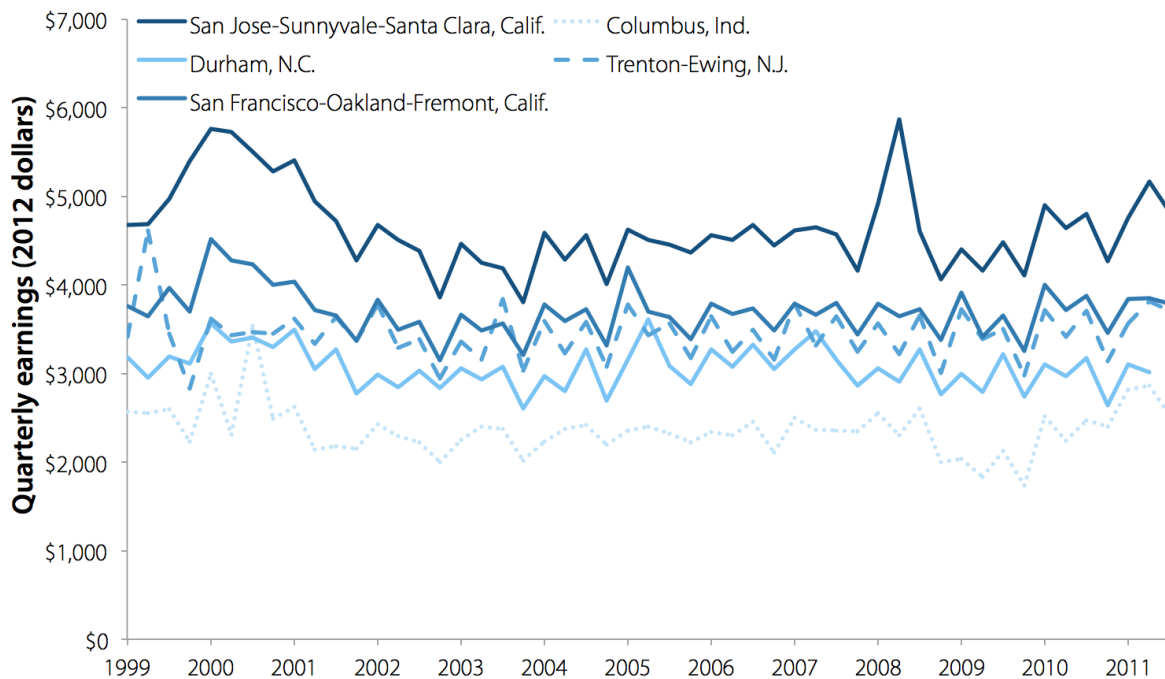
This paper has reviewed and analyzed trends in the STEM labor market and workforce and the supply of foreign high-skill guestworkers. This analysis addresses three central issues in the ongoing discussion about the demand for high-skill guestworkers and the impact of market forces on the information technology (IT) workforce in the United States:

- Is there a problem in developing STEM-educated students in sufficient numbers and performance levels to supply the labor market?
- How large is the flow of guestworkers into the STEM workforce and into the IT workforce in particular? And what are the characteristics of these guestworkers?
- What are the dynamics of the STEM labor market, and what are the employment and wage trends in the IT labor market?

The analyses of these issues provide the basis for assessing the extent of demand for IT workers and the impact of guest-worker flows on the STEM and IT workforces.

FIGURE P

Average quarterly earnings for new hires in professional, scientific, and technical services in H-1B intensive metropolitan areas, 1999–2011



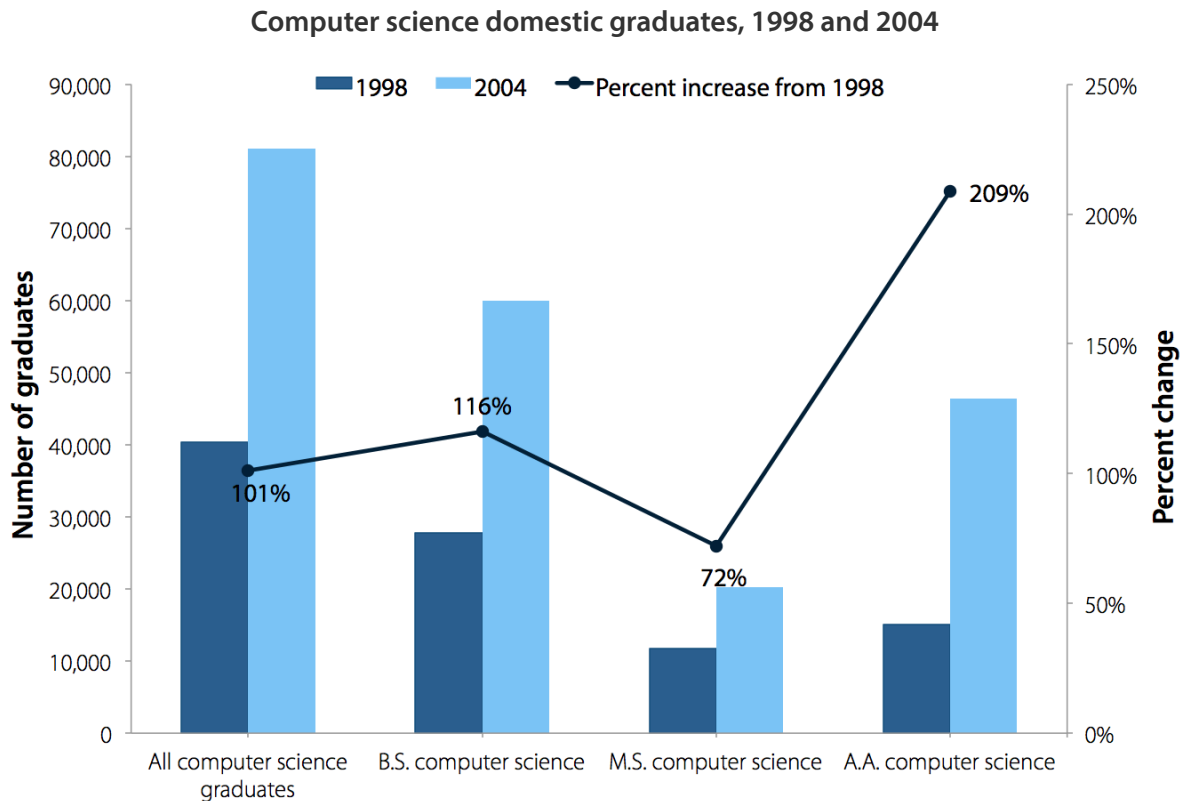
Source: U.S. Census Bureau, Quarterly Workforce Indicators (metropolitan areas)

Our review and analysis of the best available evidence indicates that the supply of STEM-potential and STEM-educated students has remained strong and appears to be quite responsive to standard economic signals of wage levels and unemployment rates. In the meantime, the flow of guestworkers has been substantial and targeted to one specific segment of the overall STEM labor market, namely IT occupations and industries. There are multiple routes into the IT labor force provided by high-skill immigration policy, from work permits to student visas to a range of nonimmigrant work visas, but these multiple routes of entry for high-skill guestworkers are not adequately tracked in immigration or labor force statistics. Moreover, policy analyses do not account for the wide range of visa and work permits, and thus do not account for the extent of available supply of guestworkers for the STEM workforce.

The IT industry was able to attract increasing numbers of domestic graduates during periods of rising wages and employment, leading to a peak in wages and numbers of computer science graduates in the early 2000s. Since that time, the IT industry appears to be functioning with two distinct market patterns: a domestic supply (of workers and students) that responds to wage signals (and other aspects of working conditions such as future career prospects), and a guestworker supply that appears to be abundantly available even in times of relatively weak demand and even when wages decline or are stagnant.

Workers from countries with low wages and limited career opportunities will find the U.S. IT labor market attractive even when wages are too low and career opportunities too limited to increase the IT supply from domestic students and workers. In other words, the data suggest that current U.S. immigration policies that facilitate large flows of guestwork-

FIGURE Q



Source: Authors' analysis of National Center for Education Statistics, Higher Education, General Information Survey and Integrated Postsecondary Education Data System

ers appear to provide firms with access to labor that will be in plentiful supply at wages that are too low to induce a significantly increased supply from the domestic workforce.

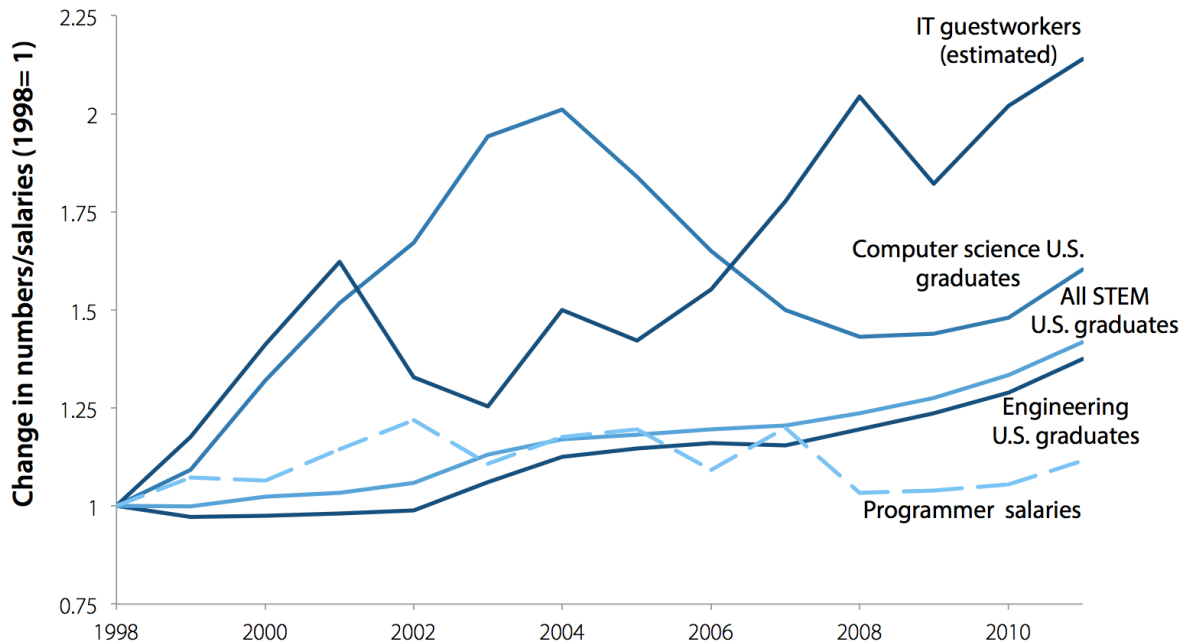
Appendix

Colleges as a route to increasing the guestworker supply

One of the major provisions in the various high-skill immigration bills currently being proposed would grant permanent residency (green cards) to foreign students on F-1 visas who graduate with a STEM degree. There has been no comprehensive assessment of the potential impact this provision would have on colleges, students, or the workforce. The analysis in this paper indicates that such a provision does not appear to be a response to a shortfall in domestic STEM student supply. The green-cards-for-STEM-graduates provision would further expand the available STEM labor pool, and because obtaining permanent residence would be dependent on obtaining a STEM job after graduation, it is likely to provide an available workforce that is highly constrained in its labor market mobility. As discussed previously (see Figure D), about a third of computer science and engineering graduates enter non-STEM jobs a year after graduation, as do more than 60 percent of physical science, biology, and math graduates. Computer science graduates move to non-STEM jobs because (for about half) they expect to find better jobs or (for roughly a third) they are unable to find jobs in the IT industry. Increasing a supply of graduates who are constrained in employment options to accept whatever job

FIGURE R

Change in programmer salaries and in numbers of U.S. STEM-related graduates and IT guestworkers, 1998–2011



Note: Optional Practical Training (OPT) visa numbers for 2009, 2010, and 2011 are estimated based on the 2008 total reported by the Department of Homeland Security. The initial OPT estimates use the OPT-extension ratio to initial OPT in 2008, and the OPT-STEM extension statistics for 2007–2013 are used to estimate 2009, 2010, and 2011 initial OPT visas.

Source: Department of State (2012) and Department of Homeland Security (2008 and unpublished DHS data)

is available in those fields is likely to have a dramatic impact on that labor market (see, for example, Teitelbaum 2008 for an analysis of the impact of increased numbers of graduates in the life sciences; see also Stephan 2012).

The other impact of the provision, less often discussed, would be on the colleges. Making a U.S. STEM degree the route to permanent residency can be expected to increase the number of foreign students seeking admission to U.S. colleges. A similar, if more limited program that is already in place is the Optional Practical Training (OPT) program, particularly the OPT extension of 17 months for STEM graduates on top of the base OPT period of 12 months. Programs such as the OPT are lauded as a way to ensure that the large population of foreign students on F-1 visas are available for employment in the U.S. economy rather than leaving to work and contribute to the economies of their home countries. Given the large population of students on F-1 visas that could be hired as guestworkers through the OPT program, it is worth considering whether the OPT population is comparable to the H-1B or L-1 population (discussed previously), or whether it represents guestworkers with substantially different backgrounds.

The OPT population appears to come largely from colleges with high foreign student enrollments as a proportion of their overall program enrollments. Characteristics of the top 10 OPT-granting universities are presented in **Table A1**. These 10 institutions represent more than 20 percent of all OPT issuances in 2011 and 2012. Nearly all OPT awardees from Stratford University (the college with the greatest cumulative number of graduates on an OPT extension) and Sil-

TABLE A 1

Top 10 Optional Practical Training-STEM extension awardees for fiscal 2012

	OPT awards (fiscal 2012)	Cumulative OPT awards through fiscal 2012	IT and computer science share of OPTs (fiscal 2012)	IT and computer science completions (2010–2011)
<i>Silicon Valley University</i>	181	546	95.6%	N/A
<i>University of Bridgeport</i>	160	1,378	16.9%	62
<i>Lamar University</i>	124	452	2.4%	16
<i>Texas A&M University-Kingsville</i>	114	492	33.3%	7
<i>Northwestern Polytechnic University</i>	110	704	48.2%	118
<i>University of Houston-Clear Lake</i>	109	321	56.9%	188
<i>Stratford University</i>	107	1,834	95.3%	343
<i>San Jose State University</i>	106	674	34.9%	357
<i>Illinois Institute of Technology</i>	102	781	48.0%	299
<i>International Technological University</i>	95	412	36.8%	155

Note: IT and computer science completions include all computer science majors and all computer software engineering majors. Discrepancies between IT and computer science completions and IT and computer science OPTs may result from differential reporting to different agencies for different major categories (for example, reporting "software engineering," which is counted here simply as "engineering").

Source: Authors' analysis of Optional Practical Training (OPT) application data, and National Center for Education Statistics, Higher Education, General Information Survey and Integrated Postsecondary Education Data System

icon Valley University (the college with the greatest number of graduates on an OPT extension in fiscal 2012) were IT or computer science majors. OPT extensions from the other top OPT-granting institutions also tend to have large shares of IT and computer science majors relative to the total OPT population, although students from these institutions have more diverse educational backgrounds than the graduates of Stratford University and Silicon Valley University.

The institutions with some of the highest ratios of OPT-STEM extension awards to enrollments (Stratford University, University of Bridgeport, and Northwestern Polytechnic University) were found by a 2011 *Chronicle of Higher Education* investigation to target foreign students as the primary population for their programs (Bartlett, Fischer, and Keller 2011). These colleges specialize in acquiring student visas and (for students with F-1 visas) OPT employment authorization for their students. In addition to tuition, students are often charged up to \$3,000 in fees for obtaining the work authorization. At some universities, such as Tri-Valley University in California, the authors of the *Chronicle* study report

that students do not even attend classes; the business model was “selling permission to live and work in the United States on student visas.” Institutions specializing in acquiring OPT employment authorization for their students that do not act as egregiously as Tri-Valley University still keep their instructional expenses down with substantial reliance on online education, or they hold classes only occasionally throughout the semester.

These questions about the OPT and OPT-STEM extension suggest more in-depth research should be conducted on the impact of expanding this type of program, especially since the change not only would expand the numbers of guest-workers but, by granting permanent residency, would also increase the incentives for foreign students to enroll in U.S. colleges and for colleges to expand their programs. The potential impacts of OPT on the labor market, and any proposed changes in entry paths of foreign STEM graduates, should also be studied because the changes would further expand the size of the entry-level labor pool in IT.

Abuses have been found in some college programs responding to high foreign-student demand for entry into the U.S. IT labor market. These colleges also appear to be serving the labor demand of some firms that hire students without even minimal college-level education and without much, if any, apparent IT experience or background. In other segments of the college market, even in well-established schools, there appears to be extensive use of the OPT extension (suggesting that there are students who are unable to find regular employment even a year after graduating), and programs are expanding by targeting foreign student enrollments. Providing permanent residency for STEM graduates could have quite significant impacts on the education system as well as the labor market. Further analysis of the OPT programs would provide a better understanding of those potential impacts.

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Endnotes

1. The best available estimate of the STEM workforce is from the NSF Science and Engineering Indicators, using Bureau of Labor Statistics (BLS) data and occupational definitions for 2009 (see table 3-3 of the NSF Science and Engineering Indicators report, 2012). The total labor force size is based on average monthly employment levels (seasonally adjusted) for 2009 according to the BLS's Current Employment Statistics data. It should also be noted that estimates of the STEM workforce can vary depending on which occupations are counted as "STEM."
2. Most STEM definitions do not include health fields because workers in these fields are considered to have practitioner or professional degrees rather than science degrees. Although this exclusion of health practitioners is consistent with definitions of "science" to denote the development rather than the practice of scientific knowledge, when used in analyses of the extent of science education, the exclusion becomes an artifact of this classification rather than an accurate reflection of students obtaining a "science education." In a brief review of the required curricula for health majors and biology majors, we found no significant differences between health and life science curricula (e.g., physiology is substituted for organic chemistry for biology majors, but the same or even more science course credits are required for health majors). Moreover, if some portion of biology and life science enrollments reflect the lack of a health major in some colleges, the analytic distinction between these courses of study becomes arbitrary. In the labor market, distinctions can be made by occupation and industry.
3. These survey results of students employed one year after graduation are consistent with the findings from field work conducted over the past decade on changes in IT and engineering labor markets (e.g., Lynn and Salzman 2007, 2009, 2010; and Salzman and Biswas 2000).
4. Tabulations of the American Community Survey tables (2005–2009 American Community Survey five-year data, U.S. Department of Commerce, U.S. Census Bureau; table source: Employment Projections program, U.S. Department of Labor, U.S. Bureau of Labor Statistics; http://www.bls.gov/emp/ep_table_111.htm) and tabulation of the National Science Foundation SESTAT Integrated Survey Data, 2008 (SESTAT PUBLIC 2008, <https://sestat.nsf.gov/sestat/sestat.html>). The education level of the IT workforce shows only a slight change in the past decade: 40 percent of the IT workforce in 1999 did not have a four-year degree (see Lerman, Riegg, and Salzman 2001).
5. The government's rationale for the 17-month extension was to "reduce some of the hardship imposed by the H-1B visa cap." At the time the extension was created, the H-1B cap for the fiscal year was reached quickly, and the OPT program was intended to allow employers to keep STEM graduates employed in the country while they waited for an H-1B visa to become available (Thibodeau 2008).
6. The IT occupations are those classified by the Bureau of Labor Statistics; some analyses classify workers based on the business of their employer, whether or not they hold a formal IT occupation. This leads to some inconsistency in estimates of "IT workers." In general, occupational analyses include only IT occupations, and the industry analyses use all workers in IT firms. Our guestworker analysis examines both occupation and industry, as noted in the figures.
7. See Immigration and Nationality Act, Section 214(i); 8 USC 1184(i).
8. We use the term "guestworker labor pool" to denote the group of people who are newly eligible entrants; they are part of the flow rather than the stock of workers. The only data available are the number of visas issued in a given year, and some of those visa holders may not start work in the year the visa is issued; however, there are also new workforce entrants issued visas in prior years, minimizing any net differences. Our estimates are broad enough to be minimally affected by any net differences, and labor markets, particularly wages, are largely affected by the size of the pool of available workers rather than by the number actually employed. Thus, the size of the pool, even if larger than the actual number of new labor force entrants, is as important as the actual flow of workers entering the labor force.

9. As noted above, we are not including estimates of guestworkers drawn from the several other employment visas or spousal employment visas—totaling nearly 400,000 employment-eligible visas issued in fiscal 2011—but presumably some number of these visa holders are also entering the IT industry; the L-2 visa holders are included because observers have noted that IT recruiters are specifically advertising for L-2 visa holders.
10. Initial OPT data are not routinely provided, and we have not identified a single source for series data; only the OPT-STEM extension data were obtained (released to a third party via the Freedom of Information Act). OPT data are listed in other sources, such as the 2008 DHS Interim Final Rule establishing the 17-month STEM OPT extension (“Extending Period of Optional Practical Training by 17 Months for F-1 Nonimmigrant Students With STEM Degrees and Expanding Cap-Gap Relief for All F-1 Students With Pending H-1B Petitions,” 73 F.R. 18944, 18950, April 8, 2008); “Currently, DHS estimates, through data collected by SEVP’s Student and Visitor Exchange Information System (SEVIS), that there are approximately 70,000 F-1 students on OPT in the United States. About one-third have earned a degree in a STEM field.” The regulation is available at <http://www.gpo.gov/fdsys/pkg/FR-2008-04-08/pdf/E8-7427.pdf>.
11. Jobs that started in the last year are a reasonable proxy for new hires in the absence of new hire data. Job tenure information is taken from the January 2012 Current Population Survey’s “Job Tenure” supplement, and should therefore serve as a reasonable proxy for jobs started in 2011 (data are available on new hires and job openings by industry, but not occupation; these data will be reviewed below).
12. An alternative measure would be to divide the annual change in the population of temporary workers by the annual change in the total workforce. But we cannot do that here because the only estimates available at this time are the annual entry numbers. An estimate based on employment change for H-1Bs was conducted for the late 1990s, and it found that the H-1B visa averaged 20 percent of total employment growth during that decade. During the peak years of H-1B entries, however, growth in the H-1B workforce was over half of total IT employment growth (Lowell 2001, 131–162).
13. See Lazonick (2009, 18–20, 57–66). Lazonick uses U.S. Census Bureau County Business Patterns data to chart employment and real wages by industrial classification by state and zip code from 1994. The latest available data are for 2010 (<http://censtats.census.gov/cbpnaic/cbpnaic.shtml>).
14. SIC classifications for 1994–1997 and NAICS classifications for 1998–2010:
- Semiconductor and related devices, SIC 3674, NAICS 334413
 - Software publishing: SIC 7372, NAICS 511610 and 334611
 - Computer programming services SIC 7371, NAICS 541511
 - Computer system design SIC 7373 plus half of 7379, NAICS 54152
15. Using data from Microsoft’s 10-K reports, Lazonick has calculated that in 2000, across about 39,000 people employed by Microsoft worldwide, the average gains from exercising stock options were almost \$450,000. Other data provided by Lazonick to the authors show that in the last part of the 2000s, however, average earnings in Washington State fell to the level of those in Silicon Valley. While still representing relatively high levels of earnings, the contribution of stock-based compensation to these earnings was much less pronounced. See Lazonick (2009, 61–66) for further analysis and discussion of the use of stock-based compensation in these segments of the IT industry, and more generally on the financial strategies of firms in the new economy.
16. These figures, with data through 2006, appear in Lazonick (2009); the figures included here are updated and graciously provided to the authors by William Lazonick.

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