Metropolitan Policy Program
at BROOKINGS

The Hidden STEM Economy

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> "The excessively professional definition of STEM jobs has led to missed opportunities to identify and support valuable training and career development."

Findings

Workers in STEM (science, technology, engineering, and math) fields play a direct role in driving economic growth. Yet, because of how the STEM economy has been defined, policymakers have mainly focused on supporting workers with at least a bachelor's (BA) degree, overlooking a strong potential workforce of those with less than a BA. An analysis of the occupational requirements for STEM knowledge finds that:

- **As of 2011, 26 million U.S. jobs—20 percent of all jobs—require a high level of knowledge in any one STEM field.** STEM jobs have doubled as a share of all jobs since the Industrial Revolution, from less than 10 percent in 1850 to 20 percent in 2010.

- **Half of all STEM jobs are available to workers without a four-year college degree, and these jobs pay $53,000 on average—a wage 10 percent higher than jobs with similar educational requirements.** Half of all STEM jobs are in manufacturing, health care, or construction industries. Installation, maintenance, and repair occupations constitute 12 percent of all STEM jobs, one of the largest occupational categories. Other blue-collar or technical jobs in fields such as construction and production also frequently demand STEM knowledge.

- **STEM jobs that require at least a bachelor's degree are highly clustered in certain metropolitan areas, while sub-bachelor's STEM jobs are prevalent in every large metropolitan area.** Of large metro areas, San Jose, CA, and Washington, D.C., have the most STEM-based economies, but Baton Rouge, LA, Birmingham, AL, and Wichita, KS, have among the largest share of STEM jobs in fields that do not require four-year college degrees. These sub-bachelor's STEM jobs pay relatively high wages in every large metropolitan area.

- **More STEM-oriented metropolitan economies perform strongly on a wide variety of economic indicators, from innovation to employment.** Job growth, employment rates, patenting, wages, and exports are all higher in more STEM-based economies. The presence of sub-bachelor's degree STEM workers helps boost innovation measures one-fourth to one-half as much as bachelor's degree STEM workers, holding other factors constant. Concentrations of these jobs are also associated with less income inequality.

This report presents a new and more rigorous way to define STEM occupations, and in doing so presents a new portrait of the STEM economy. Of the $4.3 billion spent annually by the federal government on STEM education and training, only one-fifth goes towards supporting sub-bachelor's level training, while twice as much supports bachelor's or higher level-STEM careers. The vast majority of National Science Foundation spending ignores community colleges. In fact, STEM knowledge offers attractive wage and job opportunities to many workers with a post-secondary certificate or associate's degree. Policy makers and leaders can do more to foster a broader absorption of STEM knowledge to the U.S workforce and its regional economies.

Introduction

"There must be a stream of new scientific knowledge to turn the wheels of private and public enterprise. There must be plenty of men and women trained in science and technology for upon them depend both the creation of new knowledge and its application to practical purposes."

—Vannevar Bush, 1945[1]

Innovation—primarily through the invention, development, and profusion of new technologies—is the fundamental source of economic progress, and inventive activity is strongly associated with economic growth in metropolitan areas and nationally.[2] Technological innovation, in turn, usually requires the expertise of specialists with knowledge in fields of science, technology, engineering, and mathematics (STEM).

The notion that scientific and technical knowledge are important to American living standards is embodied in the Constitution, which explicitly gave Congress the power to "promote the progress of science and useful arts" by granting patents to inventors. The federal government's explicit commitment to provide funding to enhance the STEM labor supply and promote research can be traced to Vannevar Bush, who helped initiate the National Science Foundation (NSF) with his 1945 report to President Roosevelt. Since then, reports from the NSF have emphasized the need for STEM education.[3]

More recently, national leaders from both major political parties have acknowledged the importance of STEM education. In 2006, President George W. Bush launched the American Competitiveness Initiative to improve STEM education and increase the supply of working scientists.[4] Likewise, President Obama frequently mentions the importance of STEM education in his speeches. He also created the "Educate to Innovate" campaign to boost STEM education, and signed into law a reauthorization of the Bush-era America Competes Act, which embodies many of the same goals as the Bush administration's STEM priorities. During the 2012 campaign, both President Obama and his Republican challenger, Mitt Romney, proposed policies to increase the supply of STEM workers, and the Obama administration's latest budget has a number of initiatives designed to meet that goal, related largely to improving the quality of K-12 STEM education.[5]

STEM has attracted attention not only in policy spheres, but also in the research arena. Notable reports from the NSF, the U.S. Department of Commerce, and Georgetown University's Center on Education and the Workforce have documented significant labor market advantages for those employed in STEM fields, including relatively high wages, lower unemployment rates, and growing job opportunities.[6] Academic research on the whole supports the notion that STEM knowledge is highly rewarded, at least in engineering and computer fields.[7] Yet some scholars doubt the claim that there is a shortage of scientists, pointing out that research scientists earn lower wages than doctors and lawyers, which signals an oversupply, and that competition for academic positions and federal grant money is high.[8]

Academic debate and public policy, however, have been hampered by the lack of a precise definition of what constitutes STEM knowledge and employment. With few exceptions, previous studies have used a binary classification of jobs as STEM or not STEM, overlooking variation in the level of STEM knowledge required and relying on unstated assumptions about what constitutes STEM employment.[9] Perhaps as a result, the occupations classified as STEM by the NSF as well as its critics have been exclusively professional occupations. These classifications have neglected the many blue-collar or technical jobs that require considerable STEM knowledge.

In *Rising Above the Gathering Storm*, a National Academy of Sciences book, the authors emphasize PhD training in science and even K-12 preparation, but they offer no assessment of vocational or practical training in science and technology. Aside from the Georgetown study, none of the many prominent commentaries has considered the full range of education and training relevant to workers who use STEM skills, and none has considered that blue-collar or nonprofessional jobs might require high-level STEM knowledge.[10]

Notwithstanding the economic importance of professional STEM workers, high-skilled blue-collar and technical STEM workers have made, and continue to make, outsized contributions to innovation. Blue-collar machinists and manufacturers were more likely to file a patent during the Industrial

Revolution than workers in professional occupations.[11] U.S. industrialization coincided with a "democratization of invention" beyond professional workers and researchers.[12] In 1957, one economist criticized the National Academy of Sciences for overemphasizing PhD researchers, when evidence suggested that they were the minority of inventors, and that roughly half of patent holders had not even completed a college degree.[13] At the same time, between the late nineteenth century and the 1950s, wages for manufacturing workers grew faster than wages for professional workers.[14]

The economy has obviously changed since then. Formal education in a science or technology field is more important than ever to providing the skills required to invent.[15] One recent survey found that 94 percent of U.S. patent inventors between 2000 and 2003 held a university degree, including 45 percent with a PhD. Of those, 95 percent of their highest degrees were in STEM fields, including more than half in engineering.[16] Still, most innovators— inventors or entrepreneurs—do not have a PhD, and the vast majority is employed outside of academia.

Today, there are two STEM economies. The professional STEM economy of today is closely linked to graduate school education, maintains close links with research universities, but functions mostly in the corporate sector. It plays a vital function in keeping American businesses on the cutting edge of technological development and deployment. Its workers are generally compensated extremely well.

The second STEM economy draws from high schools, workshops, vocational schools, and community colleges. These workers today are less likely to be directly involved in invention, but they are critical to the implementation of new ideas, and advise researchers on feasibility of design options, cost estimates, and other practical aspects of technological development.[17] Skilled technicians produce, install, and repair the products and production machines patented by professional researchers, allowing firms to reach their markets, reduce product defects, create process innovations, and enhance productivity.[18] These technicians also develop and maintain the nation's energy supply, electrical grid, and infrastructure. Conventional wisdom holds that high-skilled, blue-collar jobs are rapidly disappearing from the American economy as a result of either displacement by machines or foreign competition. But the reality is more complex. High-skilled jobs in manufacturing and construction make up an increasingly large share of total employment, as middle-skilled jobs in those fields wane.[19] Moreover, workers at existing STEM jobs tend to be older and will need to be replaced.

This report presents a new and more rigorous way to define STEM occupations. The foundation for this research is a data collection project sponsored by the Department of Labor called O*NET (Occupational Information Network Data Collection Program), which uses detailed surveys of workers in every occupation to thoroughly document their job characteristics and knowledge requirements. Combining knowledge requirements for each occupation with other public databases, this report presents a new portrait of the STEM economy. The approach used here does not seek to classify occupations based on what workers do—such as research, mathematical modeling, or programming—but rather what workers need to know to perform their jobs.

The next section describes the methods used to build this STEM economy database, with details available in the appendix. The Findings section details the scale of STEM jobs, their relative wages, and educational requirements nationally and in metropolitan areas. It also explores the benefits of having a more STEM-based metropolitan economy, showing that both blue-collar and advanced STEM jobs are associated with innovation and economic health. The report concludes by discussing how this new perspective on STEM both complements and contrasts with efforts at various levels of government and the private sector to promote STEM knowledge.

Methods

Measuring the STEM Economy

This section briefly summarizes the procedures used to identify STEM jobs based on the level of STEM knowledge they require. For more details, consult the Appendix.

To identify the level of STEM knowledge required for each occupation, knowledge requirement scores for STEM fields (see below) were obtained from O*NET. These data are part of an on-going project funded by the Department of Labor's Employment and Training Administration to provide comprehensive information about every occupation in the U.S. economy. The National Research

Council and other independent researchers have endorsed and validated the accuracy and utility of O*NET, with qualifications.[20]

O*NET surveys incumbent workers in every occupation to obtain information on training, education, experience, and skill-related work requirements. For the purposes of this study, O*NET's knowledge survey—which asks workers to rate the level of knowledge required to do their job—was used to grade occupations.[21] By way of comparison, the Florida Department of Economic Opportunity's definition of STEM, which relies on O*NET knowledge categories, comes closest to the one used here, but does not combine scores across fields.[22]

O*NET uses an occupational coding structure very similar to the Bureau of Labor Statistics' (BLS) Standard Occupational Classification (SOC) system and provides a crosswalk linking the two directly. In total, 736 occupations classified by O*NET were matched to SOC codes and titles. O*NET reports a knowledge score for each occupation across 33 domains. Of these, six were chosen as representing basic STEM knowledge: three for science (biology, chemistry, and physics), one for technology (computers and electronics), one for engineering (engineering and technology), and one for mathematics.

To illustrate how the knowledge survey works, for the O*NET category "Engineering and Technology," the O*NET survey asks the worker: "What level of knowledge of ENGINEERING AND TECHNOLOGY is needed to perform your current job?" It then presents a 1-7 scale and provides examples (or anchors) of the kinds of knowledge that would score a 2, 4, and 6. Installing a door lock would rate a 2; designing a more stable grocery cart would rate a 4; and planning for the impact of weather in designing a bridge would rate a 6.[23] These questions are presented to about 24 workers (that is the most frequent number) in each occupation, and O*NET presents average scores for every occupation.

To calculate a STEM knowledge score for each occupation, the average level of knowledge score for each of the STEM domains was first calculated. For example, the average computer score was 3.1; the average engineering score was 2.1. To adjust for differences in the levels across occupations, the average knowledge scores for a given field were subtracted from the actual occupation-specific knowledge score for that field. Thus, a value of 1 would represent a level of knowledge one point above the mean on a seven-point scale. The final STEM knowledge score for each of the 736 occupations represents the sum of these adjusted scores for each field. Thus, a value of 4 would indicate that the occupation scores (on average) one point above the mean in each STEM field (with the natural sciences—biology, chemistry, and physics—grouped together as one).[24]

The O*NET database was linked to both the U.S. Census (decennial years and 2011 American Community Survey) and the 2011 BLS Occupational Employment Statistics survey (OES). Census data were used for historical time-series analysis and analysis based on educational attainment, but OES data were used for contemporary summary statistics of jobs and wages. See the Appendix for details on how O*NET was linked to census data.

Gradations of STEM

The above procedure allowed for the classification of every occupation by a mean-adjusted STEM score and a specific knowledge score for each STEM field. Rather than report mean or even median abstract scores for the economy in a given year, the analysis introduces a cutoff to report the number of jobs that require a high level of STEM knowledge. The threshold of 1.5 standard deviations above the mean STEM score was chosen—using the distribution of occupations found in the individual records of the 2011 American Community Survey.

The report defines STEM jobs in two ways, the second more restrictive than the first:

1. ***High-STEM in any one field:*** The occupation must have a knowledge score of at least 1.5 standard deviations above the mean in at least one STEM field. These occupations are referred to as high-STEM throughout this report.
2. ***Super-STEM or high-STEM across fields:*** The occupation's combined STEM score—the sum of the scores from each field—must be at least 1.5 standard deviations above the mean score. The report refers to these occupations as *super-STEM*.

For example, network and computer systems administrators score highly only on computer knowledge and would only be considered a STEM job using the first definition, whereas biomedical engineers score highly in each STEM field and would be considered a STEM job in both definitions. Each definition has strengths and weaknesses. Empirically, workers tend to receive higher pay if they have knowledge in more than one field, which justifies the super-STEM criteria. On the other hand, education and training programs often focus on one specific domain of knowledge, making the first criterion more attractive for practical purposes.[25]

Education Requirements

Education, training, and experience data were taken from O*NET data files to analyze the level of each commonly required to work in occupations. O*NET records the percentage of workers in an occupation that falls into various education, training, and experience categories (e.g. no training, 1-3 years, 10 years or more, for the training category, and level of degree for education). The category with the largest number of workers (the mode) was selected as the most important source of training, experience, and education. Subsequent calculations were made based on this approach, which is consistent with the BLS Employment Projections Program.

STEM Premium by Education and Occupation

The most accurate source of wage data by occupation at the national, state, and metropolitan levels is the OES. These data were combined with an O*NET survey of the educational, training, and experience requirements for occupations to calculate the education-adjusted wage premium for each occupation, and to examine how this varies by level of STEM knowledge and other forms of knowledge.

The first step was to calculate average wages for all jobs within each level of education, using the share of jobs in each category as weights. Then actual average wages for each occupation were divided by education-predicted average wages to get education-adjusted wages (a value of one would indicate that actual wages for that occupation were equivalent to the average wage for all occupations with the same educational requirements). This exercise was repeated at the metropolitan scale using metropolitan specific wage and education-wage averages to account for local differences in living costs.

For purposes of understanding data in this report, the following formal definition of a wage premium is offered:

> ***Education-adjusted wage premium:*** The additional wage benefit, measured in percentage points, of working in an occupation (or group of occupations like high-STEM) relative to occupations with identical educational requirements.

Findings

A. As of 2011, 26 million U.S. jobs—20 percent of all jobs—require a high level of knowledge in any one STEM field.

By limiting STEM to professional industries only, STEM jobs account for 4 to 5 percent of total U.S. employment. Examining the underlying knowledge requirements of jobs, however, substantially increases the number considered STEM jobs, under both conservative (super-STEM) and more inclusive criteria (high-STEM).

Using a stringent definition—that a job must score very highly across STEM fields (though not necessarily in all) to be considered STEM—9 percent of jobs meet a super-STEM definition (Figure 1). But even that underestimates the importance of STEM knowledge in the economy. For instance, occupations such as computer programmers require expertise in one or two aspects of STEM (computer technology or perhaps even computer engineering), but there is no expectation that such workers know anything about physical or life sciences. If one uses a more inclusive approach—a job is STEM if it requires a high level of knowledge in any one STEM field—then the share increases to 20 percent of all jobs, or 26 million in total.

Engineering is the most prominent STEM field; 11 percent of all jobs—13.5 million—require high levels of engineering knowledge. This is closely followed by science with 12 million. High-level math and computer-related knowledge are less prominent but still constitute millions of jobs (7.5 and 5.4, respectively). Many jobs require high levels of knowledge in more than one STEM field, which is why the total (20 percent) is smaller than the sum of the individual STEM field percentages.

Some may assume the concept of STEM is a fleeting fad for policymakers, but there are compelling reasons to believe that STEM-related employment is a fundamental aspect of modern economies and

Figure 1. Number and Percentage of U.S. Jobs Requiring High Levels of STEM Knowledge by STEM Field, 2011

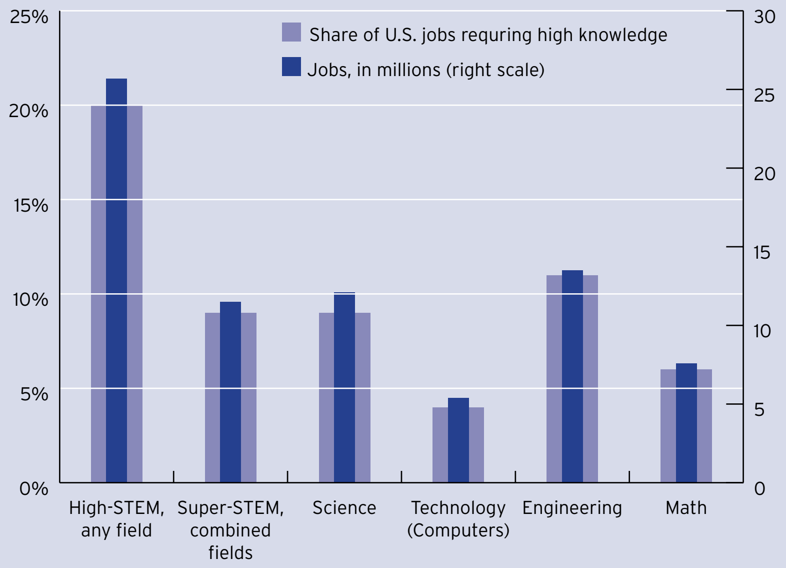
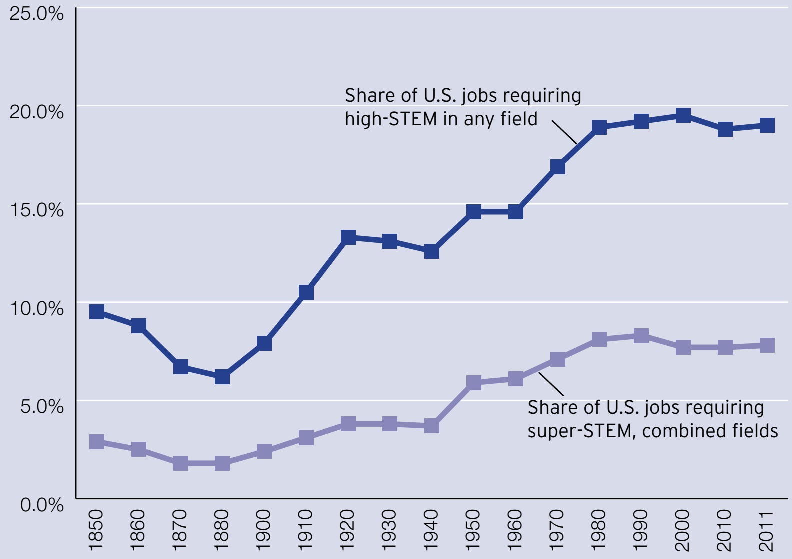


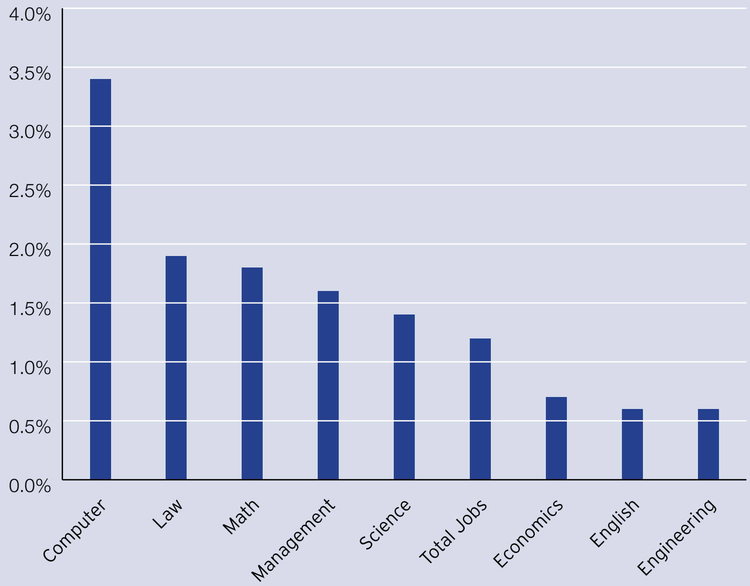
Figure 2. Share of U.S. Jobs Requiring High-Level of Overall STEM Knowledge or High-STEM Knowledge in Any Field, 1850-2010



that the prominence of STEM jobs will continue to grow as nations industrialize, urbanize, and specialize their way to higher standards of living and more complex forms of production and exchange.

Indeed, the U.S. economy appears to be in the midst of another major transformation. Since 1980, the U.S. economy has become more polarized as jobs paying very high and very low wages have replaced jobs paying moderate wages. This trend—job polarization, as some have called it—has just recently been documented and is still being understood and debated.[26] Some have interpreted the trend to imply that workers without a college degree have little hope of making middle-class wages; others suggest that unions need to be strengthened to stem the erosion of blue-collar jobs and

Figure 3. Average Annual Job Growth in High-Knowledge Occupations by Field, 1980-2010



*Source: Brookings analysis of O*NET and U.S. Census Bureau via IPUMS. Each category except total employment includes only occupations that fall at least 1.5 standard deviations above the mean knowledge score in 2011 for that particular field.*

wages.[27] But there is another possibility. Not all workers need formal college-level skills, but they do need to master a specific body of knowledge. Entry-level occupations in factories no longer pay high wages, but occupations requiring education, experience, or training in STEM fields do, even for those requiring less than four years of postsecondary education.

Since 1850, there has been a steady increase in the demand for jobs that require high-level knowledge across all STEM fields (Figure 2). Super-STEM jobs rose from 2.9 percent of the total in 1850 to a high of 8.3 percent in 1990. Since then, the share has stabilized around 8 percent. At the same time, high-STEM jobs increased as a share of all jobs, from 9.5 percent in 1850 to a high of 19.5 percent in 2000, before falling to 18.8 percent in 2010. The only major exception to this growing demand for STEM was the period just after the Civil War.[28] More recently, the erosion of the manufacturing sector has slowed this trend.[29]

In recent decades, employment growth rates for high-knowledge jobs have exceeded the national average in many fields, not just STEM related.[30] Growth in jobs requiring high-level computer knowledge was by far the fastest, with 3.4 percent annual growth (Figure 3). Next is law, followed by mathematics, management, and science, all of which grew faster than total employment. The only high-level STEM category growing slower than the national average is engineering. High-knowledge engineering jobs—which are closely tied to the manufacturing sector—declined from 2000 to 2010. In non–STEM fields, economics and English were also below the national average.

B. Half of all STEM jobs are available to workers without a four-year college degree, and these jobs pay $53,000 on average—a wage 10 percent higher than jobs with similar educational requirements.

Previous reports on the STEM economy indicate that only highly educated professionals are capable of mastering and employing sophisticated knowledge in STEM fields. Classifying STEM jobs based on knowledge requirements, however, shows that 30 percent of today's high-STEM jobs are actually blue-collar positions (Table 1). As defined here, blue-collar occupations include installation, maintenance, and repair, construction, production, protective services, transportation, farming, forestry, and fishing, building and grounds cleaning and maintenance, healthcare support, personal care, and food preparation.

Table 1. STEM Jobs by Educational Requirements and Professional Classification, by Various Sources and Definitions, 2011

	Brookings' High-STEM, Any Field	Brookings' Super-STEM, Combined Fields	Georgetown	NSF	Commerce	U.S. Total
	Share (%) of total by most significant educational requirement					
Less than a high school diploma	2	0	0	0	0	11
High school diploma or equivalent	13	11	5	4	4	50
Postsecondary certificate	17	18	1	1	1	9
Associate's degree	19	10	15	13	14	6
Bachelor's degree	37	43	71	65	74	20
Master's degree	6	4	6	8	4	3
Doctoral or professional degree	7	14	3	8	3	2
	Other Characteristics					
Nonprofessional occupations	31	29	0	0	0	42
Share of all U.S. jobs	20	9	4	5	5	100

*Source: Brookings analysis of data from 2011 OES and O*NET; see in-text citations for source definitions.*

Comparing the professional and educational characteristics of high-STEM jobs using this new Brookings definition to previous studies from Georgetown, the National Science Foundation, and the Department of Commerce reveals two important facts. First, only our definition classifies nonprofessional jobs as high-STEM. Second, the Brookings definition includes a much broader swath of occupations that do not typically require a four-year college degree. In fact, 50 percent of jobs that require high-level STEM knowledge in at least one field do not require a bachelor's degree. The share for super-STEM jobs is 38 percent. This compares with 20 percent using conventional STEM definitions.

STEM workers are demographically distinct from other workers in a number of ways. Compared to the average U.S. worker, high-level STEM workers are much more likely to be male, better educated, Asian, and far more likely to have a science degree or PhD or professional degree than the U.S. workforce (Table 2). STEM workers are also roughly two years older than the average worker, signaling a higher potential demand for replacement workers than in other fields. only 22 percent of super-STEM workers are female and 33 percent are women in jobs requiring high-level STEM knowledge in at least one field. At 18 percent, foreign-born workers are only slightly more likely to work in super-STEM jobs than their share of the workforce (16 percent) would suggest. Yet, the foreign-born share is particularly large for super-STEM jobs that require a PhD or other professional degree, as other studies have revealed. Blacks and Hispanics are generally underrepresented in STEM jobs.

High-STEM and super-STEM workers are far more likely to have a bachelor's degree in a STEM field that U.S. workers more generally. This suggests that formal education in a STEM field often leads to a STEM job. Still, a large majority of high-level STEM workers have not earned a college degree in a STEM field. Training and experience are other routes to STEM jobs. The average high-level STEM job or super-STEM job requires at least one year of on-the-job-training, compared with less than five months for non–STEM jobs. Likewise, STEM jobs typically require experience at least two years longer .

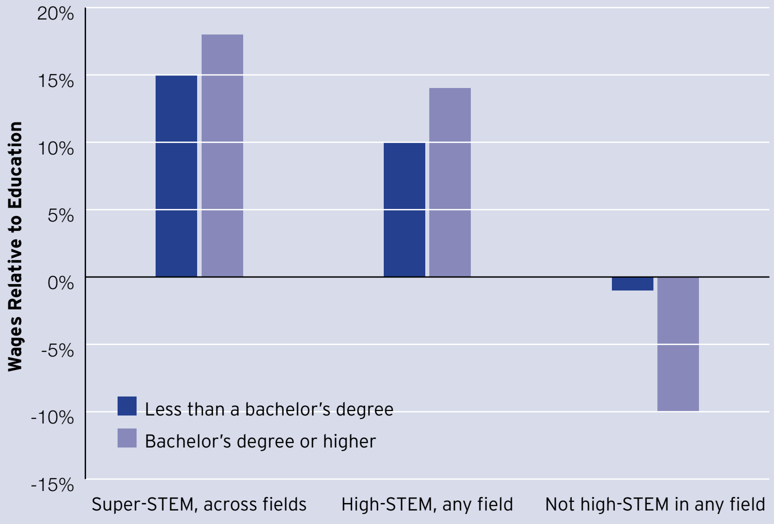
Finally, wages and employment rates are considerably higher for STEM workers. Those in super-STEM jobs earn an average of $68,000 a year—more than double non–STEM workers—and their unemployment rate is four percentage points lower than non-STEM workers. Labor market outcomes are strongly positive for those in high-STEM jobs as well.

Table 2. Characteristics of Mid- to High-Level STEM Workers in the United States Relative to Overall Working Population, 2011

	High-STEM, Any Field	Super-STEM, Across Fields	Not High-STEM in Any Field	All U.S. Workers
Age	42.9	43.2	41.1	41.4
Sex, Race, and Immigrant Status				
Female	33%	22%	51%	47%
Foreign-born	17%	18%	16%	16%
Asian (non-Hispanic)	8%	10%	4%	5%
Black (non-Hispanic)	8%	6%	12%	11%
Hispanic (of any race)	10%	9%	16%	14%
White (non-Hispanic)	72%	73%	65%	67%
Training and Highest Degree of Educational Attainment				
Average years of on-the-job-training	1	1.3	0.4	0.4
Average years of experience	3.9	3.9	1.5	1.5
Bachelor's degree in STEM field	26%	37%	5%	9%
Labor Market Outcomes				
Mean income	$59,767	$68,061	$33,454	$38,677
Unemployment rate	6.10%	5.40%	9.30%	8.70%

*Source: Brookings analysis of O*NET and 2011 American Community Survey, via IPUMS. Only workers in the labor force and employed within last five years are included. Military employees are excluded. Training and experience data are from O*NET and use non-STEM workers as the reference group. The corresponding average wages using OES data (which is only for employed workers) are $70,212 for STEM occupations, $78,266 for Super-STEM occupations, $38,922 for non-STEM occupations, and $45,204 for all occupations.*

Figure 4. Education-Adjusted Wage Premium for STEM Jobs by Educational Requirements, 2011



*Source: Brookings analysis of OES and O*NET.*

Notes: Percentage points reported above are the wage premium for the average occupation in that category, which is calculated by dividing actual wages for the occupation by the average wages for occupations with the same educational requirements. Average wages—weighted by the number of jobs—are calculated for each category of STEM by educational requirement. These wages are then divided by average wages for all U.S. jobs by educational requirement. The numbers here are ratios less 1, where 0 indicates that wages for that group are equal to the wages of occupations with the same educational requirements.

Table 3. Major Occupational Categories by Share of Jobs That Are STEM, and Share of U.S. STEM Jobs, 2011

	Mean STEM Score	High-STEM, Percentage of Jobs	Super-STEM, Percentage of Jobs	Share of U.S. High-STEM Jobs	Share of U.S. Super-STEM Jobs	Share of All Jobs
Architecture and engineering	10.6	100%	95%	9%	19%	2%
Life, physical, and social science	8.6	87%	76%	4%	7%	1%
Healthcare practitioner and technical	3.1	76%	29%	22%	19%	6%
Computer and mathematical science	2.9	100%	30%	13%	9%	3%
Installation, maintenance, and repair	2.6	53%	39%	10%	17%	4%
Management	1.1	27%	13%	6%	7%	5%
Construction and extraction	0.9	40%	13%	8%	5%	4%
Education, training, and library	-0.6	9%	7%	3%	5%	7%
Business and financial operations	-0.7	42%	8%	10%	4%	5%
Farming, fishing, and forestry	-2.6	8%	2%	0%	0%	0%
Production	-2.6	23%	4%	7%	3%	7%
Arts, design, entertainment, sports, and media	-3.2	16%	2%	1%	0%	1%
Sales and related	-4.2	0%	0%	0%	1%	11%
Legal	-4.2	0%	0%	0%	0%	1%
Protective service	-4.6	12%	2%	1%	1%	2%
Personal care and service	-5.0	1%	0%	0%	0%	3%
Transportation and material moving	-5.1	6%	2%	2%	2%	7%
Community and social services	-5.3	0%	0%	0%	0%	1%
Office and administrative support	-5.8	1%	0%	1%	0%	17%
Food preparation and serving related	-5.9	0%	0%	0%	0%	9%
Healthcare support	-5.9	5%	1%	1%	0%	3%
Building and grounds cleaning and maintenance	-6.5	5%	1%	1%	1%	3%

*Source: Brookings analysis of O*NET and OES, 2011.*

The higher educational attainment rates of STEM workers cannot wholly account for their higher wages, as STEM jobs pay well at multiple educational and professional levels. Occupations requiring high-level STEM knowledge in any one field pay 12 percent higher wages than jobs with identical educational requirements. Super-STEM jobs pay 16 percent higher wages. This wage advantage even applies to STEM jobs that require little formal education or are in blue-collar occupations. Super-STEM jobs that require less than a bachelor's degree pay 15 percent higher wages than jobs with similar educational requirements, an average of more than $50,000 annually (Figure 4). The advantage is 10 percent for high-STEM jobs, with average annual wages above $52,000. Blue-collar STEM workers earn an average of $47,000 annually, 22 percent higher wages than in jobs with similar educational requirements. STEM workers with a bachelor's degree or higher enjoy an even more substantial premium, with average wages of nearly $96,000 for super-STEM jobs (18 percent advantage) and $88,000 for high-STEM jobs (14 percent advantage).

A look at the STEM content of each major occupational category reveals the diversity and depth of the STEM economy. The two most highly STEM-oriented occupations are familiar: architects and engineers, and life, physical, and social scientists (Table 3). Most workers in these occupations are required to have high levels of STEM knowledge across multiple domains. Yet the third and fifth-highest ranked STEM occupational groups (measured by the average scores of occupations in those groups) are healthcare practitioner and technical occupations (third) and installation, maintenance, and repair occupations (fifth). Neither has previously been considered STEM, though using this definition, one-third of STEM workers fall into these occupations. The three largest craft professional or blue-collar categories are installation, maintenance, and repair; construction and extraction; and production. Together, these fields represent one-fourth of all STEM jobs (using either definition).

More high-STEM workers (those high in any one field) are health care practitioners and technicians than any other broad category. Even in less technical professional fields such as management and finance, many workers are required to have high levels of STEM knowledge.

A few examples illuminate some of these nontraditional blue-collar STEM occupations. High-STEM installation, maintenance, and repair jobs include a wide array of skilled occupations: automotive service technicians and mechanics, first-line supervisors, industrial machinery mechanics, HVAC mechanics and installers, telecommunications equipment installers and repairers, aircraft mechanics, computer and office machine repairers, heavy equipment mechanics, and electrical repairers. These jobs all score very highly on engineering and technology skills, and they are often at least in the middle, if not the high, end on other STEM fields. In the construction and extraction trades, 12 occupations qualify as high-STEM, and three as super-STEM: construction and building inspectors, electricians, and elevator installers and repairers. These and other STEM-based construction jobs tend to score highly on engineering and technology. Finally, there are 27 different production jobs that qualify as high-STEM, and nine as super-STEM, examples of which include: water and wastewater treatment plant and system operators, tool and die makers, chemical plant and system operators, stationary engineers and boiler operators, computer numerically controlled machine tool programmers, and plant and system operators. These jobs tend to score highly on science and engineering

Distribution across Industries

Jobs requiring high-level STEM knowledge can be found in every sector of the economy, although there are large differences in the demand for STEM knowledge across sectors. Utilities, professional services, construction, mining, and manufacturing are the five most STEM-intensive sectors (Table 4). Roughly 27 percent of all utility sector workers are required to have a cross-cutting, high level of STEM knowledge, and 44 percent are required to have high-level STEM knowledge in at least one field. The construction industry also has a high share of workers with high-level STEM knowledge; 17 percent have cross-cutting knowledge and 38 have knowledge in at least one field. For buildings and infrastructure to be safe and durable, the construction industry demands a considerable level of skill in engineering, physics, and mathematics. At the low end of the STEM scale are sectors such as accommodation and food services, arts, entertainment and recreation, and retail, where advanced STEM knowledge is generally not important.

More super-STEM jobs are in manufacturing than any other sector, and roughly half of all super-STEM workers are in manufacturing, health care, and construction. Using the broader high-STEM definition, health care is slightly larger than manufacturing, but here again half of all STEM jobs are concentrated in health care, manufacturing, and construction. These sectors make up 30 percent of total U.S. employment.

Analyzing industries in more detail (at the three-digit industry level, as opposed to two-digit sector level) reveals that a number of energy and manufacturing-related industries score very highly on STEM knowledge. Seven of the top 20 industries for STEM knowledge—computer and electronics, petroleum and coal, transportation equipment, chemical, machinery, fabricated metal, and electrical equipment—are patent-intensive industries according to the U.S. Patent and Trade Office (USPTO).[32] This underscores how much of the nation's scientific knowledge and innovative capacity lies within the manufacturing sector. Oil and gas extraction scores highest among detailed industries on STEM knowledge across all workers.

The detailed industry with the highest percentage of high-STEM workers is repair and maintenance, with 52 percent. The hospital industry is next with 50 percent, followed by water transportation (47 percent), computer and electronics product manufacturing (46 percent), petroleum and coal products

Table 4. Major Industries by Share of Jobs That Are STEM, and Share of U.S. STEM Jobs, 2011

	High-STEM, Percentage of Jobs	Super-STEM, Percentage of Jobs	Share of U.S. High-STEM Jobs	Share of U.S. Super-STEM Jobs	Share of All Jobs
Utilities	44%	27%	2%	3%	1%
Professional, scientific, and technical services	39	19	13	15	6
Construction	38	17	13	14	7
Mining, quarrying, and oil and gas extraction	25	15	1	1	0
Manufacturing	30	13	16	17	10
Public administration	27	12	7	8	5
Health care and social assistance	29	10	20	17	13
Other services (except public administration)	17	9	5	6	5
Information	22	7	2	2	2
Management of companies and enterprises	30	7	0	0	0
Transportation and warehousing	10	6	2	3	4
Wholesale trade	9	3	1	1	3
Retail trade	6	3	4	5	12
Educational services	7	3	3	3	9
Administrative and support and waste management and remediation services	9	3	2	2	5
Agriculture, forestry, fishing and hunting	4	3	0	1	2
Real estate and rental and leasing	10	3	1	1	2
Finance and insurance	28	2	6	1	4
Arts, entertainment, and recreation	4	1	1	0	2
Accommodation and food services	1	0	0	0	8

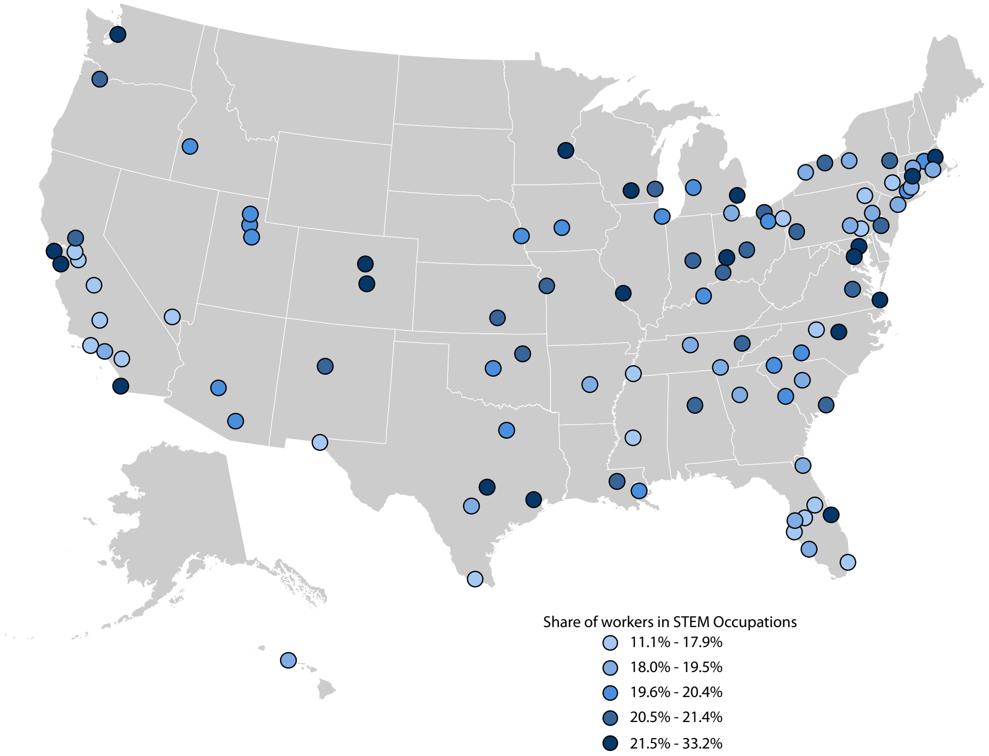
*Source: Brookings analysis of O*NET and 2011 U.S. Census American Community Survey provided by IPUMS.*

manufacturing (46 percent), data processing, hosting, and related services (43 percent), and fabricated metal product manufacturing and transportation equipment manufacturing (both 41 percent). National security has a workforce that is 40 percent high-STEM. Finally, 39 percent of jobs in the professional, scientific, and technical services industry and the telecommunications industry qualify as high-STEM.

C. STEM jobs that require at least a bachelor's degree are highly clustered in certain metropolitan areas, while sub-bachelor's STEM jobs are prevalent in every large metropolitan area.

Because they foster specialization and trade, metropolitan areas are disproportionately home to inventive activity and highly educated workers.[33] Yet large metropolitan areas are similar to smaller metropolitan and nonmetropolitan areas in the intensity of STEM knowledge embodied in the workforce. Sixty-eight percent of STEM and 66 percent of super-STEM jobs are located in the 100 largest metropolitan areas, slightly more than these metro areas' share of the U.S. population (65 percent). Many non-STEM professional and low-skilled service jobs are highly concentrated in large metropolitan areas, while many smaller metropolitan and nonmetropolitan areas have colleges and universities, or

Figure 5. Share of all Workers in STEM Occupations in the 100 Largest Metropolitan Areas, 2011



*Source: Brookings analysis of O*NET and Bureau of Labor Statistics Occupational Employment Survey*

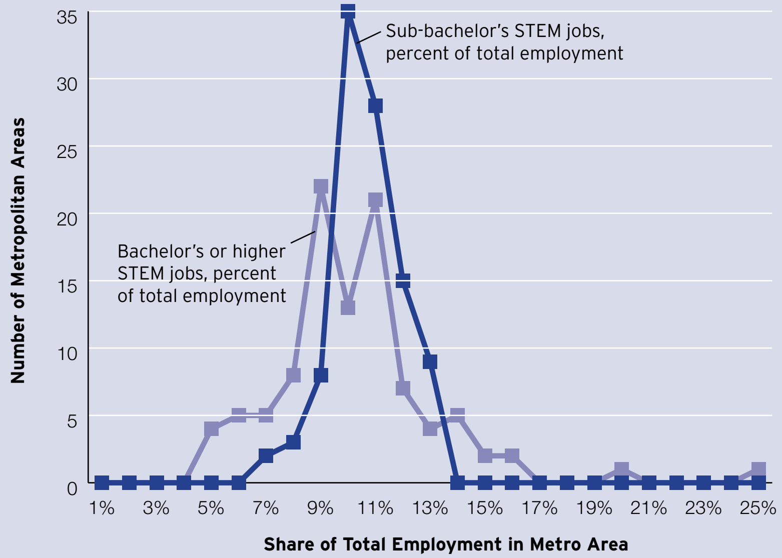
large employers in a STEM-intensive industry such as mining, power plant operations, or manufacturing. Computer knowledge is the most concentrated in the largest 100 metropolitan areas, where 77 percent of workers with high levels of computer knowledge are located, but those areas contain only 64 percent of jobs demanding high levels of scientific knowledge (often associated with energy industries).

Across broad regions of the country, the West stands out as the most STEM oriented and the Northeast the least. Among Western states, only Nevada and Hawaii score low on STEM knowledge. This pattern notwithstanding, differences across regions are relatively slight: 9.5 percent of jobs require super-STEM knowledge in the West compared with 8.5 in the Northeast. Energy and extraction-dominated states such as Alaska and Wyoming are among the most STEM oriented, as are Washington and Colorado, where computer and scientific knowledge are prevalent. The District of Columbia, Maryland, Virginia, Texas, and Massachusetts also score highly, while Nevada, New York, South Dakota, and Florida rank at the bottom.

Metropolitan areas themselves vary widely in their STEM intensity. For example, while only 5 percent of jobs in Las Vegas require super-STEM knowledge—the lowest share among large metro areas—19 percent of jobs in San Jose, CA, do. In fact, San Jose's STEM score is 4 standard deviations above the average large metropolitan area—a very high concentration. For STEM jobs more broadly defined, the range spans from 33 percent of total employment in San Jose to just 11 percent in McAllen, TX (Figure 5).

Some of the most STEM-based metropolitan economies are familiar tech hubs like San Jose, Washington, D.C., Seattle, Boston, and San Diego (Table 5). Houston makes the list because of its strong energy sector. Baltimore is home to the Johns Hopkins University and other hospital systems and a strong defense industry cluster in the suburbs. The others—Bakersfield, CA, Palm Bay, FL, and Madison, WI—may be more surprising. Palm Bay has a large IT industry presence surrounding the

Figure 6. Spread of High and Low Education STEM Jobs across 100 Largest Metropolitan Areas, 2011



Kennedy Space Center and Cape Canaveral Air Force Station. It is also home to 11 percent of the nation's aerospace engineering and operations technicians. Bakersfield has a large energy sector and, hence, employs a high percentage of its workers in technical jobs related to industrial construction, geology, and engineering. Madison is home to one of the country's leading research universities at the University of Wisconsin, which, for example, employs many scientists it its College of Agriculture and Life Sciences. The metro area also employs a large number of actuaries in its significant accounting industry.

Moreover, as Figure 5 indicates, STEM-intensive metro areas include several others outside the typical high-science, high-tech orbit. Dayton, OH, Detroit, MI, Hartford, CT, Minneapolis-St. Paul, MN, and St. Louis, MO, all rank within the top 20 on the STEM share of total employment thanks in part to their strong specializations in high-skilled manufacturing. Colorado Springs and Virginia Beach lean toward STEM owing to defense-related industries.

The metro areas with the lowest STEM concentrations include those with large hospitality sectors such as Lakeland, FL, Miami, FL, Cape Coral, FL, and Las Vegas, NV. Despite being traditional manufacturing hubs, the most distinctive occupations in Youngstown, OH, and Scranton, PA, today are in low-skilled health care. Stockton and Modesto, CA, are agricultural economies with relatively few professional services jobs.

While there is fairly wide variation in the share of STEM jobs across metropolitan areas, much of that variation reflects the highest skilled STEM jobs in engineering, computers, and science. High-STEM jobs that require at least a bachelor's degree range from just 4 percent of all jobs in McAllen, TX, to 24 percent in San Jose, CA.

By contrast, STEM jobs that do not require a bachelor's or graduate degree are much more evenly spread across metropolitan areas. Among the largest 100 metropolitan areas, the share of all STEM jobs available to workers without a bachelor's degree ranges from 7 percent in Las Vegas to 13 percent in Baton Rouge. This narrower band suggests that these STEM jobs often scale with population. Every city and large town needs mechanics and nurses. Meanwhile, scientists, engineers, and computer workers are more export-oriented and clustered. Figure 6 demonstrates the difference in the distribution of higher- and lower-education STEM jobs across the 100 largest metropolitan areas.

Table 5. Large Metropolitan Areas with the Highest and Lowest Demand for STEM Knowledge, 2011

	STEM Score, 2011 Standardized	Percentage of Jobs Requiring High-Level STEM Knowledge in Any Field, 2011	Percentage of Jobs Requiring High-Level STEM Knowledge, 2011
10 Large Metro Areas with the Highest STEM Score			
San Jose-Sunnyvale-Santa Clara, CA	4.3	33%	19%
Washington-Arlington-Alexandria, DC-VA-MD-WV	2.8	27	13
Palm Bay-Melbourne-Titusville, FL	2.4	27	15
Bakersfield-Delano, CA	2.1	18	9
Seattle-Tacoma-Bellevue, WA	2.1	26	13
Houston-Sugar Land-Baytown, TX	2.1	23	11
Madison, WI	1.7	24	10
Boston-Cambridge-Quincy, MA-NH	1.7	24	11
Baltimore-Towson, MD	1.6	23	11
San Diego-Carlsbad-San Marcos, CA	1.6	23	12
Average for top 10 STEM	**2.0**	**24%**	**12%**
10 Large Metro Areas with the Lowest STEM Score			
Lancaster, PA	-0.5	16%	6%
Lakeland-Winter Haven, FL	-0.5	15	6
Stockton, CA	-0.5	14	6
Modesto, CA	-0.5	13	5
Miami-Fort Lauderdale-Pompano Beach, FL	-0.6	18	8
Youngstown-Warren-Boardman, OH-PA	-0.6	16	6
Cape Coral-Fort Myers, FL	-0.7	18	7
Scranton--Wilkes-Barre, PA	-0.9	16	6
McAllen-Edinburg-Mission, TX	-0.9	11	4
Las Vegas-Paradise, NV	-2.3	13	5
Average for bottom 10 STEM	**-0.8**	**15%**	**6%**
Average of all 100 large metro areas	**0.0**	**16%**	**8%**

*Source: Brookings analysis of O*NET and Bureau of Labor Statistics Occupational Employment Statistics. The STEM score is standardized.*

More STEM-oriented metropolitan economies perform strongly on a wide variety of economic indicators, from innovation to employment.

Not only do workers do better economically when they work in STEM fields, but the overall economy appears to benefit as well. Economic performance is superior on a wide range of indicators in metropolitan areas with high STEM versus low STEM concentrations. Greater STEM skills at the metro level are strongly associated with higher patents per worker (an indicator of innovation), lower unemployment, a lower rate of job losses during the recent recession and early recovery, higher exports as a share of gross domestic product (GDP) (a measure of international competitiveness), and higher incomes (Table 7). To be sure, cause and effect can operate both ways if strong metropolitan economic performance attracts or creates additional STEM workers, a point returned to below.

Table 6. Wages and Job Opportunities for STEM Workers in Occupations Requiring Less than a Bachelor's Degree

	Share of All Jobs Available to STEM Workers without a Bachelor's Degree	Wages of High-STEM Workers in Sub-Bachelor's Jobs	Wages of Non-STEM Workers in Sub-Bachelor's Jobs	Wages Relative to Jobs with Same Education Requirements
10 Large Metropolitan Areas Where STEM Workers in Low-Education Jobs Earn Highest Relative Wages				
Baton Rouge, LA	12.6%	$49,764	$30,171	23%
Birmingham-Hoover, AL	12.5	$48,034	$31,522	5
New Orleans-Metairie-Kenner, LA	12.4	$51,891	$31,970	13
Cape Coral-Fort Myers, FL	12.4	$47,893	$29,534	10
Wichita, KS	12.3	$48,353	$29,752	12
Tulsa, OK	12.3	$44,851	$30,498	10
Knoxville, TN	12.2	$46,318	$29,692	8
Cleveland-Elyria-Mentor, OH	12.1	$52,164	$31,453	12
Palm Bay-Melbourne-Titusville, FL	12.0	$49,223	$29,934	7
Virginia Beach-Norfolk-Newport News, VA-NC	11.8	$51,050	$30,846	15
10 Large Metropolitan Areas Where STEM Workers in Low-Education Jobs Earn Lowest Relative Wages				
San Francisco-Oakland-Fremont, CA	8.7%	$73,465	$40,458	13%
El Paso, TX	8.5	$42,897	$25,790	6
Los Angeles-Long Beach-Santa Ana, CA	8.4	$58,009	$35,902	8
Bridgeport-Stamford-Norwalk, CT	8.3	$62,092	$40,926	5
Washington-Arlington-Alexandria, DC-VA-MD-WV	8.1	$62,979	$41,946	-1
New York-Northern New Jersey-Long Island, NY-NJ-PA	8.0	$65,297	$37,614	13
Fresno, CA	7.9	$52,832	$30,846	13
Oxnard-Thousand Oaks-Ventura, CA	7.5	$56,563	$35,497	13
McAllen-Edinburg-Mission, TX	7.0	$47,451	$24,821	4
Las Vegas-Paradise, NV	6.9	$59,238	$32,313	22

*Source: Brookings analysis of O*NET and OES. STEM jobs are included if occupation scores highly on any one field. Relative wages are calculated by dividing average wages for each occupation in each metropolitan area by the average wage for all occupations with the same educational requirement. The weighted average of this education-adjusted wage is reported.*

Within STEM, engineering knowledge has the strongest correlation with exports, and computer and electronics knowledge has the highest correlation with patenting and tech sector workers (which reinforces the importance of STEM workers to the tech sector).[37]

Median household incomes and average wages are also higher in STEM-oriented economies. More detailed analysis in the appendix establishes this more conclusively and also shows that a high share of STEM jobs in a metro area is associated with higher wages in the local service sector. The same is true for manufacturing, implying that wages are higher in both tradable and nontradable industries in more STEM-based metro areas.[38]

The positive economic effects of STEM jobs on a metropolitan economy are not confined to the high-education STEM jobs. Sub-bachelor's STEM jobs are also strongly associated with key regional

Table 7. Economic Performance of Metropolitan Areas with High and Low Levels of Occupation-based STEM Knowledge, 2011

Metropolitan Areas by STEM Score	Patents per Million Residents, 2011	Tech Sector Share of Employment, 2011	Unemployment Rate 2011	Employment Growth Rate, 2008-2012	Exports as Percent of GDP, 2010	Median Household Income, 2011
Top quartile on STEM	1.27	6.2%	8.3%	-2.8%	10.8	$58,482
Second quartile on STEM	0.72	4.4	9.0	-3.7	8.9	$54,005
Third quartile on STEM	0.48	3.0	9.9	-5.4	8.5	$46,575
Bottom quartile on STEM	0.37	2.3	10.3	-5.2	7.4	$44,184

Source: Brookings analysis of data for 357 metropolitan areas using data from Export Nation, Strumsky Patent Database, Moody's Analytics, the American Community Survey, and the Bureau of Labor Statistics. The employment growth rate measures the growth rate of employment from the first quarter of 2008 to the first quarter of 2012. Export data are available only for the 100 largest metropolitan areas. All average are weighted based on total metropolitan area employment in 2011.

measures of economic health. On exports, patents, median income, and wages, metro areas with a higher percentage of sub-bachelor's STEM jobs do significantly better, controlling for the percentage of STEM jobs that require more advanced education. Job growth and unemployment were the only factors for which sub-bachelor's STEM jobs had no additional value. The size of the sub-bachelor's STEM effect is generally smaller than the effect of higher education, but it is still sizable.[39]

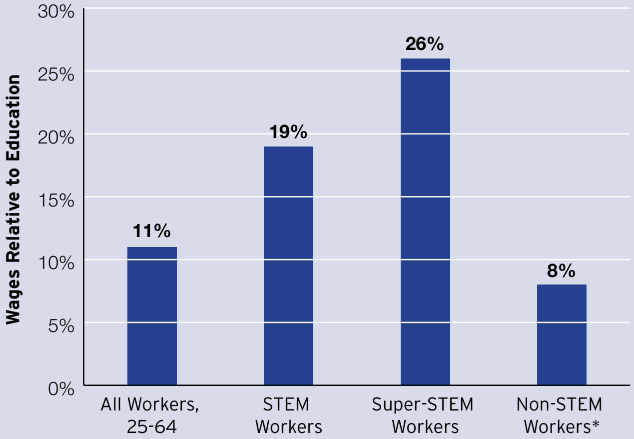
Just as the benefits of a STEM economy on economic performance are not solely the result of highly educated STEM workers, the economic wealth generated by a STEM economy is relatively broadly shared. There is no significant correlation between a metro area's STEM score and household income inequality.[40] As economists have found, more educated metro areas have higher inequality, and STEM scores are correlated with education.[41] However, controlling for the average years of education in a metro area, a higher STEM score (or larger share of workers in STEM occupations) is strongly associated with less inequality. And metro areas with larger shares of workers in sub-bachelor's STEM jobs experience significantly less inequality than other metro areas.[42]

While suggestive, the link between prosperity and STEM-oriented economies may not necessarily indicate that STEM workers drive regional prosperity. It could be that more highly prosperous communities attract STEM-oriented people and businesses, who come to take advantage of those conditions. If so, then perhaps the causality is reversed: STEM workers spring up after the metro area becomes prosperous but do little to help achieve it; they do, however, earn higher salaries, which raise measured income levels and employment rates. If so, one would expect the wages of individual STEM and non–STEM workers to be the same in high and low-STEM economies.

In fact, the evidence suggests that STEM workers earn higher wages in STEM-based metropolitan economies, beyond what their individual characteristics would predict. This implies that the association between STEM and higher income levels is not just a compositional effect. Living in a STEM economy is associated with higher spending power (i.e., wages in light of local housing costs) controlling for individual characteristics such as age, education, and sector of employment. The average worker living in the most STEM oriented metropolitan areas realizes an 11 percent boost in real wages compared with those living in the least STEM oriented metropolitan areas. The effect is much higher (19 and 26 percent) for high-STEM and super-STEM workers, and considerably lower (8 percent) and statistically insignificant for non–STEM workers.[43] The appendix presents the econometric details, and Figure 7 depicts the results.

One way to think about this is that STEM knowledge boosts the earnings of highly skilled workers but not low-skilled workers, whose wages increase only in proportion to living costs.[44] From a regional perspective, aggregate statistics—such as incomes—look better for the average worker in STEM oriented economies. This effect is not entirely dependent on the mix of individual workers living there, but there is no evidence that STEM economies directly boost the buying power of less-educated workers unless they have STEM skills. Yet, real wages and higher living standards for all workers are realized through the creation of innovative technologies to which STEM workers across the world contribute.

Figure 7. Predicted Effect of Working in Highest and Lowest STEM Metropolitan Areas on Wages, Conditional on Individual and Metropolitan Characteristics, 2011.



Source: See Appendix for details.

Note: The effect is not statistically significant for non-STEM or for workers with less than a bachelor's degree.

Policy Challenges

The research presented here identifies the previously unheralded role of blue-collar and other STEM occupations demanding less than a bachelor's degree. These jobs pay decent wages in absolute terms and relative to their educational requirements. Like STEM jobs requiring a bachelor's degree, they also contribute to the welfare and prosperity of regional economies by boosting innovation and earnings. STEM-knowledgeable professional workers are far more likely than other professional workers to contribute to the development of valuable ideas and inventions, and blue-collar STEM workers make the commercialization of those ideas and inventions feasible and profitable at every point in the supply chain.

In short, individual workers and the U.S. economy would benefit from a greater supply of STEM-knowledgeable workers at all levels of education and training.

Many researchers have studied why there is a shortage of highly educated STEM workers. Reasons range from inadequate preparation, to too few choosing those fields of study, to low retention rates for STEM majors. A number of policies are designed to correct this problem.[45] Less attention has been paid to why sub-bachelor's level STEM jobs are hard to fill.[46] Further, public policies have focused almost entirely on four-year degree pathways, ignoring the many high-paying jobs in STEM fields that do not require as much formal education.

The next section describes and discusses the federal, state, and local government policies that are most relevant to boosting the supply of STEM education. Non-profit associations and the private sector also play key roles. The policy goals can be categorized by their target population's level of education. Most also have one of the following goals:

1) Raising enrollment, retention, and attainment for bachelor's degree and graduate degree students in STEM subjects, especially for low-attainment population
2) Adult training or sub-bachelor's education in STEM fields
3) Boosting elementary and secondary interest and preparation in STEM subjects.

Various government and nonprofit or corporate sectors implement each of these goals (Table 8).

Federal Government STEM Programs by Type

Numerous laws and government programs affect the supply of and demand for education, including STEM education. Characterizing all of these is well beyond the scope of this report. For the purposes of this analysis, the discussion is limited to programs that make boosting the supply of STEM workers their primary objective or, in practice, spend most of their funds on STEM education.[47]

Even with this limited definition, the U.S. federal government is actively investing more than $4.3

Table 8. Policies to Increase the Supply of STEM Workers

	Target Population's Education		
	University Education	**STEM Career and Technical Education**	**K-12**
Federal	Funds scholarships, mentorship, apprenticeships, summer programs to encourage and retain students	Funds training and community college education	Funds programs designed to engage and inspire students in STEM fields; funds museums
State	Funds university STEM departments, labs, equipment, and programs; provides scholarships	Funds training and community college education; coordinates and administers workforce development efforts	Approves or encourages STEM schools; funds training and incentives for STEM teachers; creates content standards
Local	Provides land; coordinates workforce development and education investments across governments and sectors	Coordinates and administers workforce development efforts; provides land	Builds and funds STEM schools; provides evaluation, training, and incentives for effective STEM teachers
Non-profit/Corporate	Provides apprenticeships and internships; funds scholarships or programs	Designs community college curriculums; provides education, internships, apprenticeships, or on-the-job training; funds scholarships or programs	Provides apprenticeships, internships, and mentoring; initiates in and out-of-classroom student engagement; funds programs and museums

billion in 255 different programs with the primary goal or primary effect of increasing the supply of STEM workers. This tally combines Brookings research with a detailed assessment from the White House National Science and Technology Council (NSTC).[48]

The NSTC analysis excludes Department of Labor training and education-related programs, presumably because they are not exclusively dedicated to STEM training. Yet, three Department of Labor programs primarily support STEM careers, even if they are not limited to them or even considered STEM by conventional definitions. This adds another $862 million in spending to the $3.4 billion identified from the NSTC, bringing the total to $4.3 billion.

Of the $4.3 billion spent on STEM education, most of the funding (45 percent) is directed toward bachelor's degree or higher STEM education, while a much smaller share (22 percent) supports training or sub-bachelor's education, despite the fact that half of STEM jobs as identified in this analysis do not require a bachelor's degree (Table 9).

Different federal agencies prioritize STEM education and training at different levels. The NSF's STEM-education programs embody the conventional definition of STEM workers (developed in part by NSF): scientific researchers, engineers, and information-technology workers in professional settings. An analysis of NSF grant recipients through its Division of Undergraduate Education finds that only three programs provide significant funding to community colleges, and these funds represent just 14 percent of undergraduate education spending and 7 percent of NSF spending on STEM education.[49] By contrast, the Department of Labor's STEM training programs do not even identify themselves as STEM. They are accidentally STEM oriented in the sense that two of the programs (H-1B Technical Skills Training Grants and Jobs and Innovation Accelerator Challenge) are mandated to "design their education and training programs to support industries and occupations for which employers are using H–1B visas to hire foreign workers." Given that 90 percent of H-1B visas go to STEM workers, most of the training dollars for these two programs end up supporting STEM training, albeit at a level of education that is likely lower than H-1B visa recipients.[50] The other program, the Trade Adjustment Assistance Community College and Career Training Grant (TAACCCT) targets "emerging industries" and the health care sector, which happen to be highly STEM focused. A Brookings analysis of these grants finds that 96 percent of the TAACCT grant dollars support training in STEM industries.[51]

The remaining one-third of federal STEM funding boosts K-12 teacher quality, engages children, educates the general public, evaluates STEM-education efforts (i.e., R&D), and expands institutional capacity (e.g., funds labs or computer equipment). For example, the Department of Education targets

Table 9. Federal Government Funding for STEM Education Programs by Primary Objective

	Approx. Amount (in millions)	Share of Total
Bachelor's degree or higher STEM education	$1,942	45%
Training or sub-bachelor's level degree education (upper limit*)	$940	22%
Education research and development	$519	12%
Pre- and in-service educators	$312	7%
Public learning	$296	7%
Engagement of children	$162	4%
Institutional capacity	$137	3%
Total federal funding for STEM training or education	$4,308	

Data are for fiscal year 2010, except the training and sub-bachelor's level degree funding, which is for 2012.

*Sources: National Science and Technology Council, Department of Labor's Trade Adjustment Assistance Community College and Career Training Grant, and H1B Technical Skills Training Grants. *These funds are not exclusively dedicated to STEM degrees or careers.*

STEM learning through some of its "Investing in Innovation" program grants. In the most recent round of funding, $26 million of $143 million will go to four projects with the primary objective of boosting STEM education. One project– LEED Sacramento–will use a curriculum-based intervention called "Project Lead the Way." Another grantee is the Clark County School District in Las Vegas. Their approach will use a "Pathways to STEM" initiative to immerse students in Grades 6-12 to STEM content and role models. Its interventions include summer camps, weekly sessions with STEM professionals, and STEM Club. Another grantee in Boston will expose high school students to semester-long apprenticeships with volunteer STEM professionals in the region.[52]

State and Local STEM Policy

As shown in Table 8, state and local governments affect STEM education through many channels. They boost university and community college STEM education through funding and scholarships. They support training by coordinating workforce development efforts, and they shape K-12 STEM education by approving and funding of STEM-focused schools; the training, certification, and management of teachers; and the development and enforcement of content standards. Yet, the funding does not appear to be well coordinated across these activities, and efforts to boost STEM education through one channel (e.g., the proliferation of STEM secondary schools) may be undermined by another (e.g., lower funding for community colleges).

In 2010, state and local governments spent $242 billion on higher education.[53] Only a fraction of this was devoted specifically to STEM education, but it is nonetheless a sizable contribution. Yet, budget pressures often mean that budget needs go unmet. STEM majors cost research universities approximately two to four times more per student than sociology and English majors.[54] Likewise, community colleges often rank investment in science and computer labs as the most pressing facility-related spending need.[55] This may explain why some states have cut higher education funding for programs in STEM fields during the slow recovery from the Great Recession.[56] These cuts are part of a broader and unfortunate trend in which state and local funding per community college student has waned during the last decade.[57]

Still, state and local governments are using creative means to bolster STEM education. New York City, for example, is providing significant financial support ($100 million) and land for a new applied sciences campus for Cornell University. Likewise, the governor of Florida has recently proposed charging students lower tuition fees for pursuing STEM or other high-paying degrees at state universities.[58]

State and local governments also approve and support STEM elementary and secondary schools. These schools frequently partner with universities, community colleges, and businesses and provide on-site labs. The vast majority of faculty members have STEM degrees.[59] Most STEM schools have been established recently, but some date back more than 100 years, such as Stuyvesant High School in New York City, which started as a vocational school and is now one of the most prestigious in the city. Like Stuyvesant, some have rigorous admissions standards while others target less advantaged populations. One indication of the rising growth of STEM schools is the National Consortium for Specialized Secondary Schools in Mathematics, Science, and Technology (NCSSSMT), which began in 1988. It now includes about 100 secondary schools as members. Some states are aggressively promoting such schools. Texas spends roughly $39 million annually, in partnership with addition charitable dollars, to fund 51 T-STEM schools for 15,000 students in Grade 6 and up. Virginia has established 17 STEM academies.[60] Metropolitan Nashville Public Schools offers at least nine high school STEM academies and engages the Chamber of Commerce and other organizations to keep the curricula relevant.

States also set curriculum standards and leverage this power to encourage more science and math content. For example, 22 states require students to take at least one lab-based science course in order to earn a diploma.[61] Most states—38 by a recent count—provide incentives for STEM-degree holders to teach in public schools.[62] Ohio, for example, allocated $4 million per year to provide signing bonuses (of up to $20,000 per year) for STEM teachers who work in hard-to-staff schools. The state also offers loan forgiveness for STEM teachers at a cost of $2.5 million per year.[63]

State and city governments play another role in engaging K-12 students. As argued by the National Research Council and the U.S. Conference of Mayors, cities can support informal STEM learning through science museums, zoos, botanical gardens, and other such institutions.[64]

Like the federal government, the evidence suggests that state and local government under-fund sub-bachelor's STEM education. Community colleges receive just 42 percent less funding per student from state and local governments compared with public research universities.[65] Beyond that, compiling and comparing detailed financing at the state and local level is complicated. Therefore, this report makes no attempt to estimate how much state and local governments spend on STEM education for bachelor's level students relative to sub-bachelor's level students and adults, as it does at the federal level. Yet their critical role in supporting community colleges and implementing job training programs means that state and local governments are essential to increasing access to sub-bachelor's STEM jobs.

Nonprofit and Corporate Sector

Colleges and universities play a critical role in both providing STEM education and preparing K-12 teachers. STEM infrastructure —labs, new buildings, and the like—is costly but can boost capacity for STEM education. Scholarships or other financial incentives to support students in STEM fields provide the means and motivation to boost attainment. Finally, universities are also having an impact on K-12 STEM education. The UTeach program, for example, streamlines teacher certification by embedding teaching experience and support into traditional STEM degree programs. It has been implemented at 35 universities.[66]

Likewise, community colleges make direct and large contributions to the STEM workforce. Community colleges award more than one-half of all postsecondary STEM degrees.[67] Presidents and boards of these institutions are critical to ensuring that their STEM programs are affordable and relevant to their students. One way to ensure relevancy is to coordinate closely with local employers. For example, Chattanooga State Community College offers two STEM-intensive courses in automation mechatronics and car mechatronics in partnership with Volkswagen, which provides paid internships for the students.[68] The demanding three years of coursework touch on each of the STEM domains, including calculus, physics, "Industrial Mathematics," electronics, and electrical engineering, and include classes on computer programming with technical and mechanical applications.

Businesses and corporations can also make important contributions to STEM development at each level. For younger students, individual STEM professionals, for example, can visit classrooms, tutor, or arrange for guided tours or demonstrations at their place of work. Some corporations also host science contests, such as Siemens and Intel. IBM has partnered with New York City to create P-TECH, which will integrate computer science training into an inclusive STEM high school with a streamlined associate's degree track.[69] Chicago is setting up similar schools—called Early College STEM Schools—in partnership with IBM, Motorola, Verizon, Cisco, and Microsoft.[70] At the postsecondary level, paid internships, apprenticeships, and business-sponsored training are all viable and even profitable approaches to solving workforce needs, while inspiring and educating students or adults.

Do STEM Programs Work?

Despite the somewhat abstract nature of many STEM interventions, a surprising amount is known about their efficacy, according to the NSTC study and a survey of the research.[71] More to the point, many programs to boost STEM education work even when replicated in different regions or universities.[72] These research findings align with encouraging research on coaching, mentoring, and even low-cost financial advice in advancing STEM education.[73]

Yet there is still much work to be done in evaluating the diverse array of interventions that aim to inspire or motivate students to enter STEM careers. One challenge is that evaluations have focused on university-level training rather than community college and non-degree programs. Given that almost no federal money is directed to programs designed specifically to boost STEM associate's degrees, certificates, and on-the-job training, program efficacy remains a question. Yet a few relevant Department of Labor programs are showing positive signs.

A review of the H-1B training grant program found that almost all enrollees were in STEM fields and that the number who dropped out before completing training was very low (1,238) compared with the number that completed training (7,646).[74] The report emphasizes the need to require better tracking of student outcomes and questions whether some of the workers are skilled enough to fill in for H-1B workers. Nonetheless, the program clearly boosts STEM education, and it has the added advantage of being reasonably well coordinated with local labor market needs.

In the TAACCCT, whose initial grants were only recently awarded, the Department of Labor has made evaluation an important part of the program. So far, anecdotal evidence from community college leaders suggests that this funding is leading to valuable educational and training experience.[75] The interventions that have proved in the past to boost retention and attainment in advanced STEM degrees—mentoring, financial aid and guidance, apprenticeships—are likely to have a similar effect for community college students or adult training participants, but the outcomes data should be carefully evaluated before committing further funding.

Beyond these two programs, however, Department of Labor programs may fail to sufficiently appreciate the importance of skill acquisition, even in non-university settings. As documented above, the average STEM job requires at least one year of on-the-job training, but a recent study of Trade Adjustment Assistance grantees (not the community college program counted as part of this analyses) found that most trainees were receiving training of less than one year in both STEM and non-STEM careers.[76]

K-12 STEM interventions may be some of the hardest to evaluate given the often long duration between outcomes (a successful career in a STEM field) and the intervention itself. Still, results from STEM focused schools are suggestive.[77] Other interventions that target "inspiration" or motivation to pursue STEM have been reviewed with varying degrees of rigor and clarity, and it is not entirely clear how effective these efforts have been.[78]

Conclusion

The above discussion makes it clear that the excessively professional definition of STEM jobs has led to missed opportunities to identify and support valuable training and career development at the federal level and weakened coordination between workforce development and education at the state and local levels.

Largely through the NSF, the federal government is funding a large number of programs to boost higher-level STEM education, particularly for minorities and women. Many appear to be effective, and the next rounds of funding should clarify what works and what does not. Yet, only a small slice of federal educational spending supports the other half of STEM careers—those requiring an associate's degree or less.

The overemphasis on four-year and higher degrees as the only route to a STEM career has neglected cheaper and more widely available pathways through community colleges and even technical high schools. This neglect is all the more nonsensical given that roughly half of students who earn four-year STEM degrees start their education at community colleges.[79] While the federal government should strengthen its support of these efforts, the primary responsibility for funding and administrative support will fall to the state and local governments who benefit the most directly from a STEM-knowledgeable workforce.

It is difficult to argue, given all the attention it has received, that STEM knowledge is underappreciated. Yet, because the focus has been on professional STEM jobs, a number of potentially useful interventions have been ignored. In this sense, jobs that require less than a bachelor's degree represent a hidden and unheralded STEM economy.

APPENDIX

Methodological Appendix

*Linking O*NET to Historic Census Data Using IPUMS*

The process of linking O*NET data to other databases was complicated by the lack of complete correspondence between occupational systems, despite a universal basis in the Standard Occupational Classification (SOC) system. Table A1 summarizes the steps taken to obtain accurate matches. The first step—matching O*NET education and training data to O*NET knowledge scores (though even this did not yield a perfect match)—was the easiest. The mode (or most frequent) education, training, and experience level was taken to represent the level typically required.

The next step was to make the knowledge scores compatible with other occupational formats. For some occupational categories, O*NET's SOC coding scheme and knowledge survey contain more detailed coding (8-digits) than that collected from the BLS SOC. Likewise, there are some minor differences in how some occupations are coded. The latter mismatches could be overcome by using a crosswalk between the O*NET and BLS SOC systems. This crosswalk is provided by the National Crosswalk Service via O*NET and allowed for aggregation to 6-digit SOC codes.[80] The unmatched codes were matched manually so that multiple, more detailed 8-digit O*NET scores were matched to a single 6-digit SOC. For example, O*NET provides knowledge scores for four distinct 8-digit occupations within the single 6-digit category "Mangers, All Other" (SOC 11-9199): Loss Prevention Managers, Supply Chain Managers, Compliance Managers, and Regulatory Affairs Managers. The average knowledge scores for the more detailed O*NET codes were applied to the less detailed BLS SOC codes.

Table A1. Summary of Procedures in Calculating Knowledge Scores by Occupation Using the BLS Occupational Employment Statistics (OES) Survey and Census Data

Purpose of Procedure	Description
Include education and training data	Match O*NET knowledge survey scores to O*NET education and training survey results
Process knowledge data	Match O*NET knowledge survey scores to Bureau of Labor Statistics (BLS) coding scheme using O*NET crosswalk
Repair match to OES	65 codes did not match because O*Net provided more detailed coding than BLS; O*NET scores were averaged across the more detailed occupations
Derive knowledge scores	Code knowledge domains by stem and calculate mean-adjusted scores
Match to census	Match O*NET knowledge survey scores to IPUMS coding of 2011 American Community Survey occupations
Repair match to census data	162 unique IPUMS occupational codes (OCCSOC) did not match O*NET/BLS scheme and needed to be matched manually; average knowledge scores were calculated across more detailed occupations, using OES jobs as weight.
Determine STEM gradient	Derive standardized STEM scores for each knowledge domain; calculate range for raw scores
Analyze 2011 census data; apply STEM scores and gradient to other surveys	Use the knowledge scores and gradients (high, mid-high, mid-low, low) retrospectively in other census surveys and OES surveys

Note: IPUMs is Integrated Public Use Microdata Series; BLS is Bureau of Labor Statistics, OES is Occupational Employment Statistics

Table A2. Determining O*NET Knowledge Gradients in the Brookings STEM Database

	Value Above Mean Required to Get High Score	Mean Raw O*NET Score
STEM Fields		
STEM	>4.5	3.3
Science (physics, chemistry, and biology combined)	>2.7	1.9
Computers and electronics	>1.7	3.1
Engineering and technology	>1.2	2.1
Mathematics	>1.3	3.3
Non-STEM Fields		
Non-STEM (all non-STEM combined)	>19	3.8
Knowledge (all 33 domains)	>21.9	3.8
Law	>1.4	2.2
English	>1.2	3.6
Management	>1.5	3.0
Economics and accounting	>2.0	1.6

*Sources: Brookings analysis of O*NET; the 2011 American Community Survey (ACS) via Integrated Public Use Microdata Series, and the BLS Employment Statistics Survey (OES), 2011.*

*Notes: Scores are the sum across each domain (6 for STEM; 27 for all non-STEM) of raw occupational score minus the nonweighted mean of all occupations for that domain. High scores are 1.5 standard deviations above the mean. The standard deviations are calculated using the de-meaned knowledge scores for the occupations of all U.S. workers (or 1.8 million observations from the ACS). Mean raw O*NET score is the nonweighted average across all occupations on a 1-7 scale.*

The next step was to calculate average scores for each knowledge domain to get a mean non-weighted knowledge score. These scores are reported in the far right column of Table A2. The mean score was 3.1 out of 7 for computers and electronics knowledge and 2.1 for engineering and technology knowledge (that score is slightly more advanced than installing a doorknob but not nearly as sophisticated as designing a more stable grocery cart).

Then, the difference between the actual knowledge score, for a given 6-digit occupation, and the mean score was calculated and summed across knowledge domains for scores with multiple domains. For STEM, this meant summing over the six different domains.

To grade the level of these scores (to determine whether they were high or low), the O*NET scores had to be matched to an existing database of employment by occupations. It was decided to use individual records from the Census Bureau's American Community Survey (ACS), which are accessible via the Integrated Public Use Microdata Series (IPUMs). The most accurate source of occupational data is the Bureau of Labor Statistics' Occupational Employment Statistics Survey (OES). Over a three-year period, it samples 77 percent of U.S. establishments or 73 percent by employment and obtains survey responses from employers representing 93 million jobs. By contrast, the Census Bureau's 2010 American Community Survey (ACS) samples just one percent of the entire population (or roughly 3 million people). Yet, while specific occupational data is likely to be more accurate using the OES, the survey excludes a few large occupational categories that are likely to have low knowledge scores (household workers like nannies, the self-employed, military personnel, and many farm workers), and thus, it is less likely to yield an accurate distribution of knowledge scores than the American Community Survey.

Using the 2011 ACS (the most recent at time of research), the IPUMS OCCSOC codes, which closely approximate the BLS SOC system, were used to match the six-digit O*NET derived knowledge scores. A raw match excluded 162 different occupations. Using IPUMS and O*NET definition files, these missing occupations were coded manually (not using a formal algorithm but rather the occupational titles) by the researcher using a similar procedure as described above: multiple O*NET knowledge scores were assigned to single more aggregated OCCSOC categories. Here, BLS employment numbers by occupation were available to provide weights, so a weighted average could be calculated. For example, the ACS data would provide a code for "cooks," whereas the BLS and O*NET distinguish between cooks working in a fast food restaurant, institutional cafeteria, private household, restaurant, or short order. Rather than simply taking the average score across the more detailed categories, BLS data could be use to weight the average to make it representative (e.g. there are many more cooks at restaurants than private households or institutional cafeterias).

Once the data was linked, the standard deviation for each knowledge score was calculated. The knowledge gradient was determined by distinguishing "High" as 1.5 standard deviations above the mean; "mid-high" as between 0.5 and 1.5 standard deviations above the mean. The corresponding non-mean scores are in Table A2. To interpret these unitless numbers, consider STEM. To be high-STEM (or super-STEM), an occupation must score 4.5. That score could be obtained if an occupation scores exactly one point (on the 1-7 scale) above the mean in five different domains (e.g., all six except Computers and Electronics) and above -0.5 standard deviations below the mean on the sixth. This places a worker in the 93rd percentile of STEM knowledge, based on calculations with the census data.

Once STEM scores were calculated for all occupations in 2011, the next challenge was to link these occupations to the closest schema available in previous decennial records. For 2011, 2010, and 2000, the current SOC system could be used (called OCCSOC in IPUMS) to obtain matches for most jobs. For 1990, however, and each decennial year back to 1950, the best available system was "OCC1990," created by IPUMS using the 1990 Census classifications of occupations or the "OCC1950" variable, also created by IPUMS based on the 1950 Census. So, from 1950 to 2000, occupations were assigned STEM ratings based on the link between the SOC system in the 2010 Census and either OCC1990 or OCC1950, with priority given to earlier system. From 1850 to 1940, OCC1950 was the only consistent occupational system available.

This process started with the 2010 Census, which includes the SOC, OCC1990, and OCC1950 systems. Those occupations were first STEM coded based on their SOC designation (which could be linked to O*NET scores), and then average STEM scores were calculated for each unique SOC, OCC1990 code, and separately for each unique OCC1950 code. These STEM assignments were then applied to occupations in previous years. For those occupations in a decennial year—say 1980—not captured by the SOC or 1990 system, the OCC1950 IPUMS coding systems was used. This iterative process insured that each occupation was classified according to the occupational system closest to the 2010 O*NET system to maximize accuracy.[81]

Analytic Appendix

To test if metropolitan aggregated STEM knowledge is correlated with economic performance, a variety of economic variables were regressed on STEM knowledge, controlling for the educational attainment of the metropolitan area workforce, the non-STEM knowledge score, population, state effects, and other relevant controls listed in Table A3. The implication is that the STEM score of a metropolitan economy is robustly correlated with better economic performance across these various indicators, which include job growth since the recession, exports as a share of GDP, current unemployment rate, median household income, average local service sector wages, average manufacturing sector wages, and tech sector employment shares. In other words, even in industries with few STEM workers, real wages (median rent is used as a control) appear to be higher in metropolitan areas with a more STEM oriented labor force.

The tech-sector employment share variable is obtained from Moody's Analytics. It combines advanced manufacturing industries like computer and electronics manufacturing and chemical manufacturing with tech-services like information and R&D. In a recent Brookings report, metropolitan area employment in this sector was highly correlated with productivity growth.[82] The point here is not that STEM workers cause tech-sector entrepreneurship, though there is evidence to suggest that, but rather that the tech-sector depends on STEM workers.[83]

Next, the analysis examines whether these metropolitan area correlations hold for sub-bachelor's STEM jobs. To do this, the STEM score was dropped and replaced it by the share of workers with

Table A3. Regressions of Economic Performance Metrics on Metropolitan STEM Score and Education

	Job Growth 2008q1 to 2012q1	Exports/ GDP, 2010	Patents per Worker, 5-Year Ave. 2011	Unemployment Rate, 2011	Median Household Income, 2011	Ave. Local Service Sector Wages, 2011	Ave. Manufacturing Sector Wages, 2011	Tech Sector Share of Jobs, 2011
	1	2	3	4	5	6	7	8
STEM Score, 2011, standardized	0.00950***	0.0318***	0.384***	-0.318***	2,688***	2,247***	5,650***	0.0117***
	(0.00282)	(0.00470)	(0.0610)	(0.108)	(311.0)	(404.7)	(941.3)	(0.00142)
Non-STEM Score, 2011, standardized	-0.00960***	-0.0421***	-0.266***	0.278**	-826.7**	-894.2**	-1,641	-0.00465***
	(0.00332)	(0.00661)	(0.0678)	(0.120)	(345.2)	(449.2)	(1,045)	(0.00158)
Average years of education, adults 25 and older, 2011, standardized	0.00474**	0.00232	0.420***	-0.961***	756.0**	431.2	1,338	0.0102***
	(0.00223)	(0.00437)	(0.0518)	(0.0919)	(313.2)	(407.5)	(947.8)	(0.00121)
Housing prices Growth, 2006-2012q1	0.0951***							
	(0.0225)							
MSA Population, 2011	5.74e-10	0	-9.77e-09	7.70e-08*	6.03e-05	0.000556***	0.000308	1.42e-09**
	(1.16e-09)	(8.81e-10)	(2.61e-08)	(4.64e-08)	(0.000141)	(0.000183)	(0.000427)	(6.10e-10)
Predicted Job Growth 2008q1 to 2012q1, based on industry composition	1.430***							
	(0.200)							
Median rent, 2011					35.35***	17.34***	36.45***	
					(2.485)	(3.234)	(7.521)	
Constant	0.0260***	0.108***	0.634***	8.527***	19,829***	23,760***	29,702***	0.0314***
	(0.00732)	(0.00349)	(0.0427)	(0.0757)	(1,940)	(2,525)	(5,872)	(0.000995)
State Effects	YES	YES	YES	YES	YES	YES	YES	YES
Observations	357	100	357	357	357	357	357	357
Adjusted R-squared	0.477	0.647	0.433	0.668	0.814	0.498	0.378	0.499

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Brookings analysis of data for 357 metropolitan areas from: Export Nation, Strumsky Patent Database, Moody's Analytics, the American Community Survey, the Bureau of Labor Statistics. Job losses since recession measures the growth rate of employment from the first quarter of 2008 to the first quarter of 2012. Export data is available only for the 100 largest metropolitan areas.*

Table A4. Regressions of Economic Performance Metrics on Metropolitan STEM Score and Education

	Job Growth 2008q1 to 2012q1	Exports/ GDP, 2010	Patents per Worker, 5-Year Ave., 2011	Unemployment Rate, 2011	Median Household Income, 2011	Ave. Local Service Sector Wages, 2011	Ave. Manufacturing Sector Wages, 2011	Tech Sector Share of Jobs, 2011
	1	2	3	4	5	6	7	8
Sub-bachelor's degree STEM jobs	0.000315	0.0163***	0.140***	-0.147*	1,068***	1,020***	3,805***	0.00239**
	(0.00232)	(0.00541)	(0.0475)	(0.0887)	(251.6)	(325.9)	(743.3)	(0.00101)
Bachelor's degree or higher STEM jobs	0.00770**	0.0303***	0.566***	-0.181	2,983***	2,621***	6,324***	0.0201***
	(0.00333)	(0.00611)	(0.0709)	(0.132)	(375.2)	(486.1)	(1,109)	(0.00151)
Observations	357	100	357	357	357	357	357	357
Adjusted R-squared	0.465	0.615	0.480	0.662	0.815	0.507	0.413	0.614

*Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. The independent variables shown are standardized to have mean zero and standard deviations of one to facilitate comparisons. Brookings analysis of data for 357 metropolitan areas. All regressions include controls from previous table. See previous table for notes.*

sub-bachelor's STEM jobs and the share with bachelor's degree STEM jobs. Both variables were standardized to facilitate comparison. If only highly educated STEM workers drive innovation and other aggregate benefits, then the coefficient on that variable should be large and significant, and the coefficient on sub-bachelor's STEM jobs should be indistinguishable from zero. That is not the case. Both variables are significant in six of the eight regression analyses and all of the "innovation" metrics, such as exports as a share of GDP, patents per worker, and tech employment shares (Table A4). Incomes are also higher as the share of sub-bachelor's STEM jobs increases. Only job growth since the recession and unemployment rates are not significantly related to the sub-bachelor's growth.

Another finding from this exercise is that the size of the sub-bachelor's degree STEM effect is a fraction of the bachelor's degree effect. It is 12 percent of the effect on tech-sector employment, 25 percent of the effect on patenting, 36 percent of the effect on median income, 54 percent of the effect on exports, and 60 percent of the effect on manufacturing sector wages. In other words, sub-bachelor's STEM workers are not as valuable as the more highly educated STEM workers, but they make very important contributions to these aggregate metropolitan area measures, or, at least, their presence is highly correlated with these positive outcomes, as these regression analyses cannot prove causality.

To test if individuals are better off –in terms of higher wages—in STEM oriented economies, IPUMS was used to access the 2011 ACS. To adjust for living costs, median quality adjusted housing costs were first calculated by fitting a model to predict housing costs. Quality was adjusted using the dummy variables for the age of the home, the log of the number of room, and dummy variables for single-detached and single-attached (with multi-family omitted), garage capacity, acreage, and public access to public transportation. Actual housing costs were divided by the predicted housing costs from this model. The weighted median was then calculated.

Then in the final model, housing costs were included along with other variables aggregated to the metropolitan area using the Census data: population, bachelor's degree attainment rate, the aggregated STEM score, and the aggregated non-STEM knowledge score. Individual controls, such as age, education, race, and sector of work (2-digit NAICS) were included.

Table A5 shows that metropolitan level STEM knowledge is associated with higher individual wages (column 1). This results hold for STEM workers and workers with a bachelor's degree or higher. However, the effect is insignificant for non-STEM workers and those without a bachelor's degree

Table A5. Regression of Wages on Individual and Metropolitan Characteristics, 2011

	Ln Wage					
	1	2	3	4	5	6
MSA median quality adjusted housing costs	0.323***	0.358***	0.291***	0.332***	0.270***	0.313***
	(0.0306)	(0.0385)	(0.0336)	(0.0383)	(0.0430)	(0.0315)
MSA population	4.63e-09	7.87e-09*	2.58e-09	4.50e-09	1.67e-09	5.02e-09
	(3.95e-09)	(4.71e-09)	(3.88e-09)	(4.63e-09)	(4.61e-09)	(3.97e-09)
MSA bachelor's degree attainment rate	-10.34	-5.391	-11.81	-26.07**	-24.52*	-7.052
	(9.263)	(10.36)	(9.249)	(11.11)	(14.09)	(9.071)
MSA STEM score	0.0372**	0.0434**	0.0307	0.0655***	0.0890***	0.0289
	(0.0178)	(0.0198)	(0.0212)	(0.0178)	(0.0197)	(0.0197)
MSA Non-STEM score	-0.00279	-0.0135*	0.00333	-0.00229	-0.00585	-0.00223
	(0.00647)	(0.00753)	(0.00769)	(0.00641)	(0.00864)	(0.00718)
Individual STEM score	0.0797***	0.0724***	0.0881***	0.0252***	-0.00252	0.0366***
	(0.00168)	(0.00222)	(0.00248)	(0.00351)	(0.00569)	(0.00403)
Individual non-STEM score	0.170***	0.197***	0.151***	0.0570***	0.0514***	0.216***
	(0.00228)	(0.00420)	(0.00272)	(0.00351)	(0.00493)	(0.00308)
Age	0.527***	0.726***	0.406***	0.348***	0.348***	0.559***
	(0.0317)	(0.0502)	(0.0470)	(0.0571)	(0.0915)	(0.0376)
Age^2	-0.0163***	-0.0225***	-0.0125***	-0.00910***	-0.00851***	-0.0177***
	(0.00115)	(0.00182)	(0.00169)	(0.00202)	(0.00322)	(0.00137)
Age^3	0.000231***	0.000318***	0.000179***	0.000111***	9.48e-05*	0.000258***
	(1.80e-05)	(2.86e-05)	(2.64e-05)	(3.11e-05)	(4.91e-05)	(2.17e-05)
Age^4	-1.26e-06***	-1.72e-06***	-9.85e-07***	-5.37e-07***	-4.16e-07	-1.43e-06***
	(1.04e-07)	(1.65e-07)	(1.50e-07)	(1.75e-07)	(2.74e-07)	(1.26e-07)
Noncitizen	-0.172***	-0.246***	-0.144***	-0.139***	-0.136***	-0.181***
	(0.00909)	(0.0153)	(0.0113)	(0.0151)	(0.0189)	(0.00875)
Black	-0.164***	-0.145***	-0.168***	-0.178***	-0.158***	-0.154***
	(0.00618)	(0.00787)	(0.00704)	(0.0114)	(0.0185)	(0.00615)
Asian	-0.0830***	-0.0704***	-0.0928***	-0.0365***	-0.0458***	-0.125***
	(0.0136)	(0.0114)	(0.0215)	(0.00844)	(0.0106)	(0.0193)
Latino	-0.0725***	-0.143***	-0.0534***	-0.137***	-0.130***	-0.0550***
	(0.00874)	(0.0102)	(0.00865)	(0.00939)	(0.0141)	(0.0100)
Male	0.282***	0.285***	0.275***	0.248***	0.264***	0.285***
	(0.00391)	(0.00625)	(0.00504)	(0.00601)	(0.0100)	(0.00411)
Doctorate or professional degree	0.971***	0.382***		1.114***	1.143***	0.895***
	(0.0139)	(0.00906)		(0.0196)	(0.0349)	(0.0165)
Master's degree	0.743***	0.156***		0.884***	0.863***	0.675***
	(0.0105)	(0.00521)		(0.0154)	(0.0286)	(0.0120)

Table A5. Regression of Wages on Individual and Metropolitan Characteristics, 2011 (continued)

	Ln Wage					
	1	2	3	4	5	6
Bachelor's degree	0.582***			0.745***	0.725***	0.505***
	(0.00903)			(0.0151)	(0.0293)	(0.00922)
Some college	0.298***		0.312***	0.408***	0.353***	0.278***
	(0.00719)		(0.00694)	(0.0139)	(0.0275)	(0.00756)
Associate's degree	0.376***		0.393***	0.498***	0.411***	0.325***
	(0.00870)		(0.00874)	(0.0157)	(0.0306)	(0.00946)
High school diploma	0.202***		0.212***	0.255***	0.224***	0.195***
	(0.00707)		(0.00658)	(0.0144)	(0.0265)	(0.00750)
Constant	3.313***	1.438***	4.796***	4.994***	4.929***	3.101***
	(0.321)	(0.503)	(0.471)	(0.592)	(0.966)	(0.376)
Restrictions		Bachelor's degree and higher	Sub-Bachelor's degree	High-STEM, any field	Super-STEM	Non-STEM
State Effects	YES	YES	YES	YES	YES	YES
Industry-Sector Fixed Effects	YES	YES	YES	YES	YES	YES
Observations	823,851	314,195	489,919	742,330	79,000	616,901
Adjusted R-squared	0.316	0.261	0.219	0.261	0.298	0.282

*Robust standard errors in parentheses, clustered on metropolitan areas. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. In all regressions, sample is restricted to those in the workforce and not in the military, aged 25 to 64.*

(columns 3 and 6). One might interpret this as evidence that real wages are higher in innovative STEM economies, but only for highly educated or skilled workers. Interestingly, metropolitan educational attainment had no effect on real wages, nor did aggregated knowledge in all non-STEM domains combined. A one standard deviation in the STEM score equals 0.5 and the range is 2.9. Thus, predicted wages are 11 percent in the highest STEM metro area compared with the lowest STEM area.

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21. The knowledge survey is more preferable in identifying STEM skills than the O*NET abilities or skills survey. Those surveys are highly abstract and with the exception of "mathematical reasoning" ability and math and science skill have no clear overlap with STEM fields. The knowledge survey also overlaps with the skills required by career tracks and occupations in a much more direct way. For example, lawyers score highly on legal knowledge, managers on managerial knowledge, and chemists on chemistry. Findings associated with knowledge, which can be taught, would seems to have more practical use for training and educational policy than findings associated with the importance of "deductive reasoning" or "flexibility of closure," for example, which are O*NET fields in their Abilities survey or "learning strategies," which is a skill field.

22. See Florida Department of Economic Opportunity, STEM, available at www.floridajobs.org/labor-market-information/products-and-services/stem (April 2013). Relying on O*NET, Florida report STEM scores for each occupation for the STEM knowledge category with the highest knowledge score (it includes medicine and dentistry, in addition to those included here). Although very similar to the method used here, this discards information about knowledge in other domains that may be combined to enhance skills (e.g., biomedical engineering). O*NET itself provides a list of occupations it considers STEM, but it disregards significant information. For example, using the O*NET STEM classification, one cannot know whether one STEM job requires more or less STEM knowledge than another. Moreover many jobs that require substantial STEM-related skills are excluded all together because of the binary definition of STEM and non-STEM. O*NET Online, Browse by STEM Discipline, available at http://www.O*NETonline.org/find/stem?t=0

23. O*NET, https://O*NET.rti.org/pdf/Knowledge.pdf (March 2013).

24. Other O*NET knowledge fields were also considered as potentially STEM, but rejected. For example, Economics and Accounting was rejected on the grounds that its knowledge field does not add anything to STEM beyond mathematics, which is captured more purely by the math field. In practice, economists, accountants, and actuaries score somewhat highly on STEM because they rely heavily on mathematics. Similar reasoning was used to exclude medical knowledge, which, in STEM form, is already captured by the natural sciences.

25. In analyzing wages, we compared STEM knowledge with other knowledge classifications in O*NET. One way to classify O*NET knowledge scores is to combine knowledge across all 33 knowledge domains. This measures knowledge requirements generally and can be taken to signify broad educational requirements. Other categories considered included professional knowledge fields correlated with high-paying jobs, including "Legal and Government," "Economics and Accounting," "English," and "Management and Administration." In subsequent work, we intend to highlight how well STEM knowledge compares with knowledge in these other fields. For related analysis of O*NET knowledge scores, see Gabe, "Knowledge and Earnings," who finds that engineering and computer skills have significant marginal effects on wages, holding all other knowledge fields constant.

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34. A more precise measures of dispersion—the coefficient of variation—also shows that sub-bachelor's STEM jobs are much more evenly spread across metropolitan areas than those that require a bachelor's degree or those in computer, math, engineering, and science fields.

35. To calculate the degree of clustering by occupation across metropolitan areas, we calculated location quotients (MSA share of occupational employment divided by U.S. share of occupational employment) across metropolitan areas for each major two-digit occupational group, 22 in total. The coefficient of variation was then calculated using the mean and standard deviations of the location quotients in a sample of all metro areas. Those occupations with the highest coefficient of variation measures were deemed the most clustered. The top four were farming, scientists, engineers, and computer and mathematics occupations. In this measure of dispersion, installation, maintenance, and repair occupations ranked 19th of 22 and health care practitioners ranked 16th.

36. These results are robust to controlling for metropolitan area population, non-STEM knowledge, and educational attainment.

37. The finding that STEM skills predict better economic performance is robust to different definitions of STEM, other than the one introduced here. As discussed in the appendix, we also used the binary professional-oriented STEM definitions from Georgetown, the NSF, and the Department of Commerce to rate metropolitan areas by the share of jobs in STEM fields. A comparison between those measures and our O*NET measure reveals that the professional-oriented measures do a better job of predicting tech-sector employment and patenting rates, but our broader O*NET measure does a better job of predicting job growth and exports as a share of GDP. In other words, the focus on professional STEM jobs captures researchers involved in patenting, but misses many workers involved in the commercial production of goods and services. The strongest metropolitan areas are those that score highly on both attributes, such as San Jose, which ranks first on both measures. That said, our O*NET method allows one to examine each field of the STEM score. None of these measures predicts patents or tech sector workers better than the percentage of the workforce in high-level

computer and electronics occupations as determined by the Brookings O*NET definition.

38. This holds true adjusting for median rental prices, suggesting that real wages are higher for workers in high-STEM metro areas.

39. The sub-bachelor's effect is roughly 25 percent of the bachelor's effect on patents, 36 percent of the effect on median incomes, and 54 percent of the effect on exports.

40. As measured by the Gini coefficient.

41. Edward L. Glaeser, Matt Resseger, and Kristina Tobio, "Inequality in Cities," *Journal of Regional Science* 49(4) (2009): 617-646.

42. These results are available upon request. In addition to what is described in the text, the analysis regressed the 2011 Gini coefficient for 357 metro areas on 2011 STEM score, controlling for population, average years of education, state-fixed effects, and the O*NET knowledge score for all other non-STEM fields combined, which captures high-knowledge jobs in fields such as finance, management, and law. The results were highly robust in showing that STEM oriented is negatively correlated with inequality. The same is true when the STEM score is replaced by the sub-bachelor's STEM share of the workforce or both the sub-bachelor's and bachelor's shares, both of which are negatively correlated with inequality in these regressions.

43. In contrast with STEM knowledge, metropolitan area measures of non-STEM knowledge—and even educational attainment—are not associated with higher earnings. Yet, high individual knowledge scores in both STEM and non-STEM fields boost wages.

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49. This analysis examined all awards from the Division of Undergraduate Education given out during fiscal year 2010. These three programs are the Advanced Technological Education (ATE), NSF Scholarships in STEM (S-STEM), and STEM Talent Expansion Program. The ATE program appears to dedicate almost 100 percent of its funding to support community college education, while the other two allocate roughly 14 and 10 percent of their spending to community colleges, respectively. These calculations were based on searching for key words

"community" and "technical" in the organization names and reviewing abstracts of grantees. The Interdisciplinary Training for Undergraduates in Biology and Mathematical Sciences program apparently gave out one grant to a community college.

50. This finding is based on Brookings analysis of O*NET and data from the Foreign Labor Certification Data Center, available at http://www.flcdatacenter.com/CaseH1B.aspx. More detailed results will be discussed in forthcoming work. In practice, there are concerns that some of the money is going to short-term training programs that are not necessarily meeting the program's goals. Neil G. Ruiz, Jill H. Wilson, and Shyamali Choudhury, "The Search for Skills: Demand for H-1B Immigrant Workers in U.S. Metropolitan Areas" (Washington: Brookings, 2012).

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52. Not included in this funding tally are unfunded Obama administration proposals, including $80 million for a K-12 STEM teacher-training program through the Department of Education's Effective Teachers and Leaders State Grants program (Washington: Office of Management and Budget, March 2013), available at www.whitehouse.gov/omb/budget/Overview. For other programs see, Jane J. Lee, "Obama's Budget Shuffles STEM Education Deck," Science, February 14, 2012.

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66. The UTeach Institute, available at http://www.uteach-institute.org/ (March 2013).

67. Brookings analysis of IPEDS data from the National Center for Educational Statistics, 2011.

68. Chattanooga State University, Engineering Technology Department, available at www.chattanoogastate.edu/engineering-technology/partnerships/vw-academy/ (March 2013)

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79. National Research Council and National Academy of Engineering, *Community Colleges in the Evolving STEM Education Landscape*.

80. See 2010 SOC Crosswalk, available at www.O*NETcenter.org/supplemental.html#ncsc (March 2012).

81. Two important changes to coding were required to accurately capture farmers and software developers. O*NET does not provide a knowledge score for the occupation "Farm and Ranch Managers," which is coded as 11-9013 in the SOC or 11-9013.02 in O*NET. Instead, O*NET provides knowledge scores for nursery managers and aquaculture managers, which are very different occupations than farmers, but differ only at the 8-digit level, in terms of O*NET classification. The Census Bureau's OCCSOC uses 11-9013, which combines these three types of managers, and these are all classified as farm owners and tenants using the OCC1950 system. Instead of applying an incorrect knowledge score, we changed this occupation code to 45-2093 (Farmworkers, Farm, Ranch, and Aquaculture Animals), which seemed to more appropriately capture the knowledge required to be a farmer, even if sacrificing some of the managerial skills (though farm management is listed by O*NET as a key knowledge domain for occupation 45-2093). A different problem required a change to the software classification. The 2010 Census and IPUMS do not have a six-digit SOC code for software developers, despite its existence in the SOC system. Instead, they use 15113X, which, at the 5-digit level, is the same as less skilled computer programmers. Instead of applying knowledge scores for computer programmers (or all workers with 15-113 codes) to software developers, we changed the Census code from 15-113X to the appropriate code of 15-1333 to accurately distinguish software developers from programmers, which are coded as 15-1131 by IPUMS. For all other cases, if IPUMS used a 5-digit code with an X or Y, we dropped the X or Y and used the five-digit code for matching the SOC and O*NET systems.

82. Rothwell and others, "Patenting Prosperity."

83. Vivek Wadhwa, Richard Freeman, and Ben Rissing, "Education and Tech Entrepreneurship."

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