H-1B Visas and the STEM Shortage: A Research Brief

Last Revised May 10, 2013

By: Jonathan Rothwell and Neil G. Ruiz[1]

The Senate introduced a landmark comprehensive immigration reform bill last month that has the potential to both increase the number of available H-1B visas for skilled foreigners working in specialty occupations and shift the U.S. employment-based visa system to a more merit-based scheme that favors science, technology, engineering, and mathematics (STEM) workers.[2] As the Congressional process moves forward, debate continues over the role of immigrants in the U.S. labor market. Focusing on demand-side arguments, businesses say they cannot find the skills they need from the domestic labor pool and need access to a global pool of skilled workers.[3] On the other hand, some analysts have argued that there are plenty of U.S. native-born workers who can do these jobs.[4] Such positions fit into a broader literature analyzing whether or not there is a sufficient supply of STEM workers to meet employer demands and foster innovation.[5] This article examines new and rarely-used metrics on the supply of and demand for STEM occupations in an effort to inform public policy and better understand the market for STEM workers and H-1B visas.

An analysis of the demand for STEM skills in H-1B occupations and the supply of the current U.S. STEM workforce reveal that:

- **The vast majority—90 percent—of H-1B petitions request workers in occupations requiring high-level STEM knowledge, but 25 percent of these occupations are commonly staffed by workers with just an Associate's degree.**

- **H-1B STEM job vacancies are harder-to-fill than other job openings.**

- **H-1B workers are paid more than non-H-1B workers generally and even within the same occupation for workers with similar experience.**

- **For occupations with the most H-1B requests, recent wage growth has been much higher than the national average.**

- **In the Metropolitan Areas with the most H-1B requests, average wages for STEM occupations with H-1B requests are extremely high, the vacancies are hard-to-fill, and industry wages are growing.**

The measurements and trends reviewed in this article offer new national and sub-national information about the demand and supply for high-skilled foreign labor. The evidence suggests that the H-1B program does help fill a shortage in labor supply for the occupations most frequently requested by employers. Most of these are for STEM occupations. Vacancies for H-1B positions are hard-to-fill, and H-1B holders earn more than comparable U.S. native-born residents suggesting that they provide hard-to-find skills. Moreover, the industries with the most H-1B requests have experienced significant wage

growth in recent years. In the metropolitan areas with the most H-1B requests per worker, high and growing wages in difficult-to-fill occupations persist despite a large influx of immigrant workers.

There are two important caveats. First, hard-to-fill high-skilled jobs do not always require many years of post-secondary training. Even among H-1B visas requests, many require only an Associate's degree, meaning that the current U.S. workforce could be trained to do these jobs at relatively little cost. Second, not all STEM jobs are experiencing the same symptoms of shortage. Employment has declined and wage growth has stalled for life science occupations in recent decades. Wages for engineers are up, but job growth has only recently recovered from a sustained slump. On the other hand, wage and job growth has grown robustly for computer and math workers, physical scientists, and health practitioners.

Overall, there is compelling evidence that the H-1B visa program is helping to alleviate acute shortages in various occupations. Yet, because of data limitations, the evidence is far from complete. If the Senate bill is passed into law, the proposed Bureau on Immigration and Labor Market Research should collect better information from employers about job openings, including the occupation, the number of qualified applicants, the number of interviews conducted, and the length of time it takes to fill the job. These would be akin to college admission statistics for vacancies. Likewise, the bureau should also consider how demand and supply play out in regional or metropolitan area labor markets, since jobs search and recruitment often happen locally.[6] Armed with such information, as well as indicators presented below, visas and public funding for training and education in hard-to-fill occupations could be more confidently allocated.

The detailed findings of this analysis are summarized below. Details are available in the appendix.

****

1. The vast majority—90 percent—of H-1B petitions request workers in occupations requiring high-level STEM knowledge, but 25 percent of these occupations are commonly staffed by workers with just an Associate's degree.

When labor demand exceeds labor supply for a particular occupation, one would expect employers to expand their search for workers and devote more time and costs to finding them. One indication of this extra effort is recruiting foreign workers who have to be approved by the U.S. government. The most expedited path to legal working status for professionals without legal permanent residency is the H-1B visa program, which provides temporary visas to workers in specialized occupations. This requires employers to pay fees between $1,575 and $4,325 depending on employer size and composition plus legal costs.[7] Therefore, one would expect employers to use the H-1B program for hard to fill positions.

Employers are far more likely to use the H-1B program for STEM jobs than for other occupations. This report breaks with previous definitions of STEM by defining an occupation as a STEM job if the occupation requires high level STEM knowledge, as determined by surveys of workers (see appendix). Thus, many jobs in medical and blue collar technical fields are considered STEM by this standard.

STEM jobs comprise 90 percent of H-1B visa applications—compared to roughly two-thirds using conventional definitions of STEM). Most H-1B applications—75 percent—demand high-level computer knowledge, in particular, but roughly half require significant engineering and math skills. High-level scientific knowledge is less commonly requested.

Table 1. Share of H-1B Applications Requiring High-Levels of STEM Knowledge and Education, 2011

	H-1B Requests	Share of all H-1B Requests
STEM Requirements		
STEM in any field	638,461	90%
High Science Knowledge	81,339	11%
High Computer Knowledge	533,003	75%
High Engineering Knowledge	348,439	49%
High Math Knowledge	344,216	48%
Educational Requirements		
Doctoral Degree	33,400	5%
Master's Degree	28,902	4%
Bachelor's Degree	451,968	64%
Associate's Degree (or other 2-year degree)	180,757	25%
Total H-1B Jobs	710,352	

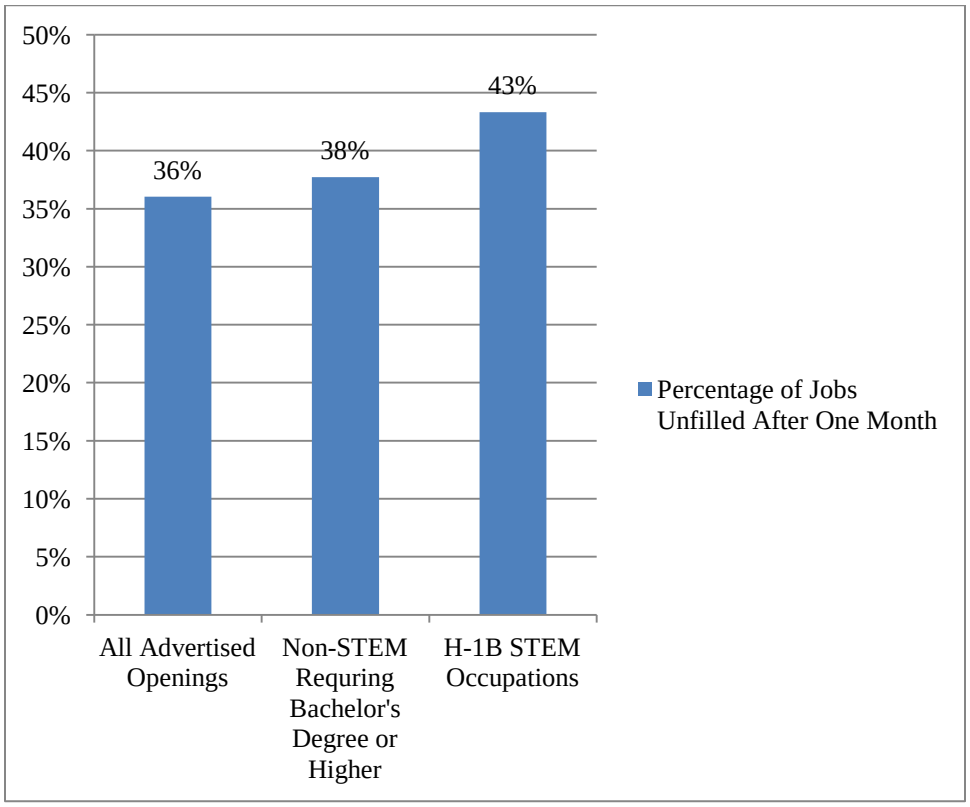
Source: Brookings analysis of data from U.S. Department of Labor's Labor Condition Applications (LCA) for 2011 and O*NET.

Despite the requirement that H-1B applicants work in jobs that require a Bachelor's degree or higher, many of the positions for which they are hired—25 percent—are usually staffed by non-H-1B workers with an Associate's degree. In other words, employers do not typically require a bachelor's degree for these occupations and with just two years of post-secondary training, many in the existing U.S. workforce could perform these jobs. By far the most common H-1B occupation that does not require a bachelor's degree is "Computer Systems Analyst," which comprises 94 percent of such jobs. Other jobs include operations managers and nurses.

2. H-1B STEM job vacancies are harder-to-fill than other job openings.

An analysis of 2011 job openings data in the 100 largest metropolitan areas, finds that 36 percent go unfilled within one month of posting.[8] That is only slightly higher than rates found in the 1960s, and in-line with pre-recession trends. However, the share of H-1B jobs unfilled is significantly higher: 41 percent of vacancies for H-1B requests are re-posted after a month. Finally, H-1B occupations in STEM fields are particularly difficult to fill: 43 percent of new vacancies for STEM occupations with H-1B requests go unfilled after a month (see Figure 1), compared to 40 percent for jobs requiring a bachelor's degree (which include STEM and non-STEM). This represents a large share of total vacancies that are apparently harder to fill. In the average large metropolitan area, 46 percent of job openings that go unfilled for one month or longer require significant STEM knowledge.

Figure 1. Unfilled H-1B Job Vacancies in the 100 Largest Metropolitan Areas by H-1B and STEM, 2011



Historic and contemporary data on the difficulty of filling job vacancies suggests that education and skill requirements of jobs both predict how long it takes to fill jobs. [9] In fact, there is a strong correlation between the skill, education, training, and experience requirements of jobs and the share that are unfilled after one month. STEM jobs are significantly harder to fill by this metric.

Some may wonder if the share of announcements being reposted after one month (or other time periods) is a reasonable proxy for the difficulty of filling a position. While imperfect, labor market information experts agree that it can proxy for hiring difficulty, and there is evidence to support this contention.[10] The U.S. government and economists at the National Bureau of Economics Research tested the relationship between hiring difficulty and duration of vacancy in analyzing a 1964 survey, which asked why some of their jobs were going unfilled after one month.[11] They found that the most common answer—56 percent of responses—was a lack of qualified applicants. In other words, there was a shortage of skilled workers. In 22 percent of cases, the reason for the delay was that the job was only recently posted, and the rest were explained by low pay or difficult working conditions that made the job unattractive to workers.

Contemporary job vacancy surveys from state governments and private data providers support this interpretation of vacancies in STEM jobs going unfilled for relatively long periods because qualified candidates are hard to find.[12] For example, a Colorado job vacancy survey found that the occupations employers report as the most difficult to fill also tend to be the occupations that take the longest time to fill.[13] Surveys from states like Idaho and Oklahoma find have found that STEM jobs are more likely to go unfilled for 60 days than other occupations.[14] In the United States, roughly half of companies reported

difficulty filling positions because of lack of talent in 2011 and 2012, and this number increased from just 14 percent during the heart of the recession in 2010.[15] Moreover, they report that the hardest to fill jobs are for STEM workers—skilled technicians, engineers, and IT staff.

3. H-1B workers are paid more than non-H-1B workers generally and even within the same occupation for workers with similar experience.

Critics of the H-1B program have argued that foreign workers are paid less than natives, providing a strong incentive for American companies to import lower cost labor. Proponents argue that the program brings in highly specialized workers that are difficult to find domestically, which should result in higher wages. Unfortunately, most analyses have not examined the actual wages of H-1B workers and have instead used proxies like foreign-born status.

Only one study, that the authors are aware of, has compared the actual earnings of H-1B workers, as provided by employers, to U.S. native-born residents.[16] Using 2009 Census data, Lofstrom and Hayes found that H-1B workers earn higher than average earnings relative to U.S. born native-born, but they are also more highly educated, working in more remunerative occupations, and younger. Adjusting for these characteristics, they find that H-1B workers earn significantly higher earnings than native-born workers with bachelor's degrees or more education. This suggests that H-1B workers do have specialized skills that are not readily found in the labor market; moreover, it is unlikely that the program substantially lowers U.S. native-born earnings since these workers are not outcompeting U.S. native-born workers on pay. One suspects that they are, instead, outcompeting native-born workers on skill—at least as perceived by the company's hiring them.

This article analyzes the Lofstrom and Hayes data to gain insight on which occupations have the highest premiums. We replicate their findings using 2010 data from the Census Bureau's Community Survey. H-1B workers earn higher earnings than employed U.S. born residents with Bachelor's degrees ($76,356 versus $67,301), but are ten years younger and slightly more educated.

Comparing workers of the same age cohort and occupation, H-1B workers earn higher wages. Table 2 lists the 20 most common cohort-minor occupation combinations found in the H-1B program. These cohort-occupation groups comprise 73 percent of all H-1B workers in the database. In 17 of the 20 groups, wages are significantly higher for H-1B workers, and there is no significant difference for the other three. Engineers aged 35 to 40, computer workers aged 40 to 45, and life scientists aged 30 to 35 are the only larges H-1B groups that do not earn higher wages than their Native-born counterparts in the same cohort. The difference is statistically significant and negative only for life scientists. Consistent with Lofstrom, we also find that young engineers in the H-1B program earn lower wages than older Native-born engineers but higher wages than Native-born engineers in the same age cohorts.

Table 2. Wages of H-1B Workers Compared to U.S.-Born Workers in Same Minor Occupation and Age Cohort for 20 Largest Cohorts, 2010

Cohort	Minor Occupation	Number of H1B Workers in 2010	Average H1B Wages, 2010	Average American Wages, 2010	Percent Difference, 2010
25 to 30	Computer Occupations	38,607	$72,903	$57,880	26%
30 to 35	Computer Occupations	28,104	$82,869	$71,630	16%
21 to 25	Computer Occupations	11,144	$65,240	$40,590	61%
35 to 40	Computer Occupations	9,025	$85,999	$81,722	5%
30 to 35	Postsecondary Teachers	5,851	$57,977	$41,227	41%
25 to 30	Engineers	5,439	$75,376	$65,686	15%
30 to 35	Engineers	4,588	$82,604	$78,195	6%
30 to 35	Health Diagnosing and Treating Practitioners	4,225	$117,717	$74,860	57%
35 to 40	Postsecondary Teachers	3,488	$61,228	$54,865	12%
25 to 30	Financial Specialists	3,426	$67,921	$57,582	18%
25 to 30	Health Diagnosing and Treating Practitioners	3,332	$79,019	$55,302	43%
25 to 30	Postsecondary Teachers	3,101	$53,857	$26,807	101%
30 to 35	Financial Specialists	2,579	$77,736	$73,096	6%
40 to 45	Computer Occupations	2,280	$87,997	$86,790	1%
25 to 30	Other Management Occupations	2,181	$86,037	$49,637	73%
30 to 35	Other Management Occupations	2,103	$100,283	$68,514	46%
35 to 40	Engineers	1,968	$86,742	$85,852	1%
30 to 35	Life Scientists	1,871	$54,875	$59,182	-7%
21 to 25	Engineers	1,719	$65,243	$49,151	33%
35 to 40	Health Diagnosing and Treating Practitioners	1,643	$147,186	$94,277	56%

Brookings analysis of data from Brookings analysis of FOIA H-1B approvals data from U.S. Citizenship and Immigration Services (USCIS) for 2010, provided by Magnus Lofstrom and Joe Hayes, and the 2010 American Community Survey via IPUMS.

4. For occupations with the most H-1B requests, recent wage growth has been much higher than the national average.

Even if paid higher wages, a large inflow of H-1B workers could result in suppressed wages for all native-born workers in the H-1B occupations, if the visa-approved workers satiate demand in the relevant occupations. If the effect is large, one would expect to see slower wage growth for H-1B-heavy occupations relative to all occupations or those with similar educational requirements. This is not the case.

In recent years, 2009 to 2011, nominal wage growth for U.S.-born workers with at least a bachelor's degree has been high for the most prominent H-1B occupations.[17] The average native-born worker experienced flat annual growth in wages over that period (0.0 percent), but wage growth for those in computer occupations—the largest H-1B category—grew by 1.3 percent each year since 2009 and 2.7 percent each year since 2000 for those with a bachelor's degree. Wage growth was even higher for engineers, with 2.1 percent growth since 2009 and 3.0 percent growth since 2000.

For every prominent H-1B occupational category except Life Scientists and operations specialties managers, wage growth was stronger than the national average since 2009. Since 2000, all but postsecondary teachers have seen higher than average wage growth.[18]

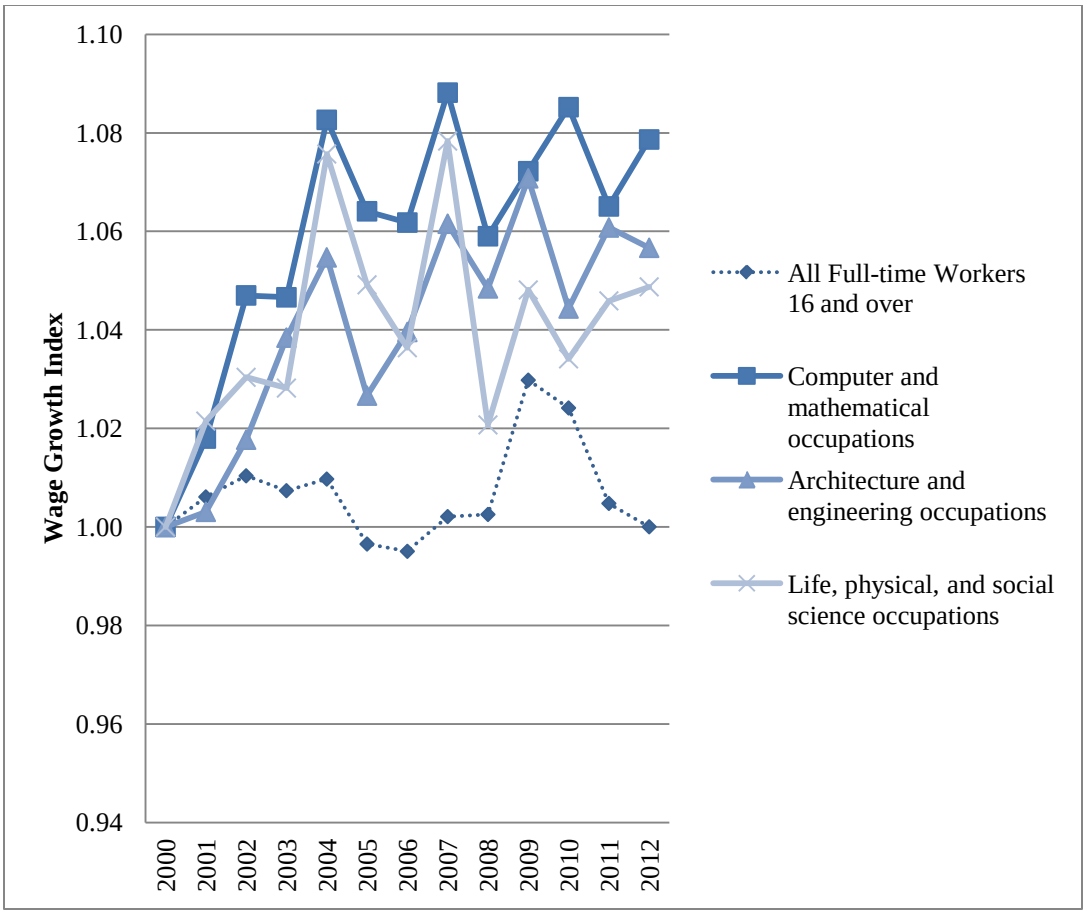
Table 3. Nominal Wage Growth of U.S.-Born Workers Aged 21-64 with Bachelor's Degree or Higher in Most-Heavily Demanded H-1B Occupations, 2009-2011

	H-1B Requests	Share of H-1B Requests	Annual Wage Growth 2000-2011, U.S. Born	Annual Wage Growth 2009-2011, U.S. Born
Computer Occupations	473,836	68%	2.7%	1.3%
Engineers	36,433	5%	3.0%	2.1%
Financial Specialists	29,082	4%	3.4%	0.9%
Business Operations Specialists	28,161	4%	2.7%	1.0%
Health Diagnosing and Treating Practitioners	28,000	4%	2.8%	0.4%
Operations Specialties Managers*	15,407	2%	2.7%	-0.1%
Preschool, Primary, Secondary, and Special Education School Teachers	12,620	2%	2.6%	0.8%
Life Scientists	11,497	2%	3.2%	-3.3%
Mathematical Science Occupations	8,398	1%	2.9%	1.0%
Postsecondary Teachers	7,413	1%	2.2%	0.8%
All U.S. born Workers			**2.4%**	**0.0%**

Source: Brookings analysis of data from U.S. Census Bureau's American Community Survey, via IPUMS. These occupations represent 93 percent of all H-1B positions requested, as reported on data from U.S. Department of Labor's Labor Condition Applications (LCA) for 2011. All other occupational categories are less than one percent of the total. Wages are not adjusted for inflation and are calculated as compound annual growth rates for employed U.S. born residents with a bachelor's degree or higher, aged 21 to 64. *Includes Computer and Information Systems Managers.

The finding that wages are growing in STEM and H-1B prevalent occupations is robust to different data sources. The Bureau of Labor Statistics publishes occupational median weekly wage trends from the Current Population Survey for workers aged 16 and over. These data show that workers in the three major STEM occupations have experienced both positive inflation-adjusted wage growth since 2000 and faster growth than the median worker (Figure 2). While inflation-adjusted wages were unchanged since 2000 for most U.S. workers, they increased by 8 percent for those in computer and mathematical occupations, 6 percent in architecture and engineering occupations, and 5 percent in life, physical, and social science occupations. Wages were also 6 percent higher for Healthcare practitioner and technical occupations, which is another frequently requested H-1B group that would be considered STEM using our method. Wage growth was also higher from 2011 to 2012 for these occupations relative to the median worker.

Figure 2. Growth in Inflation-Adjusted Median Wages for All U.S. Workers Aged 16 and Over in Common STEM Minor Occupational Groups



Source: Brookings analysis of Current Population Survey and Consumer Price Index

Wage growth was high over this period (2000 to 2012) in the specific occupations most frequently requested in H-1B applications in 2011. This is true for computer programmers (the most frequently requested occupations), software engineers, electrical and electronics engineers, and physicians and surgeons, though not database administrators, for which wages fell sharply during the recession before almost recovering 2000 (inflation-adjusted) levels in 2012.[19]

From a theoretical standpoint, it is likely that the extra supply of foreign-born workers does bring downward pressure on the wages of incumbent workers, as research suggests.[20] Yet, it appears that demand is so strong relative to supply that even the inflow of H-1B workers is not enough to meet the demand of U.S. companies and push wage growth down to normal levels. Moreover, even if the high wages of well-paid workers are lower than they would be in the absence of immigration, the broader economy is likely to be much richer as a result of increased competition and greater efficiency.

Another way to assess the consequences of immigrant through the H-1B program is to examine wage trends in industries most affected by the program. By far the largest is Computer Systems Design and Related Services, with 60 percent of the total. If the H-1B program is not well-aligned to workforce demand or is greatly suppressing the wages of workers by bringing in comparatively cheap foreign labor then one would expect to see slow wage growth in these industries. In fact, wage growth in this industry has been much larger than the national average since 1990 and 2009 (ending in 2012) with 5.5 and 7

percent annual growth, compared to 0.8 percent and 1.6 percent annual wage growth across all industries.[21]

5. In the Metropolitan Areas with the most H-1B requests, average wages for STEM occupations with H-1B requests are extremely high, the vacancies are hard-to-fill, and industry wages are growing.

Businesses in high-tech and other highly educated industries tend to be geographically clustered. Therefore, requests for skilled foreigners through the H-1B program are also geographically clustered.[22] While national trends might wash out some of the effect of immigration, a focus on specific metropolitan area labor markets is more likely to pick up any effects.

As it happens, the metropolitan areas with the largest number of H-1B requests per worker all exhibit extremely high wages in specific STEM H-1B occupations (occupations with H-1B requests in STEM fields) and have a hard time filling vacancies for those occupations. In fact, two-thirds of job vacancies that go unfilled after one month of advertising in San Jose are for STEM occupations with H-1B requests.[23] The share is close to half in other H-1B intensive metro areas.

Moreover, wage growth in the industry with the most H-1B requests (Computer Systems Design and Related Services) is positive and large in all of these H-1B intensive metro areas. This positive wage growth is true since 1990 and since 2009. The most likely interpretation is that these metro areas have high and growing demand for specialized STEM workers that is going unmet, resulting in higher wages.

Table 4. Wage Growth in Top H-1B Industry and Average Wages and Difficulty of Filling Vacancies for H-1B Occupations in Metro Areas with High H-1B Demand, 2011

	Average Wage for STEM H-1b Occupations	Share of Unfilled Vacancies in STEM Occupations	Annual Real Wage Growth in top H-1B Industry, 1990-2012	Annual Real Wage Growth in top H-1B Industry, 2009-2012
San Jose-Sunnyvale-Santa Clara, CA	$112,380	67%	9%	7%
Bridgeport-Stamford-Norwalk, CT	$96,980	52%	6%	3%
San Francisco-Oakland-Fremont, CA	$101,094	51%	8%	10%
New York-Northern New Jersey-Long Island, NY-NJ-PA	$96,634	47%	5%	6%
Hartford-West Hartford-East Hartford, CT	$88,726	47%	4%	6%
Seattle-Tacoma-Bellevue, WA	$90,111	53%	9%	8%
Oxnard-Thousand Oaks-Ventura, CA	$93,680	45%	3%	2%
Boston-Cambridge-Quincy, MA-NH	$93,950	49%	6%	5%
Richmond, VA	$83,366	48%	9%	6%
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$88,264	46%	4%	3%

Source: Brookings analysis of data from Conference Board Help-Wanted Online, Department of Labor LCA, and Bureau of Labor Statistics. Industry wage growth data is from the Bureau of Economic Analysis via Moody's Analytics. The top H-1B industry is Computer Systems Design and Related Services. Wage growth is adjusted for inflation using the Consumer Price Index for urban consumers. H-1B occupations report data wage data for occupations in STEM fields with at least one H-1B applicant nationally.

APPENDIX

Methods

This appendix is intended for scholars interested in replicating our analysis or learning more about where the data came from and how it was analyzed.

H-1B Applications

H-1B data was used to measure the level of demand for occupation and the relative wages paid to workers. These data came from two different sources.

To measure the number of H-1B positions ("jobs") requested by occupation and by metropolitan area, data from the Department of Labor was downloaded and analyzed.[24] Because of the data is user-reported, there are many obvious coding errors. Job titles were used to recode Standard Occupational Codes (SOC) when the SOCs were invalid. Address data used to match company-establishments to metropolitan areas were fixed by research assistants using procedures described in previously published work.[25] 2011 data was the most recent cleaned data available to us from our previous work.

Data on the wages paid to H-1B workers was provided to the authors by Magnus Lofstrom and Joseph Hayes, who obtained the underlying data from a Freedom of Information Act request through the U.S. Citizenship and Immigration Services agency (USCIS).[26] These are administrative data from the petition request forms, entitled I-129. The data include both new (40 percent) and continuing visas (60 percent) and report the type of visa from which the H-1B worker transferred (e.g. F-1 student visa).

The raw administrative occupation titles are presented using occupational classifications from the Dictionary of Occupational Titles. These were re-coded to match the SOC system (codes as "occsoc") available from the Integrated Public Use Microdata Series (IPUMS) in the American Community Survey. Industry titles in the USCIS data were matched to the NAICS (North American Industry Classification System), which is available from IPUMS.[27] The most recent year available from the USCIS data was 2010. These individual records—which include education and age—were appended to the 2010 American Community Survey (ACS), the largest annual survey of individuals conducted by the Census Bureau. To make the data more comparable, the ACS was restricted to workers aged 21 to 64 who are currently employed and have earned at least a bachelor's degree.

Appendix Table 1 reports the summary statistics for the H-1B petitions and the U.S. workers who responded to the 2010 American Community Survey. It is clear that H-1B workers are considerably younger but earn higher wages than U.S. native-born residents with a Bachelor's degree or higher.

Appendix Table 1. Summary Characteristics of H-1B Workers Compared to All Employed U.S. Workers Aged 21-65 with at Least a Bachelor's Degree

	Sample Size	Mean Wages	Age	Education Level
H-1B Holder	189,298	$76,356	32	5.7
All workers in Census	432,697	$67,301	43	5.5

Brookings analysis of data from Lofstrom and Hayes (obtained from US Citizenship and Immigration Services) and 2010 American

Community Survey, via IPUMS. Education level equals 5 for Bachelor's degree, 6 for Masters, and 7 for PhD or professional degree.

Appendix Table 2 shows the results of a regression of the log of annual earnings—as reported by the Census Bureau or as reported on H-1B petitions—on worker characteristics and H-1B status. The analysis controls for education, age, occupational effects, and industry effects, with varying levels of detail. Column 5 compares workers in the same detailed occupation in the same industry with the same age and educational status. We also control for foreign-born status of respondents in the Census Bureau, who tend to earn lower wages. This makes the comparison between native-born U.S. workers and H-1B workers, rather than just all U.S. native-born workers. In the most fully specified regression model (column 5), with industry and occupational effects, the data show that H-1B workers earn 20 percent higher wages, on average, than U.S. workers.[28]

Appendix Table 2. Regression of H-1B Status, Education Level, Age, and Occupational Effects on Wages, 2010

	Ln Wages				
	1	2	3	4	5
H-1B Worker	0.185***	0.115***	0.249***	0.208***	0.196***
	(0.00280)	(0.00337)	(0.00305)	(0.00355)	(0.00351)
Foreign-born Worker (not H-1B petitioner)	0.00485	-0.00893***	-0.0545***	-0.0565***	-0.0566***
	(0.00327)	(0.00321)	(0.00311)	(0.00308)	(0.00307)
Education Level (5-7)			0.170***	0.131***	0.127***
			(0.00156)	(0.00164)	(0.00164)
Age			0.103***	0.100***	0.100***
			(0.000666)	(0.000655)	(0.000653)
Age^2			-0.00105***	-0.00102***	-0.00101***
			(7.87e-06)	(7.75e-06)	(7.72e-06)
Constant	10.83***	10.86***	7.653***	7.917***	8.098***
	(0.00140)	(0.00150)	(0.0158)	(0.0160)	(0.0179)
Occupation Effects	3-digit SOC	6-digit SOC	3-digit SOC	6-digit SOC	6-digit SOC
Industry Effects	Omitted	Omitted	2-digit NAICS	2-digit NAICS	3-digit NAICS
Observations	599,384	599,384	586,125	586,125	586,125
Adjusted R-squared	0.243	0.288	0.336	0.362	0.369

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Brookings analysis of FOIA H-1B approvals data from U.S. Citizenship and Immigration Services (USCIS) for 2010, provided by Magnus Lofstrom and Joe Hayes, and the 2010 American Community Survey via IPUMS.

STEM, Education, Training, and Experience Requirements of Occupations

To determine if a job is STEM, we use occupational level survey data from O*NET. O*NET publishes scores for the level of knowledge required by domain. These scores are based on surveys of incumbent workers that ask them to rate the level of knowledge required to do their job in various domains of knowledge. The six domains most relevant for basic STEM knowledge were chosen: three to represent science, “Biology,” “Chemistry,” and “Physics,” one for technology, “Computers and Electronics,” one

for engineering, “Engineering and Technology,” and one field for mathematics, “Mathematics.” A job was considered STEM if it scored 1.5 standard deviations above the mean on the STEM score for any of the STEM letters. The distribution was calculated by matching 2011 American Community Survey occupational micro data (from IPUMS) to O*NET scores. This method will be explored further in forthcoming Brookings work.

From a separate survey of workers (“Education and Training Survey”), O*NET also reports the distribution of education, training, and experience for each occupation. The mode responses from this survey were used to assign the requirement for each occupation. This technique is used by the Bureau of Labor Statistics and was validated by comparing results of this mode-assignment to more direct survey data that asks employers to list the educational requirements of their jobs.

To elaborate, educational requirements data were obtained from the Massachusetts’s Executive Office of Labor and Workforce Development’s Job Vacancy Survey-Second Quarter 2012, which asks employers to list the occupation and educational requirements of their job openings. For 57 percent of occupations, the mode level of education required by employers in MA exactly matches the national mode level of education of incumbents and 85 percent of occupations were within one level (approximately year) of education. Jobs requiring higher education were more likely to match. Finally, the average occupation has 57 percent of its workers in one of six educational categories (using both the mode and employer-reported data), and so does the median. In other words, most occupations have a single major educational requirement.

Wages by Occupation

To calculate wage trends by occupation, the analysis relies primarily on the American Community Survey (ACS) from the Census Bureau and provided by IPUMS. This survey provides more accurate data than alternative sources frequently used by economists, the Current Population Survey. The primary difference is that the ACS is a sample of one percent of the entire U.S. population, or 2.1 million households whereas the CPS is a sample of just 60,000 households. See details about ACS here, http://www.census.gov/acs/www/methodology/sample_size_data/index.php and CPS here, http://www.bls.gov/opub/hom/homch1_b.htm. Nonetheless, median hourly wage data for workers 16 and over was compiled from the Current Population Survey and compared to the Census data. As discussed in the text above, the results yield the same basic conclusions.[29]

Job Vacancies and Unfilled Vacancies

Data on job openings come from the Conference Board Help Wanted Online Data Series (HWOL). These data represent all online advertised job vacancies, which are accumulated from a large number of job boards before removing duplicate announcements. Data used in this report cover the period from January of 2011 to December of 2011 for only the 100 largest metropolitan areas in the United States. The data were aggregated to detailed occupational codes (using the six digit Standard Occupational Classification system from the Bureau of Labor Statistics) for each metropolitan area.

HWOL reports the number of new job openings each month as well as total job openings each month. The difference between the two is the number of job openings posted last month that went unfilled. As discussed in the text, the share of jobs going unfilled for a given occupation can be roughly interpreted as

the difficulty of filling the job, with the exception that some low-skilled positions are always open due to high turnover.[30]

In the text above, occupations were classified as "H-1B occupations" if any H-1B petitions were filed for those occupations nationally. The share of jobs going unfilled for this subset of occupations was compared to all occupations and occupations that are both H-1B and STEM.

More broadly, this analysis also examines whether STEM jobs are harder to fill, given that most H-1B jobs are STEM jobs. To analyze if STEM jobs were harder to fill than other jobs, reported openings were aggregated to 6-digit occupational codes (SOCs) for each of the 100 largest metropolitan areas. The percentage of vacancies going unfilled in each metro-occupation was regressed on the occupational characteristics of the job and metropolitan level fixed effects.

The results clearly show that STEM jobs are significantly harder to fill—adding roughly 4 to 5 percentage points to the unfilled share, on average, depending on whether one controls for average wages (Appendix Table 3, columns 1 and 3). Column one controls for educational requirements, years of experience required, and years of on-the-job-training required for the occupation, all of which is available from O*NET. The second column adds controls for management knowledge (which is correlated with high pay) and cumulative knowledge score in all non-STEM knowledge domains surveyed by O*NET, as well as the log of average annual earnings (using BLS OES data). The STEM score is highly predictive of difficulty filling jobs, and the standardized STEM score has a larger effect than the standardized management knowledge score, which also is associated with delays in filling vacancies.

In general, these results replicate survey results on the length of time it takes to fill jobs: High-paying jobs requiring high skills take the longest to fill, and STEM jobs take longer than other high-paying skilled jobs.[31]

One concern with these data is that some occupations (often low-wage) are always open or otherwise continuously posting job openings because of high-turnover rates. O*NET metadata reports job turnover data for 233 occupations (specifically, it asks how long workers have been at their job). This was used to calculate the average years of incumbency by occupation. Matching this to the metro-occupation openings data allowed for the inclusion of job-duration as a control variable. The raw correlation with the unfilled rate was almost zero, but in a regression with the other controls, job-duration is strongly negatively correlated with the unfilled rate. This reflects that fact that the unfilled rate is higher for low-wage jobs with high-turnover. STEM jobs tend to have lower turnover (over a year of longer incumbency than non-STEM jobs), so the previous results likely biased the relative difficulty of filling STEM jobs downwards. Adding this variable to the regression reduces the sample size from roughly 51,000 occupations to 13,000, but the STEM variables are still significant.

As another robustness check, the analysis looked at how H-1B requests correlated with the unfilled rate. In results not shown to conserve space, these regressions were repeated using the sample of occupations in metropolitan areas with at least one H-1B request. This allowed an additional variable to be entered: the occupation's share of metropolitan area H-1B visa requests. This variable was highly and significantly correlated with the share going unfilled (the other variables remained significant and only slightly smaller). For every ten percentage point increase in the metro-occupational share of H-1B requests, the

unfilled rate increased by one percentage point. These results are available upon request. They reinforce the straightforward interpretation of H-1B requests as hard-to-fill occupations.

Appendix Table 3. Regression of Difficulty of Filling Vacancy on Occupational Skill and Educational Requirements, in 100 Largest Metropolitan Areas

	Percentage of vacancies reposted after 1 month			
	1	2	3	4
Job Requires high STEM knowledge in at least one field	0.0465***		0.0363***	
	(0.00103)		(0.000996)	
STEM O*NET Score, standardized		0.0283***		0.0208***
		(0.000601)		(0.000594)
Management O*NET Score, standardized		0.0165***		0.00752***
		(0.000648)		(0.000646)
Non-STEM Knowledge O*NET Score, standardized		-0.00458***		-0.00553***
		(0.000704)		(0.000682)
Ln Wage			0.108***	0.101***
			(0.00160)	(0.00170)
Education Level	0.0253***	0.0223***	0.00288***	0.00401***
	(0.000326)	(0.000346)	(0.000452)	(0.000453)
Years of Experience Required	0.00728***	0.00422***	0.00141***	0.000582***
	(0.000175)	(0.000203)	(0.000188)	(0.000206)
Years of On-the-job Training Required	-0.00450***	-0.00890***	-0.0116***	-0.0135***
	(0.000428)	(0.000437)	(0.000422)	(0.000429)
Constant	0.215***	0.252***	-0.858***	-0.762***
	(0.00108)	(0.00136)	(0.0159)	(0.0172)
Observations	51,820	51,820	50,971	50,971
Adjusted R-squared	0.390	0.402	0.441	0.440

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. All regressions include metropolitan area fixed effects and are weighted by the number of new openings. Brookings analysis of data from the Conference Board's Help-wanted On-line (job openings), O*NET (knowledge scores, education, training, and experience requirements), and Bureau of Labor Statistics Occupational Employment Survey (wages).

[1] The views here are the opinions of the authors and not necessarily The Brookings Institution or its funders. Jonathan Rothwell is Senior Research Associate and Associate Fellow, and Neil G. Ruiz is Senior Policy Analyst and Associate Fellow at The Brookings Institution's Metropolitan Policy Program. The authors would like to thank Alan Berube, Jill Wilson, Mark Muro, Audrey Singer, and Magnus Lofstrom for helpful comments.

[2] Neil G. Ruiz and Jill H. Wilson, "A Balancing Act for H-1B Visas," *UpFront*, April 18, 2013, available at http://www.brookings.edu/research/articles/2013/04/18-H-1B-visa-immigration-ruiz-wilson; *Border Security, Economic Opportunity, and Immigration Modernization Act of 2013*, S.744, 113 Cong. 1 sess. (Government Printing Office, 2013).

[3] Microsoft, "A National Talent Strategy: Ideas for Security U.S. Competitiveness and Economic Growth" (2012); Information Technology Industry Council, Partnership for a New American Economy, and U.S. Chamber of

Commerce, "Help Wanted: The Role of Foreign Workers in the Innovation Economy," available at http://www.renewoureconomy.org/index.php?q=content/stem-report.

[4] Hal Salzman, Daniel Kuehn, and B. Lindsay Lowell, "Guestworkers in the High-Skill U.S. Labor Market: An analysis of supply, employment, and wage trends," (Washington: Economic Policy Institute, 2013).

[5] Committee on Prospering in the Global Economy of the 21st Century and others, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington: The National Academies Press, 2007); Members of the 2005 "Rising Above the Gathering Storm, *Committee, Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (Washington: The National Academies Press, 2010); Economics and Statistics Administration, "STEM: Good Jobs Now and for the Future" (U.S. Department of Commerce, 2011); Anthony P. Carnevale, Nicole Smith, and Michelle Melton, STEM: Science, Engineering, Technology, and Mathematics," (Washington: Georgetown University Center for Education and the Workforce, 2011); Todd Gabe, "Knowledge and Earnings," *Journal of Regional Science* 49 (3) (2009): 439-457; Paolo Buonanno and Dario Pozzoli, "Early Labor Market Returns to College Subject," Labour 23 (4) (2009): 559–588 ; Jin Hwa Jung and Kang-Shik Choi, "Technological Change and Returns to Education: The Implications for the S&E Labor Market *Global Economic Review* 38 (2) (2009): 161-184; B. Lindsay Lowell and Harold Salzman, "Into the Eye of the Storm: Assessing the Evidence on Science and Engineering Education, Quality, and Workforce Demand" (Washington: Urban Institute, 2007); Terrence K. Kelly and others, *The U.S. Scientific and Technical Workforce Improving Data for Decision-making* (Santa Monica: RAND Corporation, 2004); Beryl Lieff Benderly, "Does the U.S. Produce Too Many Scientists?" *Scientific American*, February 22, 2010; Richard B. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" Working Paper 11457 (Cambridge: National Bureau of Economics Research, 2005).

[6] Ruiz, Wilson and Choudhury, "The Search for Skills."

[7] Ibid.

[8] Data are from Conference Board Help Wanted On-Line series.

[9] Vladimir Chavrid and Harold Kuptzin, "Employment Service Operating Data as a Measure of Job Vacancies," in The Measurement and Interpretation of Job Vacancies (New York: Columbia University Press, 1966), available at http://www.nber.org/chapters/c1610; Kansas Labor Information Center, 2011 Kansas Job Survey, available at https://klic.dol.ks.gov/gsipub/index.asp?docid=437; Oklahoma Employment Security Commission, "Oklahoma Job Vacancy Survey: 1st Half 2006" (2006); Washington State Employment Security Department, "2012 Job Vacancy and Hiring Survey," (2012).

[10] A national working group of experts summarized the interpretation of unfilled duration data: "Statistics on "time-open" can be considered an indicator of hiring difficulty. In fields that are well-supplied with qualified, interested workers, job vacancies can be filled quickly. Where shortages exist, job vacancies are likely to remain vacant and open for hire longer." National JVS Workgroup [Bureau of Labor Statistics, Employment and Training Administration, State Labor Market Information Offices], "About JVS: How-To Guide for States Implementing a Job Vacancy Survey" National JVS Workgroup (2002), available at http://www.jvsinfo.org/downloadFiles/aboutjvs.pdf (May 2013).

[11] Chavrid and Kuptzin, "Employment Service Operating Data as a Measure of Job Vacancies."

[12] Delottte, "Boiling point? The skills gap in U.S. manufacturing," (2011); Manpower Group, "2012 Talent Shortage Survey Results" (2012), available at http://www.manpowergroup.us/campaigns/talent-shortage-2012/ (May 2013); Oklahoma Employment Security Commission, "Oklahoma Job Vacancy"; Washington State Employment Security Department, "2012 Job Vacancy and Hiring Survey;" Connecticut Department of Labor, "Connecticut Job Vacancy Survey" (2005); Idaho Department of Labor, "Idaho Job Vacancy Survey Report, Spring 2010" (2010).

[13] Colorado Department of Labor and Employment, "Mesa County Job Vacancy Survey 2005," (2005).

[14] Idaho Department of Labor, "Idaho Job Vacancy Survey Report, Spring 2010" (2010); Oklahoma Employment Security Commission, "Oklahoma Job Vacancy Survey: 1st Half 2006" (2006).

[15] Manpower Group, "2012 Talent Shortage Survey Results."

[16] Magnus Lofstrom and Joseph Hayes, "H-1Bs: How Do They Stack Up to US Born Workers," (San Francisco: Public Policy Institute, 2011), available at http://ftp.iza.org/dp6259.pdf.

[17] Data are not adjusted for inflation. The important point of comparison is average wages for all workers. Moreover, the CPI likely understates increases in the quality of goods.

[18] These results are not an artifact of the data base or timing of the analysis. Higher wage growth for STEM occupations (computer, engineers, life, physical, and social scientists) can be found using median wage data from the Current Population Survey for the period 2009 to 2011, 2000 to 2012, and 2011 to 2012 for the U.S. population aged 16 and over.

[19] Wage trends were not available for some of the most frequently requested occupations because of changes to occupational definitions (e.g. Computer Systems Analysts and Web Developers). It is difficult to compare wage trends over long time periods in the CPS or even larger surveys like the American Community Survey for detailed occupational categories because of changes to occupational definitions. This study relied on data downloaded from the Bureau of Labor Statistics website from its user-interface (Weekly and Hourly Earnings from the Current Population Survey), for which economists there have determined that the occupational data is of high enough quality to publish.

[20] George J. Borjas ,"The Labor Demand Curve *is* Downward Sloping: Reexamining the Impact: of Immigration on the Labor Market," *The Quarterly Journal of Economics* 118(4) (2003): 1335-1374; Abdurrahman Aydemir and George J. Borjas, "Attenuation Bias in Measuring the Wage Impact of Immigration," *Journal of Labor Economics*, 29 (1) (2011): 69-113.

[21] These are inflation adjusted numbers from the Bureau of Economic Analysis via Moody's Analytics. H-1B industry distributions were calculated from the Department of Labor's LCA data.

[22] Neil G. Ruiz, Jill H. Wilson and Shyamali Choudhury, "The Search for Skills."

[23] In other words, these are occupational categories that are classified as STEM and that have received at least one H-1B request nationally. It is also the case that the share of vacancies going unfilled after one month is significantly higher for STEM H-1B occupations than other occupations.

[24] These data are available here, http://www.foreignlaborcert.doleta.gov/performancedata.cfm (May 2013).

[25] 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 Institution, 2012).

[26]Magnus Lofstrom and Joseph Hayes, "H-1Bs: How Do They Stack Up to US Born Workers," (San Francisco: Public Policy Institute, 2011), available at http://ftp.iza.org/dp6259.pdf.

[27] In matching occupational titles, the USCIS website presents the list of relevant occupational titles and codes. The list implies that all scientific occupations were classified in the professional codes (15- or 19-), rather than the post-secondary teaching codes (25-). For a given level of education, private sector professional tend to be paid more than academics. So, if anything, this coding decision will bias the wages of comparable non-H-1B workers upwards, making it harder to conclude that H-1B workers are paid more.

[28] All of these results are robust to dropping the foreign-born dummy variable, which was set to zero for H-1B workers to avoid confusing H-1B workers with foreign-born workers more generally.

[29] See Weekly and Hourly Earnings from the CPS, http://www.bls.gov/data/#wages.

[30] A national working group of experts summarized the interpretation of unfilled duration data: "Statistics on "time-open" can be considered an indicator of hiring difficulty. In fields that are well-supplied with qualified, interested workers, job vacancies can be filled quickly. Where shortages exist, job vacancies are likely to remain vacant and open for hire longer." National JVS Workgroup [Bureau of Labor Statistics, Employment and Training Administration, State Labor Market Information Offices], "About JVS: How-To Guide for States Implementing a Job Vacancy Survey" National JVS Workgroup (2002), available at http://www.jvsinfo.org/downloadFiles/aboutjvs.pdf (May 2013);Vladimir Chavrid and Harold Kuptzin, "Employment Service Operating Data as a Measure of Job Vacancies," in The Measurement and Interpretation of Job Vacancies (New York: Columbia University Press, 1966), available at http://www.nber.org/chapters/c1610; Manpower Group, "2012 Talent Shortage Survey Results." Delottte, "Boiling point? The skills gap in U.S. manufacturing," (2011); Kansas Labor Information Center, 2011 Kansas Job Survey, available at https://klic.dol.ks.gov/gsipub/index.asp?docid=437;

[31] Vladimir Chavrid and Harold Kuptzin, "Employment Service Operating Data as a Measure of Job Vacancies," in The Measurement and Interpretation of Job Vacancies (New York: Columbia University Press, 1966), available at http://www.nber.org/chapters/c1610; Kansas Labor Information Center, 2011 Kansas Job Survey, available at https://klic.dol.ks.gov/gsipub/index.asp?docid=437; Oklahoma Employment Security Commission, "Oklahoma Job Vacancy Survey: 1st Half 2006" (2006); Washington State Employment Security Department, "2012 Job Vacancy and Hiring Survey," (2012).