Still Searching:
Job Vacancies and STEM Skills

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Findings

This report uses a unique database from the labor market information company Burning Glass and other sources to analyze the skill requirements and the advertisement duration time for millions of job openings. It reaches the following conclusions:

- **Job openings for STEM positions take longer to fill than openings in other fields.** The median duration of advertising for a STEM vacancy is more than twice as long as for a non-STEM vacancy. For STEM openings requiring a Ph.D. or other professional degree, advertisements last an average of 50 days, compared to 33 days for all non-STEM vacancies. Even sub-bachelor's STEM job openings take longer to fill than non-STEM jobs requiring a bachelor's degree. Health care and computer openings are advertised 23 and 15 days longer, on average, than openings for non-STEM occupations, like those in office and administrative support. Moreover, professional STEM vacancies take longer to fill now than before the recession, while vacancies for lower-skilled occupations remain much easier to fill. These indicators signal that STEM skills are in short supply in the labor market, relative to demand.

- **Specific high-value skills requested by employers and common to STEM occupations are particularly scarce relative to demand and yet particularly valuable to employers.** Computer skills are associated with the highest salaries and longest advertisement duration times among all major occupational groups. Employers advertised 255 distinct computer skills in at least 500 job openings for an average of 40 to 71 days on their websites.

- **The regional supply of workers in a given occupation affects the length of vacancy advertisements.** The typical job opening in an occupation for which the regional unemployment rate was below 3 percent was advertised for 16 days; most of these occupations are in STEM fields. By contrast, the typical job opening was advertised less than half that duration (seven days) for occupations with regional unemployment rates above 10 percent. These and other factors explain why Fresno, CA (68 days) and tech hubs like San Jose, CA (59 days), San Francisco (56 days), and Seattle (48 days) ranked among the metro areas with the longest average durations for professional STEM openings.

These job openings data provide new evidence that, post-recession, STEM skills, particularly those associated with high levels of educational attainment, are in high demand among employers. Meanwhile, job seekers possessing neither STEM knowledge nor higher education face extraordinary levels of competition for a scarce number of jobs. Governments at all levels, educators, training organizations, and civic leaders can utilize job vacancy data to better understand the opportunities available to workers and the specific skills required of them. Improving educational and training opportunities to acquire STEM knowledge should be part of any strategy to help unemployed or low-wage workers improve their earnings and employability.

Introduction

Workers with skills in science, technology, engineering, and mathematics (STEM) play a hugely important role in driving innovation and economic growth.[1] As economies have developed in wealth and complexity since the industrial revolution, scientists, engineers, and other STEM workers have grown in relative importance as a share of the labor market, and STEM skills are widely needed across a wide variety of blue-collar, craft, and professional occupations.[2] Likewise, the rewards for both education and STEM skills have grown relative to other positions, and workers in STEM today are among the highest paid.[3]

This report addresses a set of issues of increasing interest to policy makers, educators, businesses, and workers of all ages: What skills are most in demand and most likely to lead to a rewarding career? Is there a shortage of workers possessing the skills used in STEM occupations (i.e., STEM skills)? What skills and bodies of knowledge should schools and post-secondary institutions offer to teach students in order to provide them the best chances of economic success?

The results show that skills common to STEM occupations are in short supply relative to demand and are valued more by employers. Moreover, companies located in regions with low unemployment rates for STEM workers have greater difficulty filling their openings, all else being equal. It follows that increased training in STEM fields like computer science and medicine will ease hiring for employers and lead to high-paying career paths for workers.

While this is certainly not the first report to highlight the economic advantages that accrue to those with STEM skills, the data and analysis here are novel and useful in a few ways. First, unlike most reports on the STEM workforce or skill-shortage issues more broadly, this report draws on a database (developed by the labor market information company Burning Glass) that allows one to measure the duration of job vacancy advertisements—a measure of hiring difficulty. There has never been a nationwide analysis of vacancy duration for the United States by occupation. The closest such study came from a 1964 survey conducted by the United States Employment Service of unfilled openings posted at local government employment centers in 78 metropolitan areas.[4] Among the few recent studies that have looked at vacancy duration, none have examined differences by occupation, let alone skill level, geography, company, educational requirements, or status as a STEM worker, as this report does. This report also draws upon a uniquely large sample size: 1.1 million advertisements were used to calculate summary statistics for the first quarter of 2013, and 3.3 million were used in the formal statistical analysis, across 52,000 companies. These make up the full universe of job advertisements listed on company websites, not a survey, which would be subject to sampling and response bias. Finally, each vacancy is listed on a company website, not a job board, and examining only these listings insures that duplication is not an issue and there are no differences across companies in advertisements costs.

In short, the technological breakthroughs in "big data," such as those provided by Burning Glass and used here, mean that no previous job vacancy database has ever been assembled that can so thoroughly test labor market theories related to job search, skill mismatch, and shortage.

Even with these advantages, no database is perfect. Job openings posted online tend to require higher levels of skill and education than openings that are not advertised online, and the interpretation of advertisement duration is complicated by the fact that low-skilled, low-wage, high-turnover positions are often advertised continuously (see the appendix for details).

Understanding Job Vacancies in the Context of Long-Run Versus Short-Run Skill Shortage

Over the last three decades, the earnings of college graduates have soared far above the earnings of those with just a high school diploma. Leading labor economists have argued that this trend represents a long-standing shortage (or inadequate growth in supply) of college-educated workers in the United States relative to demand.[5] As it happens, the earnings for STEM knowledge have also increased at any given level of education and experience. In 1970, workers earned 12 percent higher earnings if they worked in an occupation that was significantly more STEM oriented (scoring one standard deviation higher). By 2012, that premium was up to 21 percent (see Appendix Figure 1).[6]

The Great Recession obviated long-run shortage problems but only temporarily. As the economy recovered, signs of hiring difficulty for STEM workers returned. For young graduates with STEM

degrees, census data show rising relative salaries from 2009 to 2012, the only years with field-of-degree data.[7] Meanwhile, job vacancy data for the United States in early 2014 reveal five job openings for every unemployed computer worker, 3.3 for every unemployed health care practitioner, and 1.7 and 1.1 for those in architectural/engineering and science occupations, respectively. By contrast, there were just 0.7 openings for those in legal occupations, 0.2 for production workers, and 0.1 for construction workers.[8]

In order for businesses to succeed, they need to match the right employee to the right position. Accordingly, businesses invest heavily in searching for the right employees, through methods such as advertising their vacancies and thoroughly evaluating candidates. According to one survey, the average U.S. company spends $3,500 per new hire in job advertising costs and human resources staff, or $124 billion per year.[9]

Meanwhile, previous studies estimate that the average job vacancy lasts approximately 20 days.[10] For companies, lengthy searches are a necessary if expensive cost of matching. Each day a job goes unfilled costs the enterprise the value of that potential worker, and this cost is higher for higher-paying and highly skilled positions, even as the cost of hiring a skilled worker who is the "wrong fit" is also higher. Employer surveys report large costs from hiring difficulty, including overworked current staff, lower quality output, loss in revenue, and delays in product delivery.[11] In short, companies have a strong incentive to fill vacancies as quickly as possible, but first they must identify qualified and willing candidates.

Job matching is an ocean of economic activity. Across the United States, 4.7 million workers are hired in a typical month.[12] That churn dwarfs the number of net new jobs created, which has averaged just 160,000 per month since 2010.[13] Economists have a well-developed theory of job search to guide their thinking on labor market matching and its macroeconomic consequences, and the three leading theorists in this field were awarded the Nobel Prize in 2010.[14] In this framework, hiring is determined by both supply and demand, not just the number of vacancies—a measure of demand. In particular, when there are many unemployed workers looking for work, such as during a recession, jobs vacancies are filled quickly, leading to many new hires for a given level of vacancies. Likewise, when unemployment falls, as in the recovery from the recession, vacancies become harder to fill.[15]

Yet, job openings data do not garner the same level of attention from researchers and the media as do other measures like GDP growth, job growth, and the unemployment rate. The reason may be the lack of detailed data that are collected and reported by the government. The Bureau of Labor Statistics' Job Openings and Labor Turnover Survey (JOLTS) does not provide any information on openings by occupation or even detailed industry. Nor does it provide regional or even state-level information. It is probably not very helpful to a laid-off auto worker in Michigan to know that there is a job opening somewhere in the Midwest in the manufacturing sector, but that is the most detailed information provided by the underfunded JOLTS program. The pioneering work cited above has relied on private-sector data sources, such as that provided by the Conference Board.[16]

The analysis here confirms the broad theoretical predictions of "search theory"—that hiring difficulty is affected by both supply and demand—and provides new insight into the characteristics of jobs that take long periods to fill. This report goes beyond previous studies by considering a much larger and richer set of factors that influence job duration—including the local labor market, the value of specific skills required to do the job, and the company doing the recruiting.

After summarizing previous research and describing the data, this paper will analyze trends in hiring difficulties by skill, education, and occupation, with a focus on STEM occupations and the skills common to them. The results show that there is a national relative shortage of workers with STEM skills, and the shortage is roughly as severe now as before the recession. Generally, more valuable STEM skills—measured by salary offers—are more difficult to fill. The problem is particularly acute in specific regions with few STEM workers or few unemployed STEM workers. These results imply that enhanced STEM training and education would have enormous benefits for individuals, firms, and regions.

Summary of Previous Studies of Shortages and Vacancies

The formal economic analysis of job vacancies as a sign of shortage issues goes back at least to the 1950s. Kenneth Arrow and William Capron argued that unfilled vacancies represent a "dynamic shortage" that will persist until wages rise sufficiently to attract enough workers to acquire the necessary

skills.[17] While the theory implies shortages will only be temporary, long-term shortages can persist in reality because financial incentives have a very weak effect on the learning of children, as recent experimental evidence demonstrates.[18]

Empirical research on job vacancies has been limited by a dearth of data, but a few published articles shed light on how vacancy data can be used to discern skill shortage. In the 1960s, economists analyzed openings data collected from government staffing agencies and found that highly skilled positions took longer to fill and that employers cited a lack of qualified candidates as the most common explanation for why jobs were hard to fill. Consistent with the claims of employers, the studies also documented fewer job applicants per vacancy for more skilled positions. This gap, moreover, varied widely across regions, suggesting that skill mismatches have an important geographic component.[19]

More recent work confirms that job vacancies requiring more education, training, or experience take longer to fill.[20] Economists have interpreted long vacancy periods as synonymous with shortage, after adjusting for job characteristics that would make the open position unattractive, such as low wages.[21] Openings for higher-skilled positions receive fewer initial applications, prolonging the duration of the vacancy.[22] There is a strong correlation between firm reports of shortage and the duration of vacancies.[23] Shortages, in this sense, can be attributed to firm factors—such as rapidly increasing demand—or regional labor market factors—such as the presence of few skilled workers and low unemployment rates.[24] Shortages are particularly common in firms using advanced technologies, suggesting that skill shortages will persist unless there is continued advancement in the attainment of technical skills.[25] Other evidence shows that raising wages may not be sufficient to fully address shortages. Firms that pay high relative wages often report shortages.[26] Finally, skill shortages appear to negatively affect firm productivity and growth.[27] To summarize, there is small but consistent academic literature establishing the usefulness of job vacancy data to interpret skill shortages and other labor market trends.

Despite this literature, however, a few scholars have recently argued that skill shortages are created by bad human resource practices or do not exist at all.

The first argument suggests that the adoption of flawed software algorithms used to sort through resumes are excluding many qualified candidates for skilled positions and thus leading firms to misdiagnose their recruitment challenges as shortage.[28] While probably true in some cases, it seems unlikely that human resource practitioners are systematically sabotaging—accidentally or not—their companies' profits by excluding thousands of qualified workers for trivial reasons. Moreover, this software-based argument cannot explain why the duration of job vacancies fell during the recession and has since increased, as will be shown below. Nonetheless, the data analyzed below adjust for human resource practices specific to companies to test if this theory explains differences in vacancy duration across skill levels.

A related and more persuasive argument along these lines is that firms are not training as much as they used to and are putting too much pressure on workers to have the perfect skills before being hired. Systematic evidence is not available on this point, but a recent global survey found that only 10 percent of companies report offering additional training to current employees to help overcome talent shortages.[29]

The second argument is that weak wage growth for engineering and computer occupations are inconsistent with shortage claims, and that there may even be a surplus of workers with computer and engineering skills.[30] Yet, evidence does not support these contentions.[31] Nominal and real earnings for these positions have increased significantly and much faster than wages in other occupations at least since 2000, and even further back using consistent definitions of occupations or skill.[32] A more likely explanation for wage patterns in recent years is that the Great Recession temporarily eliminated most shortage problems and reduced wages, but the resumption of economic growth is once again tightening the labor market and regenerating a long-run shortage. It often takes a few years for wages to adjust to market conditions.[33]

Related to the second argument on whether a shortage exists, a recent analysis of an employer survey in the manufacturing sector concluded that a shortage of production workers was a problem only for a small minority of manufacturing firms.[34] Only a small percentage of firms in manufacturing (24 percent) report having vacancies lasting three months or longer. Yet, that low percentage includes firms with no vacancies, which by definition could not have a recruitment problem. Considering only

firms eligible to have a recruitment problem (i.e., those with vacancies), these data show that two-thirds of firms report having a long-term unfilled vacancy. At the same time, these data show that most production jobs do not require many years of formal education or technical training, though the report did not examine vacancies for engineers or other professional STEM occupations.

Job vacancy information is widely used outside of academia. Indeed, U.S. government labor market statisticians released a guidebook suggesting that lengthy openings durations for given occupations can be interpreted, with some caution, as indicating a shortage.[35] Many U.S. state labor departments now conduct their own job vacancy surveys, and some ask employers to report the duration of their job vacancies and which occupations are hard to fill and why. The conclusions that follow from these data are that hard-to-fill vacancies take longer to fill often because of a lack of qualified candidates. Yet, there are also a large number of low-skilled occupations that take a long time to fill because employers face high turnover and a constant need to recruit new employees, and so the employers maintain vacancy advertisements for long periods.[36] Thus, the interpretation of ad duration can generally be taken to be synonymous with hiring difficulty except for positions with very high turnover and typically low wages.

The state-level data suggesting skill imbalances are consistent with national surveys. According to Manpower, roughly half of U.S. companies reported difficulty filling positions in 2011 and 2012 because of lack of skills, and this number increased from just 14 percent 2010.[37] In 2013, the share reporting difficulty fell somewhat to 39 percent, but that remains above the global average and above what many European countries report.[38] Moreover, companies report that many of the hardest-to-fill jobs require STEM skills—skilled trades and technicians, information technology (IT) staff, financial analysts, and engineers. Another survey of human resource managers found that roughly half of large U.S. companies report a STEM shortage, to which the managers attribute lower productivity and firm growth.[39]

Small businesses also report increased hiring difficulty. Since 1986, the National Federation of Independent Business has surveyed small businesses on a monthly basis. Its February 2014 report shows the share of small businesses reporting at least one unfilled vacancy has returned to pre-recession levels, and the share reporting a lack of qualified job candidates increased from 25 percent in October 2009 to 40 percent in October 2013.[40]

Data Sources and Methods

To analyze characteristics of skill shortage in 2013 generally and at the most detailed level, this study uses data purchased from Burning Glass, a Boston-based labor market information company founded in 1999. Burning Glass aggregates job postings from approximately 15,000 Internet job boards (as well as company websites) and codes and categorizes those openings and their requirements to facilitate interpretation and analysis.

This study relies on a subset of Burning Glass data that uses job postings advertised on company websites for companies located in metropolitan areas. In all, the database contains 4.7 million job postings from company websites, representing 25% of all Burning Glass ads for 2013 in metropolitan areas. Fifty-two thousand different companies are represented. Unlike the full Burning Glass database, this subset includes information on the date the job vacancy was first posted and when it was taken down from the company's website. The difference in days between when a job was first posted and when it was taken down provides a measure of its *duration in days*, which will form the basis for key measures used in this analysis.

Advertisement duration is not precisely the same concept as vacancy duration. Employers advertise to attract applicants and obtain a pool of suitable candidates. Then, during a selection period, they sift through that pool and conduct interviews.[41] It is not clear at what point in this process they remove advertisements. Moreover, an ad may be re-posted months later after an unsuccessful round of interviews. These measurement issues are addressed more directly in the appendix.

Summary findings on vacancy duration are reported only for the first quarter of 2013. The reason for limiting the analysis to this period is that the data are cut off in November 2013. As a result, vacancy duration artificially appears shorter for advertisements posted later in the year simply because the ads have not been allowed as much time to last. For the more sophisticated econometric

analysis, which undergirds the summary findings, ads posted from January to August (3.3 million in total) are utilized and the results are adjusted by the quarter in which the ads were posted.

In addition to vacancy duration, Burning Glass provides many other useful pieces of information about job openings. The data include occupational codes, industry codes, company names, and metropolitan location. Many ads also include information on educational requirements (55 percent of total), experience requirements (52 percent of total), and, to a lesser extent, salary (7 percent of total).

Summary tables and statistics for the duration of STEM and non-STEM vacancies by educational requirements use the minimum educational requirements listed on the advertisement collected by Burning Glass.

The more sophisticated econometric analysis takes a slightly different approach. To avoid discarding observations with incomplete information, the baseline econometric analysis imputes educational requirements to detailed (six-digit) occupations using the most frequent educational level of workers, as reported by the Occupational Information Network (O*NET), a collection of detailed occupational-based surveys. Results are also shown using only the Burning Glass educational requirements. Here, the average of minimum and maximum educational requirements will be used. For example, an advertisement showing a range of possible educational levels from a bachelor's to a Ph.D. would receive a higher education score than one showing only a bachelor's.

Burning Glass also lists specific "skills" and certifications required for the job as mentioned in the advertisement. This information allows one to distinguish skill levels between jobs within the same occupation. For example, one computer occupation may require fluency with Microsoft Windows, while another requires fluency in Java script or another programming language. These skills can be quantified by taking advantage of salary information associated with each job and calculating a mean salary for each skill. For example, if a skill—like Microsoft Powerpoint—appears in 5,000 ads and 100 list salary information, the mean salary from those 100 ads is used to quantify the value of the skill.[42]

Since Burning Glass provides data on vacancy duration starting only for 2013 (at least presently), alternative job vacancy data sources were used to analyze broad trends in hiring difficulty.

The Conference Board's Help Wanted Online (HWOL) data series has comprehensive historic coverage of job openings advertised on websites and Internet job boards starting in 2005. It distinguishes between job openings that are newly posted in a calendar month and those that are re-posted (or unfilled) from the previous month. In this report, the *unfilled rate* is the share unfilled from the last month divided by the share of total postings last month; it is an indicator of hiring difficulty. Brookings purchased HWOL's occupational-level openings data from 2005 to February 2012 for the 100 largest metropolitan areas. This report

A Bias Toward Professional Occupations?

There is a well-known bias in online posting data that gives disproportionate weight to professional occupations.* Many small retail businesses or restaurants do not advertise their job vacancies online, and they may also believe that recruitment of any kind is not worth the cost, given the low wages and high turnover of most of their employees. Many accept walk-in applications for jobs that are "always open." To gauge the size of this bias, this paper compares traditional surveys of employers—conducted by mail or phone—to aggregated online job posting data. By comparing the distribution of openings across major occupations, one can assess the degree of bias. From this, it seems two major occupational groups—computer workers and managers—are strongly overrepresented in online advertisements, and one major group—food preparation and serving occupations—is severely underrepresented. The bias in the composition of occupations advertised online compared to those advertised in other formats makes it difficult to assess the true level of opportunity for workers with various skills.

Yet, this compositional bias does not appear to extend to advertisement duration. Employers report longer recruitment durations for the same sets of occupations as those that are posted for longer periods online. (See the appendix for details.) Moreover, there is evidence that most employers post jobs online. A survey of employers in Northeastern Ohio found that 89 percent posted job advertisements on an online job board.** By contrast, another problem arises with interpreting job-openings duration by skill or occupation: Many high-turnover, low-skill, entry-level jobs are "always hiring," an effort by firms to ensure that there is an adequate work team at any one time. This issue will be addressed in more detail below.

*Jonathan Rothwell, "Education, Job Openings, and Unemployment in Metropolitan America" (Washington: Brookings Institution, 2013).

**ERC, "2013 ERC Hiring Trends & Practices Survey" (Mayfield Village, OH: 2013).

focuses on the period just before the recession (2006-Q4) until the latest available data. National summary-level openings data are available for free from the Conference Board's website.

To understand and analyze the characteristics of job openings, a number of other public data sources are merged with Burning Glass data. To calculate the education, training, and skill requirements of vacancies, occupational codes are matched to Bureau of Labor Statistics data and O*NET. Previous work by Brookings classifies the skill level of occupations in terms of STEM and other skills using the O*NET knowledge survey.[43] This method is used here.

A STEM job is defined as one that requires an extraordinary level of STEM knowledge in one or more core STEM knowledge domains. Additionally, an overall STEM score is assigned to each occupation based on the aggregation of knowledge scores in each STEM domain (i.e., science, computers, engineering, and math). The same method is used to score occupations in other knowledge domains with O*NET data, like law, English, and management. This approach greatly expands the number and diversity of occupations that one may deem STEM to include occupations like industrial designers, plumbers, computer machine programmers, nurses, doctors, and accountants, which in most previous studies would not be considered STEM jobs. Occupations that score highly on this STEM measure in one or more STEM domains are referred to as requiring higher-level STEM skills.

Unemployment rates by major and minor occupational groups by metropolitan area are calculated from the 2012 American Community Survey using the University of Minnesota's Integrated Public Use Microdata Series (IPUMS), which can be used to analyze individual-level census records.[44] The census asks unemployed workers to list their last occupation, provided they have worked within the last five years. This information can be used to measure the unemployment rate by occupation. Public use micro-geographies (called PUMAs) were matched to metropolitan area geographies using online tools provided by the Missouri Census Data Center. The final variable—the unemployment rate by occupation by metropolitan area—is used to explain advertisement duration by occupation.

Finally, the appendix discusses a formal econometric analysis used to predict the duration of advertisements. To summarize the approach, the regression analysis controls for job characteristics (including skill, education, turnover, and experience requirements), firm characteristics (all firm characteristics unchanged from January to August 2013), and regional characteristics (including the number of workers and the regional unemployment rate for those with the same occupation as the ad). In a limited subset of the data, the analysis also adjusts for ad-specific requirements and the difference in regional wages and ad-specific salary. The main results consistently show that ads seeking more valuable skills and/or STEM skills, ads requiring higher educational attainment, and ads running in regions with fewer workers and low unemployment rates for the vacant occupation are all associated with longer vacancies.

Findings

Job Openings for STEM Positions Take Longer to Fill Than Openings in Other Fields

Which jobs in the economy are hardest to fill? For which skills is demand from employers high relative to supply from the U.S. labor force? The duration of job advertisements is one way to examine these questions, though to avoid errors of interpretation it is important to keep a few things in mind.

As previous research documents, many job vacancies fill almost immediately, or at least the advertisement is taken down almost immediately.[45] Within one day, 44 percent of U.S. job advertisements in the Burning Glass database are taken down. In some cases, the removal may be due to internal promotion, and the ad itself may represent a symbolic gesture intended to meet human resource standards. It is not possible to know from these data, but ads taken down within one day share many characteristics with ads taken down a few days later.[46] Fully half of all ads are taken down within one week. Previous research finds that employers stop advertising once they have collected a sufficiently large pool of applicants. Yet, for higher-skilled vacancies, employers often receive relatively fewer applications, prolonging the vacancy.[47]

After an initially high probability of success in matching, the odds of filling vacancies fall quickly. Just two-thirds of jobs are filled within 33 days. One-fifth of vacancies are posted for at least 70 days.

Table 1. Duration of Advertised Vacancies in Days by Level of STEM and Minimum Educational Requirements, 2013-Q1

	Median duration	Mean duration	Duration at the 80th percentile of advertisements	Number of ads
Occupations requiring STEM knowledge				
PhD/professional degree	25	50	93	6,432
Master's	21	48	89	23,158
Bachelor's	18	42	81	206,171
Associate's degree	12	40	78	24,638
High school	8	40	77	47,577
No education requirement mentioned	5	34	62	167,887
All STEM openings	11	39	76	480,903
Occupations not requiring STEM knowledge				
PhD/professional degree	14	43	87	4,306
Master's	11	40	80	17,403
Bachelor's	13	37	73	135,914
Associate's degree	5	31	55	18,763
High school	6	35	69	193,593
No education requirement mentioned	2	30	54	338,503
All non-STEM openings	5	33	64	711,535
All ads	6	35	70	1,192,438

*Source: Brookings analysis of data from Burning Glass. Sample is all vacancies advertised online through company websites in the first quarter of 2013. STEM requirements are based on analysis of data from O*NET. Educational requirements are the minimum education listed on the advertisement by employers.*

Almost half of the 239,000 jobs posted for at least 70 days require high levels of STEM knowledge. Another 10 percent are in non-STEM and high-turnover occupations—like food preparation and health care support—and likely represent constant recruitment effort rather than search difficulty.

A detailed analysis of these data show that the difficulty of filling vacant positions increases as the level of STEM knowledge increases. Likewise, higher levels of education, higher pay, and more valuable skills are associated with longer duration times. Still, STEM knowledge has an effect on vacancy duration that is independent of education, salary, company characteristics, industry characteristics, and the regional labor market. Even after controlling for all of these factors, STEM knowledge remains a highly significant predictor of the duration of a vacancy. These results come from a regression analysis discussed in detail in the appendix. The highlights of that analysis are summarized in this and subsequent sections.

The highly uneven distribution of vacancies suggests that a single metric (like the average) may not adequately capture the differences across groups. This analysis starts by showing the median (the point at which half of ads have a shorter duration and half have a duration as long or longer), the mean (the total duration per ad), and the duration at the 80th percentile (the point at which 80 percent of ads have a shorter duration and 20 percent have a duration as long or longer).

Across various metrics of duration, jobs that require higher levels of STEM skill are advertised for longer periods (Table 1). At the median, STEM job postings last over twice as long as non-STEM jobs (11 vs. five days). At the mean, the difference is proportionately smaller but still highly significant (39 vs. 33 days). Higher educational requirements also prolong advertising, and the effect is particularly pronounced in STEM occupations.

The duration of advertising for a STEM occupation that typically requires a graduate degree is 25 days at the median, 50 days average, and 93 days at the 80th percentile. These search times are much longer than the average for all non-STEM U.S. vacancies, for which the median is just five days, the average is 33, and the 80th percentile is 64.

Focusing only on the median (column 1 of Table 1) shows that STEM vacancies require longer advertising durations at every level of education compared to non-STEM jobs. The differences are largest for STEM jobs for which minimum education requirements are a Ph.D.: 25 days for STEM vs. 14 days for non-STEM. At the master's level, the difference is 10 days: 21 vs. 11. At the bachelor's and associate's degree levels the differences are five and seven days, respectively.

The patterns change somewhat when looking at the average and the 80th percentile. Again, the STEM jobs requiring more education post the longest, but using these metrics reveals that "blue collar" or sub-bachelor's-level STEM jobs are harder to fill than even bachelor's-level non-STEM jobs. The mean duration for associate's-level and high-school-level STEM jobs is 40 days, compared to just 37 days for non-STEM jobs requiring a bachelor's degree and 31 days for non-STEM jobs requiring an associate's degree. These results suggest that the supply-demand imbalances at the middle education levels are very different for those with STEM skills than those without. At these education levels, those with STEM skills are at a distinct advantage over their non-STEM counterparts.

At the 80th percentile, sub-bachelor's STEM jobs are advertised for four to five days longer than non-STEM bachelor's vacancies. Associate's-level STEM openings are advertised for 23 days longer than their non-STEM counterparts at the same education level. Meanwhile, non-STEM jobs requiring a master's or Ph.D. are also advertised for long periods, suggesting that skill shortage is not limited to STEM, even if it tends to be more severe for those skills.

Aggregating the data to these broad categories misses some of the important variation and diversity of hard-to-fill STEM jobs, especially within the lower levels of education. Using the educational requirements specifically requested in the advertisement shows the occupational groups with highly skilled STEM jobs that are hard to fill at various levels of education.

At the high school level, STEM-intensive health care practitioner occupations are among the most difficult-to-fill jobs, with the most frequent vacancies in this category occurring for medical and lab technicians. These occupations advertise for 61 days, on average.

Advertisements for blue-collar STEM occupations—i.e., those requiring no more than a high school education—in arts, design, entertainment, sports, and media occupations, and installation, maintenance, and repair occupations also last long periods, an average of 42 and 40 days, respectively. STEM jobs in these occupations include broadcast technicians, HVAC technicians, geothermal technicians, and auto mechanics. Jobs in skilled-construction trades, such as building inspectors, carpenters, sheet metal workers, plumbers, and pipefitters, can also be difficult to fill at this level.

At the associate's degree level, the longest-advertised STEM jobs include health care practitioners (like registered nurses), with an average of 44 days; office support jobs (like statistical and database technicians), with an average of 41 days; installation, maintenance, and repair workers (e.g., supervisors and avionics, automotive, and telecommunications technicians), with an average of 38 days; and computer workers (e.g., user support specialists), with an average of 34 days.

At the bachelor's level, industrial and commercial design occupations are among the STEM art and design occupations that advertise for long periods—49 days on average. Engineering positions advertise 45 days, as do education-related STEM positions. Computer occupations at the bachelor's level—with software developers being the most common—advertise 43 days, as do various managerial STEM positions including engineering managers, computer managers, and industrial, financial, and loss-prevention managers.

At the master's level, STEM jobs in engineering advertise the longest (61 days), followed by education (54), science (50), computers, (48), health care (47), and management (41). Finally, at the Ph.D. or professional-degree levels, vacancies last 58 to 45 days, on average, for jobs spread across managerial positions (58 days), computer occupations (53 days), engineering (52), science (51), and health care (45).

As implied in the above, the duration of job advertisements differs widely across major occupational groups (Table 2). The median duration of vacancies for health care practitioners and computer workers is 18 and 15 times longer, respectively, than for five large occupational groups including

Table 2. Average Duration of Job Vacancy Advertisements Posted on Company Websites, by Major Occupation, 2013

	Median duration of opening	Average duration of opening	Number of ads
Health Care Practitioners and Technical Occupations	18	47	109,760
Computer and Mathematical Occupations	15	39	166,043
Architecture and Engineering Occupations	13	41	53,134
Management Occupations	13	39	118,819
Sales and Related Occupations*	11	38	160,346
Education, Training, and Library Occupations*	8	54	14,965
Food Preparation and Serving Related Occupations*	8	38	31,951
Life, Physical, and Social Science Occupations	7	39	16,651
Business and Financial Operations Occupations	7	33	104,362
Arts, Design, Entertainment, Sports, and Media Occupations	5	36	18,729
Legal Occupations	5	33	4,588
Health Care Support Occupations*	4	30	28,255
Installation, Maintenance, and Repair Occupations	3	33	46,908
Farming, Fishing, and Forestry Occupations	2	34	1,419
Protective Service Occupations	1	32	14,858
Personal Care and Service Occupations	1	31	11,841
Construction and Extraction Occupations	1	31	11,570
Transportation and Material Moving Occupations*	1	30	47,031
Community and Social Service Occupations	1	30	13,480
Building and Grounds Cleaning and Maintenance Occupations	1	28	17,328
Production Occupations	1	26	47,567
Office and Administrative Support Occupations	1	24	152,833

Source: Brookings analysis of Burning Glass data. Sample is limited to metropolitan area advertisements on company websites posted between January 1, 2013 and March 31, 2013, with last day of observation occurring on November 20, 2013.
**Indicates occupation with high portion of vacancies continuously open due to high turnover.*

construction, production, and office administration. Roughly 40 percent of vacancies for health care practitioners and computer workers are advertised for at least 30 days compared to 24 percent for office and administrative workers.

Occupations with the lowest advertisement durations offer low wages and have few educational requirements, making the pool of potential workers larger. But even some high-paying jobs with high educational requirements fill quickly. Legal occupations, for example, have a median advertising duration of five days, reflecting particularly weak labor demand for lawyers since the recession.[48] It is also notable that most vacancies in science and social science are not as hard to fill as those for engineers, computer workers, and health care workers, suggesting variation in the market for different kinds of STEM skills.

If one were to plot out the number of vacancies that last each day, the distribution would not be a "bell curve," which describes variables like human height that cluster around a mean that can be

Table 3. Average Duration of Job Vacancy Advertisements Posted on Company Websites by Major Occupation and Quintile of Duration in Days, 2013

	80th percentile of ads	60th percentile of ads	40th percentile of ads	20th percentile of ads
Education, Training, and Library Occupations	109	31	1	1
Health Care Practitioners and Technical Occupations	89	34	4	1
Architecture and Engineering Occupations	81	29	1	1
Food Preparation and Serving Related Occupations	81	25	1	1
Life, Physical, and Social Science Occupations	77	24	1	1
Computer and Mathematical Occupations	76	29	2	1
Management Occupations	76	27	1	1
Sales and Related Occupations	75	24	2	1
Farming, Fishing, and Forestry Occupations	72	18	1	1
Arts, Design, Entertainment, Sports, and Media Occupations	67	20	1	1
Protective Service Occupations	66	16	1	1
Business and Financial Operations Occupations	64	21	1	1
Legal Occupations	62	18	1	1
Installation, Maintenance, and Repair Occupations	62	17	1	1
Transportation and Material Moving Occupations	56	13	1	1
Health Care Support Occupations	55	16	1	1
Personal Care and Service Occupations	55	14	1	1
Construction and Extraction Occupations	55	7	1	1
Community and Social Service Occupations	55	8	1	0
Building and Grounds Cleaning and Maintenance Occupations	48	8	1	1
Production Occupations	43	6	1	0
Office and Administrative Support Occupations	39	7	1	1

Source: Brookings analysis of Burning Glass data. Sample is limited to metropolitan area advertisements on company websites posted between January 1, 2013 and March 31, 2013, with last day of observation occurring on November 20, 2013.

**Indicates occupation with high portion of vacancies continuously open due to high+A2 turnover.*

considered "normal." Rather, the distribution of vacancy durations is highly skewed, with a very long tail. STEM occupations tend to require the longest advertisement durations at each point in the distribution, but there is considerable variation even within the same occupational groups.

For every major occupational group (Table 3), at least 20 percent of ads are taken down within one day (fourth column, "20 percentile of ads"), but at the other extreme duration times extend out for every occupation. Even for the easiest-to-fill occupation—office and administrative support—20 percent of vacancies ("80th percentile of ads") are advertised for at least 39 days (column 1). Still, the distribution or the share of jobs requiring very long fill times varies widely between occupations. For life, physical, and social science occupations and computer occupations, 20 percent of ads are posted at least 77 and 76 days, respectively. That number is even higher—81 and 89—for architecture and health care occupations.

Installation, maintenance, and repair occupations often require STEM knowledge, acquired through

Table 4. Differences in Job Vacancy Advertisement Durations Within the Same Large Establishment for Ads Posted in 2013-Q1

Occupation	Average extra days required to fill vacancy	Total ads with duration data
Health Care Practitioners and Technical Occupations	7.6	20,008
Computer and Mathematical Occupations	7.1	16,934
Life, Physical, and Social Science Occupations	6.3	1,797
Farming, Fishing, and Forestry Occupations	5.3	35
Architecture and Engineering Occupations	2.5	2,010
Management Occupations	2.5	12,509
Protective Service Occupations	2.2	621
Transportation and Material Moving Occupations	0.7	584
Personal Care and Service Occupations	0.4	323
Education, Training, and Library Occupations	0.4	472
Food Preparation and Serving Related Occupations	-0.5	1,196
Installation, Maintenance, and Repair Occupations	-0.7	1,031
Production Occupations	-1.9	688
Community and Social Service Occupations	-2.1	1,296
Legal Occupations	-2.4	392
Construction and Extraction Occupations	-3.5	190
Business and Financial Operations Occupations	-3.5	9,572
Sales and Related Occupations	-3.6	8,433
Arts, Design, Entertainment, Sports, and Media Occupations	-4.1	909
Building and Grounds Cleaning and Maintenance Occupations	-6	691
Health Care Support Occupations	-6.2	3,639
Office and Administrative Support Occupations	-12.2	9,188

Source: Burning Glass. Sample limited to establishments with at least 500 vacancies. The derivation of extra days calculates the difference between average ad duration for the occupation listed and average ad duration for all other vacancies within the establishment. Establishment ads defined as all company ads within the same metropolitan area.

on-the-job-training or post-secondary education at a community college. At least 60 percent of these vacancies could be regarded as easy to fill, but for 20 percent—perhaps those requiring very specific skills or those advertised in places with a shortage—advertisements are posted for at least 62 days.

An alternative concern with the interpretation of vacancies advanced thus far is that company-specific practices (like human resource and recruitment practices) may explain some of the variation in vacancy duration across occupations. It may be that tech companies or other companies more likely to hire STEM workers have common practices that delay matching workers to job openings because of "pickiness" or formalized processes that subject large number of candidates to interminable automated screening processes. If such practices explained the longer duration of advertisements for STEM positions, one would expect to see few differences in ad duration between engineering and office administrative workers within the same company.

As it happens, even within the same business establishment (defined here as the same company and regional location), STEM jobs take much longer to fill than low-skilled positions. Health care, computer,

science, engineering, and management jobs take significantly longer to fill, on average, relative to the average of all other vacancies within the same establishment (Table 4). On the other hand, office and administrative positions, health care support, and building maintenance jobs are filled much faster than other occupations in the same establishment. Legal occupations also fill relatively quickly. Overall, the average computer occupation takes 19 days longer to fill than the average office administrative job within the same business establishment.

A few examples illustrate the differences across companies. Google advertised over 100 vacancies for computer workers in the San Jose metropolitan area in early 2013, and the ads were posted for an average of 97 days. In the same area, Google posted almost 100 ads for sales occupations, but only for an average of 56 days. In between, management occupations lasted 79 days, on average. At Volvo, in the Greensboro, NC metropolitan area, ads for architecture and engineering occupations lasted 79 days, on average, compared to 57 days for installation, maintenance, and repair occupations, and just 22 and 21 days for business workers and production workers, respectively. Finally, at Pfizer, in the New York metropolitan area, ads for science jobs were left up for an average of 63 days compared to 13 days for jobs in sales and 12 days for office administrative jobs.

Trends in Hiring Difficulty Suggest Tightening Labor Market for STEM Workers

The above analysis establishes that STEM skills are relatively more difficult to fill, suggesting a relative shortage of STEM skills, but those findings do not prove that there is an "absolute" STEM shortage. It may be the case there are *no* skills that are in shortage. After all, the Great Recession had a wrenching effect on unemployment and the demand for goods and services. It may be that before the recession jobs were difficult to fill, but elevated unemployment and depressed demand during the recovery period made jobs easy to fill, eliminating any shortage. Analyzing trend data on hiring difficulty can shed light on these issues. To capture hiring-difficulty trends, this report relies on the *unfilled rate*, the percentage of jobs taking at least one month to fill, which is the only measure of hiring difficulty available to us from the Conference Board data. If STEM jobs are as difficult to fill now as before the recession, then the *relatively* high level of shortage looks more like an *absolutely* high level of shortage, at least as severe as before the recession.

National data on job openings from the Bureau of Labor Statistics' JOLTS program show a clear increase in hiring difficulty since the recession, but they provide no information on whether this increase varies by occupation (see appendix). As it happens, the Conference Board's HWOL data reveal that trends in hiring difficulty have played out very differently according to the education and skill requirements of vacancies.

Hiring difficulty for STEM positions at higher levels of education eased only slightly during the recession before becoming as difficult as before by early 2012 (Table 5). This was the only category of workers to see an increase in hiring difficulty from late 2006 to early 2012. The trend is consistent with the idea that there is an absolute shortage, not just a relative shortage, of highly educated STEM workers (defined as those with a bachelor's degree or higher, but not necessarily those at the Ph.D. level).

Hiring for STEM jobs at mid-levels of education (those requiring some college, perhaps a certification or an associate's degree) remained easier in early 2012 than before the recession, but not by much compared to jobs requiring only a high school diploma (STEM or not), as Table 5 shows. Meanwhile, hiring difficult for STEM jobs at high and mid-levels of education consistently remained harder than for non-STEM jobs at high levels of education. The easiest jobs to fill were those requiring only a high school diploma and no significant STEM skills.

The gaps in hiring difficulty between occupations has expanded in recent years. The broad trend across all of the 100 largest metropolitan areas shows that demand for professional STEM occupations—health care practitioners and computer workers, engineers, and scientists—was less negatively affected by the recession and more positively bolstered by the recovery, leading to increased hiring difficulty relative to before the recession.

In the fourth quarter of 2006, jobs for health care occupations went unfilled at a rate of 40.2 percent after one month; for computer, engineering, and science occupations the unfilled rate was 39.5 percent (Table 6). These unfilled rates were only slightly higher than less-STEM-intensive professional jobs (39.4 percent) and skilled blue-collar jobs in construction, production, transportation and

Table 5. Percentage of Vacancies Reposted After One Month by Broad Occupational Group

	Unfilled rate 2006-Q4	Unfilled rate 2008-Q3	Unfilled rate 2012-Q1	Change, unfilled rate 2006-Q4 to 2012-Q1
STEM, bachelor's or higher	40.2%	35.7%	40.7%	0.5%
STEM, some college or associate's	40.6%	32.8%	36.4%	-4.1%
STEM, less than high school	40.4%	29.6%	30.4%	-9.9%
Non-STEM, bachelor's or higher	39.4%	32.0%	34.5%	-4.9%
Non-STEM, some college or associate's	38.3%	32.6%	33.3%	-5.0%
Non-STEM, less than high school	36.5%	25.3%	26.2%	-10.2%

Source: Brookings analysis of Conference Board Help Wanted Online (HWOL) series in 100 largest metropolitan areas.

Table 6. Percentage of Vacancies Reposted After One Month by Broad Occupational Group

	Unfilled rate 2006-Q4	Unfilled rate 2008-Q3	Unfilled rate 2012-Q1	Change, unfilled rate 2006-Q4 to 2012-Q1
Health Care	40.2%	36.4%	44.6%	4.4%
Computers, Engineering, and Science	39.5%	34.2%	40.9%	1.4%
Management, Business, Legal, and Design	39.4%	33.4%	36.9%	-2.4%
Public Service	36.0%	27.5%	32.8%	-3.1%
Service	35.8%	25.8%	28.8%	-7.0%
Construction, Production, Transportation, and Repair	38.7%	25.3%	28.2%	-10.4%

Source: Brookings analysis of Conference Board Help Wanted Online (HWOL) series in 100 largest metropolitan areas.
"Public service" consists of community and social service workers, protective service occupations, and education occupations. "Service" consists of food preparation, building maintenance, personal care, sales, and office and administrative support occupations.

installation, maintenance, and repair (38.7 percent), and just four percentage points higher than the unfilled rate for public service (e.g., education, protection, and social service) and less-skilled service jobs.

This pattern changed dramatically once the recession hit. By the third quarter of 2008, the unfilled rate plummeted 13 percentage points for construction and production workers, 10 percentage points for low-skilled service jobs, and almost 9 percentage points for public service jobs. The other occupations saw a much smaller decrease in the unfilled rate (between 4 and 6 percentage points).

The gap in hiring difficulty between STEM and non-STEM jobs widened still further during the initial years of the recovery. From 2008-Q3 to 2012-Q1, the unfilled rate increased 8 percentage points for health care workers and 7 percentage points for other professional STEM workers. The recovery for non-STEM professional occupations was comparatively lackluster at 3 percentage points for construction and production workers and low-skilled service positions.[49]

Looking at occupations in greater detail (not shown in table) reveals that computer occupations and health care practitioner occupations had the largest increase in unfilled rates between 2006-Q4 and 2012-Q1 (3 and 6 percentage-point increases, respectively). Hiring difficulty for social and other scientists and engineers increased slightly between 2006-Q4 and 2012-Q1, as the unfilled rates were 3 and 2 percentage points higher. Similar patterns were observed for management and business occupations.

Meanwhile, legal occupations saw unfilled rates plummet from 36 percent to 27 percent.

To summarize, the relatively high levels of difficulty in filling job vacancies for computer and health care occupations appear to be as acute after the recession as before—a period of low unemployment and tight labor markets. Therefore, the contemporary relative shortage of workers in these positions is especially severe. The market for scientists and engineers, as well as professional workers in less-STEM-intensive fields, is also quite tight, though hiring difficulty was not back to pre-recession levels as of early 2012. Meanwhile, for legal occupations and most blue-collar or less-skilled service occupations, hiring difficulty practically disappeared during the recession and has not returned.

Given the striking differences across occupations, one may wonder how these trends in hiring difficulty correspond to more conventional measures of economic performance by occupation. It turns out that the overlap is strong, especially for the hardest-to-fill occupations. Since the start of the recession in 2007, no occupational category has added net jobs at a faster rate than computer and mathematical occupations, which experienced 21 percent growth and a net increase of 725,000 jobs.[50] The next-fastest-growing category has been health care practitioner occupations, which increased by 16 percent from a larger base and added 1.2 million jobs on net. The slowest-growing occupations are still below their 2007 job totals. These include construction and production occupations, which are off 23 percent and 13 percent, with net decreases of 2.2 and 1.3 million jobs, respectively. Office and administrative support occupations also saw a large job decrease from 2007 to 2013, a loss of 1.7 million.

These employment growth changes are highly correlated with the level and changes in unemployment since the recession. As of March 2014, the national unemployment rate was 2.2 percentage points above its 2007 level of 4.6 percent, but unemployment rates for computer and health care practitioners stand at just 0.7 and 0.9 percentage points above 2007 levels. Architectural and engineering occupations, as well as life, physical, and social science occupations did not fare as well, increasing by 1.4 and 2.0 percentage points, which is still below the national average. Yet, unemployment was so low before the recession that current unemployment is still only 3 and 4 percent for these workers, which helps explain why job vacancies are difficult to fill despite a net decrease in job growth from 2007 to 2014. Meanwhile, construction workers still suffer from unemployment rates that are 4.2 percentage points above the 2007 level.

Specific High-Value Skills Requested by Employers and Common to STEM Occupations Are Particularly Scarce Relative to Demand and Particularly Valuable to Employers

Skills vary both between and within occupations. Every job is classified into an occupation according to various characteristics like skill, task, and educational requirements. Yet, some occupations are more uniform across industries, companies, and work teams (like cashiers or electricians), while others differ widely in the specific skills required in different settings. This is the case for many computer, health care, and management jobs, as one can see by looking at the number of distinct skills requested by employers in job advertisements (Table 7).

In the first quarter of 2013, employers requested 1296 distinct skills for health care workers and 1272 distinct skills for computer workers. For health care jobs, the most common skill requirements include patient care, treatment planning, case management, Lotus Notes (a form of collaboration software), clinical experience, medical coding, and rehabilitation. For computer jobs, Oracle, Microsoft Windows, JAVA, SQL, SAP, quality assurance and control, LINUX, and UNIX are frequently mentioned skill requirements. Thus, for these sorts of jobs, one needs to have a very specific skill to be qualified. It is not enough to have worked in the same occupation for the requisite amount of time and to have obtained the requisite degree. Skills matter.

Likewise, some skills have much greater value to employers than others. The value of a distinct skill is measured by calculating the average pay associated with each skill. For example, if two jobs in early 2013 mention "JAVA programming" as a required skill, and one of the advertisements cites a salary of $100,000 and the other a salary of $50,000, then the average value of the skill is $75,000.[51]

This value is a function of both the skill's relative scarcity and its capacity to generate value for the firm. The skills common to computer occupations are collectively the most valuable in the economy at present, at least as reflected by job advertisements that report specific salaries and are advertised on company websites. Architectural and engineering skills are also highly valued, as are skills in other professional occupations. Among the least-valued skills are those commonly found in building and

Table 7. The Value and Diversity of Skills Within Major Occupational Groups

Occupation	Average value of distinct skills	Number of distinct skills
Computer and Mathematical	$76,590	1,272
Architecture and Engineering	$67,229	615
Business and Financial Operations	$67,043	747
Management	$66,384	843
Sales and Related	$63,081	358
Health Care Practitioners and Technical	$60,578	1,296
Legal	$59,306	67
Community and Social Service	$58,053	80
Arts, Design, Entertainment, Sports, and Media	$53,661	149
Life, Physical, and Social Science	$52,817	597
Education, Training, and Library	$52,635	63
Installation, Maintenance, and Repair	$49,407	340
Health Care Support	$48,331	258
Construction and Extraction	$46,024	171
Office and Administrative Support	$44,881	529
Food Preparation and Serving Related	$43,614	32
Transportation and Material Moving	$43,416	78
Personal Care and Service	$43,063	56
Production	$42,318	225
Protective Service	$38,905	64
Building and Grounds Cleaning and Maintenance	$38,857	47

Source: Brookings analysis of data from Burning Glass. Sample is all vacancies advertised online through company websites in 2013-Q1.

grounds cleaning, security, production, and personal care. For occupations with at least 50 vacancies, the most valuable computer skills include data visualization, Netcool, process management, natural language processing, Mathematica, automation tools, wireless telecommunications, machine learning, PIG, software as a service, iOS, game development, Android Software Development Kit, and structured query reporter. Each of these skills is worth well over $100,000 in average salary, as advertised in early 2013.

Not only are computer skills the most valuable, they are advertised for the longest period of time, suggesting that they are the most difficult to fill (Table 8). For each distinct skill, the data allow a calculation of the median advertising duration in days, and that value is averaged across all skills according to which occupation requested the skill most frequently. The weighted average median duration for computer skills comes to 22.7, just ahead of skills in the sciences. Engineering and health care skills are also relatively difficult to fill, whereas skills in construction, legal, office, and production are easy to fill, requiring about half as much time.

Among particular skills requested in at least 500 different job announcements in the first quarter of 2013, 434 distinct computer-related skills are advertised for at least 30 days on average. Another 255 distinct computer skills linger in company website ads for at least 40 days. There are 80 such skills related to engineering occupations and 20 related to science occupations.

Compare these to skills common to legal professions. Just one skill with at least 500 vacancies—intellectual property—is advertised for an average of 40 days. Since intellectual property lawyers often work for tech companies to initiate or enforce patents, this is arguably the most STEM intensive of all

Table 8. The Duration of Advertisements for Distinct Skills by Most Frequent Major Occupational Group

Occupation	Average median duration of distinct skills
Computer and Mathematical	22.7
Life, Physical, and Social Science	22.4
Management	21.7
Education, Training, and Library	21.6
Personal Care and Service	21.1
Architecture and Engineering	20.8
Health Care Practitioners and Technical	20.3
Arts, Design, Entertainment, Sports, and Media	20.3
Business and Financial Operations	17.9
Sales and Related	16.5
Building and Grounds Cleaning and Maintenance	15.4
Health Care Support	13.5
Community and Social Service	13.3
Food Preparation and Serving Related	11.8
Installation, Maintenance, and Repair	11.4
Transportation and Material Moving	11.0
Construction and Extraction	10.6
Legal	10.6
Office and Administrative Support	9.9
Production	9.6
Protective Service	8.9

Source: Brookings analysis of data from Burning Glass. Sample is all vacancies advertised online through company websites in 2013-Q1.

legal skills. Meanwhile, just eight skills sought in 500 or more openings in office and administrative positions meet or exceed an average duration of 40 days; these include qualitative analysis and policy review.

Among the most difficult-to-fill computer skills are many unfamiliar to all but computer programmers and software experts (see Appendix Figure 5 for partial list). The hard-to-fill skills include Mathematica, PIG, Apache Hadoop, OpenGL, NoSQL, Python, R, C++, Android, iOS, Biostatistics, Ruby on Rails, and PERL. Ads with these skills linger on company websites for an average of 50 days. At the opposite end of the spectrum are a smaller number of computer skills that are relatively easy to fill. Among these, requiring 33 days or fewer, are support skills, which include technical support, IT support, help desk support, and telephone technical support. These are also skills associated with lower advertised salaries.

Engineering analysis, HAZOP, electronic design, Mathcad, circuit design, chemical engineering, engineering software, and power distribution are among the hardest-to-fill engineering skills, requiring at least 45 days of advertising (Appendix Figure 6). Also high on the list are ads requiring the "Six Sigma" engineering process management certifications, which post an average of 43 days for black and green belts. The easier-to-fill skills include manufacturing engineer, which may reflect a

still-depressed manufacturing sector relative to five to 10 years ago, and architecture-related skills like LEED, permitting, and CAD, which may reflect the still weak commercial and residential construction markets. These ads are posted for 36 or 37 days, on average.

For science and social science vacancies, the hardest-to-fill skills include Stata, an analysis and programming tool commonly used by economists; biologics development; proteins; cell biology; biotechnology; and analytical chemistry (Appendix Figure 7). These skills are posted for at least 40 days, on average. Among the easiest skills to fill are policy analysis (32 days) and environmental studies (25 days).

A high percentage of installation, maintenance, and repair occupations require significant STEM knowledge in at least one field, and the occupations cover a diverse array of skills (Appendix Figure 8). Among the hardest-to-fill skills, each lasting at least 40 days, are plotters, a kind of printer used in technical designs; sockets; computer hardware/hardware knowledge; engine repair; and equipment inspection. Among those advertised for the shortest period are PC support, masonry, carpentry, and plumbing repairs. The last three are common in the hard-hit construction sector.

The regional supply of workers in a given occupation affects the length of vacancy advertisements

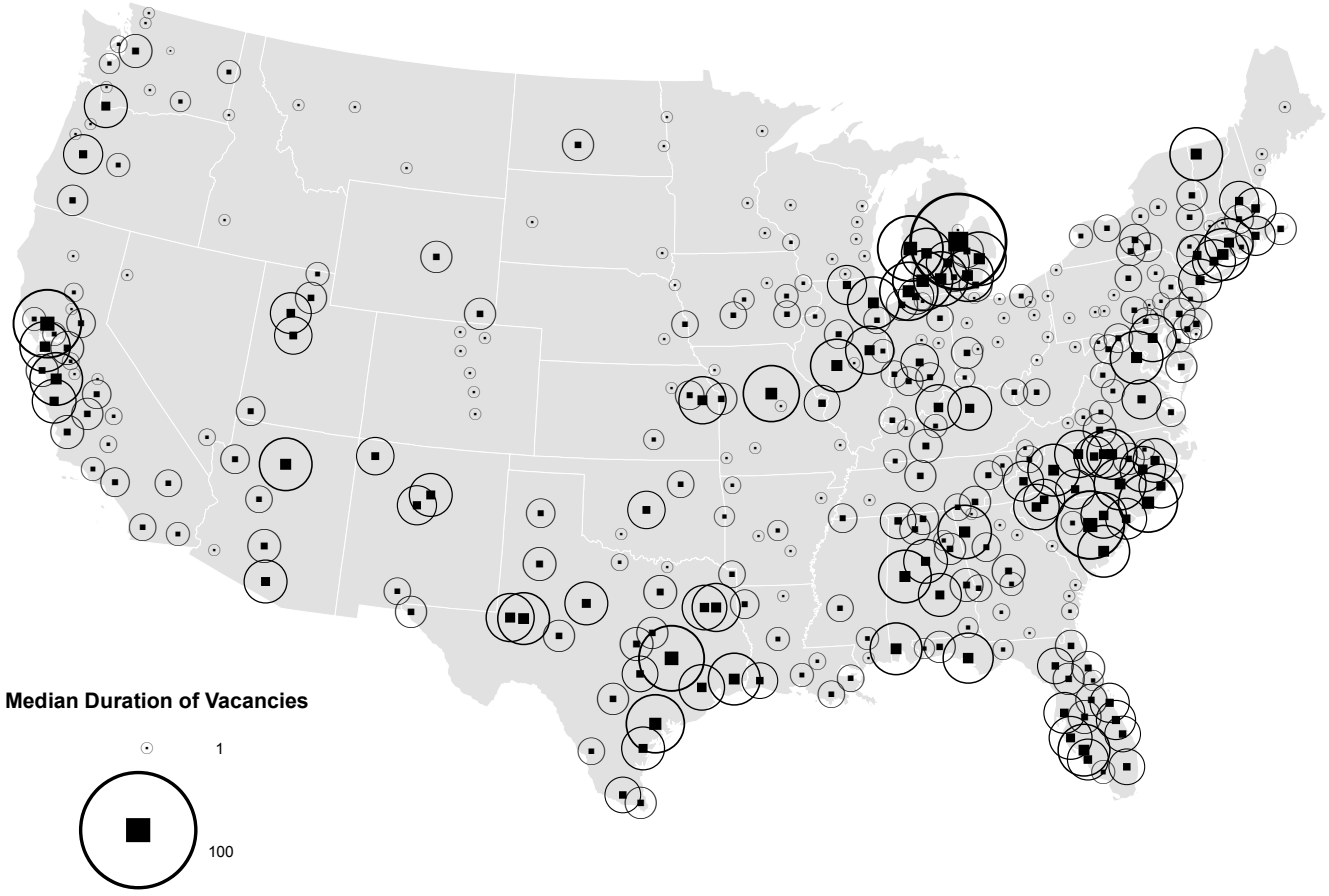
Hiring difficulty varies widely across U.S. regions. In general, metropolitan areas in the South have somewhat longer median advertisement duration times than those in the Northeast and West. The difference is three days (eight versus five), but statistically significant. The Midwest has greater variation with some states at either end of hiring difficulty spectrum.[52]

The large metropolitan area with the longest median duration time, at 21 days, is Detroit, followed by San Jose, CA and Washington (20 days), and by New Haven, CT; Charleston, SC; Chicago; Grand Rapids, MI; San Francisco; and Durham-Chapel Hill, NC (18 days). Those with a median duration of just one day include Columbus, Toledo, and Youngstown, OH; Madison and Milwaukee, WI; Akron, OH; Pittsburgh and Lancaster, PA; Boise, ID; Minneapolis; and Denver and Colorado Springs, CO. Figure 1 illustrates this variation using median ad duration for all metropolitan areas.

What explains this variation? No one factor, certainly. As the appendix shows, company characteristics, ad characteristics, and metropolitan supply and demand factors all have an effect, not to mention individual idiosyncrasies of resumes and hiring managers. Yet, broad patterns are evident, with the strongest single explanatory variable being the average value of skills advertised for the job opening.

Many of the metropolitan areas with the most valuable skills demanded by employers are also those with the longest median duration times (the correlation is 0.55 for large metro areas). The average skills mentioned in a San Jose job announcement are the most valuable in the country—worth $68,000 on average, using salary data from the entire country associated with each skill advertised. Next is San Francisco at $63,500, followed closely by Washington; Austin, TX; New York; Durham-Chapel Hill, NC; Seattle; Charlotte, NC; Hartford, CT; Raleigh, NC; Boston; Bridgeport, CT; and San Diego—all with averages above $60,000. At the low end, the average skills advertised are worth less than $53,000 in metros such as Toledo and Lancaster, OH; Boise, ID; Youngstown, OH; and McAllen, TX.

Figure 1. Map of Median Duration



Source: Brookings analysis of Burning Glass data

Table 9. Labor Supply Characteristics of Workers' Occupations by Level of Unemployment and Duration of Job Vacancies in Metropolitan Areas

	High unemployment		Low unemployment	
Unemployment rate of occupational group	>10%	<=10%, >=5%	<5%, >=3%	<3%
Median duration of opening (days) for occupational group	7.4	8.5	13.7	14.3
Vacancies per unemployed worker for occupation	0.1	0.2	0.5	1.4
Percentage of openings requiring STEM expertise for occupation	15%	21%	55%	68%

*Source: Brookings analysis of 2013-Q1 Burning Glass data on job openings and 2012 American Community Survey data on worker characteristics by two-digit major occupation for each metropolitan area. STEM classifications use O*NET and are described in Rothwell, "Hidden STEM Economy." Many vacancies for high-turnover occupations are almost never taken down because the company is constantly filling openings created by quits. These should not be interpreted as hard-to-fill. They are almost always in the high-unemployment category.*

As mentioned above, STEM jobs tend to demand more valuable skills. And so, despite the variation in ad duration times across metropolitan areas, STEM jobs, especially those requiring more education, take longer to fill consistently across metropolitan areas. In 82 percent of all metropolitan areas and 91 of the 100 largest metropolitan areas, STEM jobs take longer to fill, on average, than non-STEM jobs. In 82 of the top-100 metro areas, the average STEM job is advertised for at least 30 days. Yet, different STEM occupations, requiring different levels of education, are more or less mismatched between supply and demand across metropolitan areas.

For STEM jobs requiring a bachelor's degree or higher, Fresno, CA has the longest average duration, at 68 days. Health care practitioner jobs in Fresno are advertised for 74 days on average, and the length is 71 and 108 days, respectively, for computer and life, physical, and social science jobs in the area. In San Jose, it takes 59 days on average to fill a STEM job requiring a bachelor's degree, and 54 days in San Francisco. In Seattle and Washington, it takes 48 and 46 days, respectively. On the other extreme, in Des Moines, IA; Columbus, OH; Syracuse, NY; and Knoxville, TN, it takes less than 30 days to fill the average STEM vacancy for occupations that typically require a bachelor's degree.

In other metropolitan areas, sub-bachelor's STEM jobs stand out as hard to fill. In Stockton, CA, the average advertising duration of a job requiring STEM knowledge and a mid-level of education (between some college and an associate's degree) is 91; it is 85 in Omaha, NB; 69 in North Port, FL; 62 in Worcester, MA; and 60 in Providence, RI. Across these metros, a large percentage of the hard-to-fill mid-level STEM jobs are in health care occupations. By contrast, health care and other mid-level STEM jobs are relatively easy to fill in places like Madison, WI and Pittsburgh. In other areas, like Durham-Chapel Hill, Seattle, San Diego, and Detroit, installation, maintenance, and repair vacancies—which are STEM intensive—endure for long periods: 51, 45, 44, and 43 days, respectively. However, in Denver and Hartford, CT, it takes just 21 days to fill vacancies for these occupations.

Of course, there is no pure national labor market—a given vacancy is not at all equally likely to be filled by a worker living in any part of the country. In many ways, the capacity of a company to find the workers it needs in a timely fashion depends on the time of the vacancy and location of the job. Companies can draw workers—especially young workers who face lower social costs from relocating—from around the country and even around the world. At the same time, travel, information, and social costs mean that the metropolitan area is the most relevant labor market for recruiting.

Empirically, it turns out that metropolitan-area location has a large and important effect on how quickly a company can fill its vacancies, and evidence discussed in the appendix suggests that the local market is more important than the national market. The median duration of a job opening increases as the unemployment rate for workers in the same occupation decreases. That is, when unemployment is high for a given occupation in a given metropolitan area, the local supply of workers willing and able to apply for and accept a position is also high. Therefore, companies can easily

fill their vacancies, even for some highly skilled positions. At the same time, a larger absolute number of even employed workers also helps a company fills its vacancies faster because some percentage of employed workers will be willing to seek a more attractive opportunity, especially if the pay is higher. These results are robust to a number of competing interpretations, including company differences, as the appendix discusses.

The relationship between local labor markets and vacancy duration is clear from simple summary statistics. For workers in an occupation with a regional unemployment rate of 10 percent or higher, the median ad duration is 7.4 days (Table 9). The duration increases to about nine days for workers with a regional unemployment rate between 5 and 10 percent and jumps to roughly two weeks once the unemployment rate falls under 5 percent. There is a similar relationship between ad duration and the unemployment rate in terms of the share of vacancies posted more than 30 days and the within-company differences in average duration.

Another way to see the supply-demand mismatch for these occupations is to examine the number of vacancies per worker. In the first quarter of 2013, there were just 0.1 vacancies for every unemployed worker in an occupation for which the regional unemployment rate was greater than 10 percent. Meanwhile, there were 1.4 vacancies per worker if the occupation's regional unemployment rate was below 3 percent. Simply put, workers in high-demand/low-unemployment occupations face much less competition in the labor market than do those in low-demand/high-unemployment occupations. A construction worker or food preparation worker living in a metropolitan area with high unemployment has about the same odds of getting a job as an applicant to an Ivy League university has of getting admitted.

A few caveats are worth noting in interpreting the ratio of vacancies per unemployed worker. The total number of job vacancies listed here is likely understated for all occupations, since these ads are taken only from company websites and not job boards. Also, food preparation and serving openings, a high unemployment occupation, are probably understated the most, though not nearly enough to make up the differences here. In other words, the gaps between groups are much too large to be explained by data limitations.

Finally, these results show that the dominant characteristic of occupations with low regional unemployment rates and high numbers of job vacancies is that they are in STEM fields. Over two-thirds—68 percent—of online job advertisements for occupations for which the regional unemployment rates were below 3 percent are for STEM occupations. When unemployment rates for STEM workers are over 10 percent, just 15 percent of ads seek workers with STEM expertise, and the jobs advertised tend to be for non-professional occupations in areas such as construction or production.

A few metropolitan-level examples illustrate the statistical link between regional occupational-specific unemployment rates and vacancy duration. The national unemployment rate for computer and mathematical science workers in 2012—the latest year with comparable metropolitan data—was 3.5 percent, but it varied considerably across large metropolitan areas.

In metropolitan San Jose and Boston, the unemployment rate for computer and math workers was 3.5 and 3.1 percent, respectively, but in metropolitan New York City and Las Vegas it was 5.1 and 9.2 percent. Partly as a result, companies filled vacancies in early 2013 much faster in New York and Las Vegas than in San Jose and Boston. The mean vacancy duration for computer workers was 34 days in Las Vegas and 36 days in New York; in San Jose and Boston, mean duration times dragged out to 61 and 43 days.

Examples from engineering occupations further illustrate the trend. In metropolitan Dallas, the unemployment rate for architects and engineers is 3.6 percent compared to 2.8 percent in Houston, and it takes 10 extra days to fill a vacancy for architects and engineers in Houston—51 versus 41 days. Likewise, in metropolitan Atlanta the unemployment rate for architects and engineers is 7 percent, compared to just 1.8 percent in Raleigh, NC. Vacancies for these workers are posted for 29 days in Atlanta compared to 54 days in Raleigh.

To some extent, these differences in ad duration time are attributable to differences in the skill level required of the workers and other factors, but a more detailed analysis—discussed in the appendix—shows that metropolitan area unemployment rates explain some of the differences even accounting for those skill-related factors. Metropolitan areas with larger numbers of workers in a given occupation also tend to fill vacancies faster, all else being equal.

Conclusion

This report analyzes an extraordinary new database of millions of job openings and their characteristics in terms of skills, occupations, educational requirements, location, and advertising duration. To the author's knowledge, this is by far the largest database of vacancy duration to be analyzed, and this is the first national research database of vacancy duration by skill level. In that respect, this report offers a powerful tool for understanding the supply and demand for skills, yet it touches on only a few of many research issues that the data can help address with new clarity and precision.

The principle finding is that there is a relative shortage of U.S. workers with STEM skills. In other words, STEM skills are in high demand relative to supply, and the problem is especially acute in certain metropolitan areas, where the average vacancy for STEM workers takes months to fill. As a result, workers with STEM knowledge tend to readily find job opportunities, even as large categories of workers with little education or STEM skills compete over a relatively small number of jobs.

The extent to which there is an absolute shortage of STEM skills is harder to determine. One might consider things like the actual number of job vacancies by field and how it compares to the number of potential workers with the right skills. This would involve estimating how frequently employed workers in various fields would be able or willing to switch jobs. Alternatively, and more directly, one could analyze data on the number of qualified applicants for each STEM job, but such data do not currently exist.

Whether the absolute STEM shortage is mild or severe, important consequences follow from even a relative shortage. Without major changes in training or education policy and practice, the relative shortage of STEM workers will likely play out by enlarging the already sizable long-term gap in lifetime earnings and unemployment rates between STEM and non-STEM workers, exacerbating income inequality generally and inequality across racial/ethnic groups and gender more specifically.

At the same time, as the economy continues to recover from the Great Recession, opportunities for low-skill workers will also expand, lowering unemployment and reinforcing growth. That prediction is consistent with previous Brookings research emphasizing the importance of cyclical demand in explaining changes in unemployment.[53] Still, macroeconomic recovery will not erase the large differences in earnings or unemployment rates across occupations, which have favored STEM workers for a number of years across cycles of recessions and booms.[54] This is an important aspect of inequality of opportunity, and the only way to systematically address it is by offering greater access to STEM-relevant training and education.

Previous Brookings research on the STEM economy describes the wide array of federal,

State Initiatives to Understand and Address STEM Labor Demand

Labor market data has the potential to improve education and training practices, but in order to maximize the benefits states need detailed data and a policy framework that connects data to funding allocations.

On the data gathering side, Washington and Oregon state governments conduct what are perhaps the most detailed state-specific vacancy surveys and include explicit questions about hiring difficulty and duration by occupation. Florida's Department of Economic Opportunity does not collect ad duration data, but it does use Conference Board data to track growth in STEM vacancies posted online, and it combines these data with detailed administrative records from colleges and universities to estimate supply-demand mismatches.

On the policy side, many, if not all, states use labor market data to inform policy, but some go further in making direct connections between job openings data and spending for training and education. North Carolina's state legislature is considering a proposal from its Community College Board to boost spending on sub-bachelor's STEM education programs for high demand occupations by 15 percent, or $16.8 million.[a] . Likewise, Pennsylvania created the Pennsylvania Targeted Industry Program, which allocates $5 million to STEM-relevant training and education programs.[b] At the university level, Florida created a new performance funding model which allocates state funding to universities based, in part, on how well colleges are doing at graduating students in high-demand STEM fields.[c] A handful of community colleges are also using job openings data to inform curriculum development.[d]

a. State of North Carolina, http://www.governor.state.nc.us/newsroom/press-releases/20140410/governor-pat-mccrory-proposes-higher-investment-high-demand

b. Pennsylvania Higher Education Assistance Agency, Pennsylvania Targeted Industry Program, available at http://www.pheaa.org/funding-opportunities/pa-tip/ (June 2014).

c. State University System of Florida, Board of Governors, Performance Based Funding Model, available at http://www.flbog.edu/about/budget/performance_funding.php (June 2014).

d. Mary Wright, "Aligning Career Training With Employer Demand" (New York: Jobs for the Future, 2014).

state, local, non-profit, and corporate efforts being made to boost the supply of STEM workers.[55] These efforts cut across political party lines, levels of government, and sectors at a time when the nation's leaders can seem to agree on little else. A less conventional conclusion from that research is that there is little relative effort at the federal level to train incumbent workers or educate young workers for sub-bachelor's degree STEM careers. The findings from this study are consistent with the implication that STEM careers at the post-secondary but sub-bachelor's level (e.g., nurses; technicians; and installation, maintenance, and repair workers) are in high relative demand.

There are exceptions, however. Blue collar STEM jobs in construction and production jobs are relatively easy to fill nationally. This exception can be explained by the extraordinary number layoffs that hit the construction and manufacturing sectors during the recession, combined with long-term competition with developing countries with respect to manufacturing. There are regional pockets of hiring difficulty for these occupations, but nationally, on average, they are easier to fill than most non-STEM jobs.

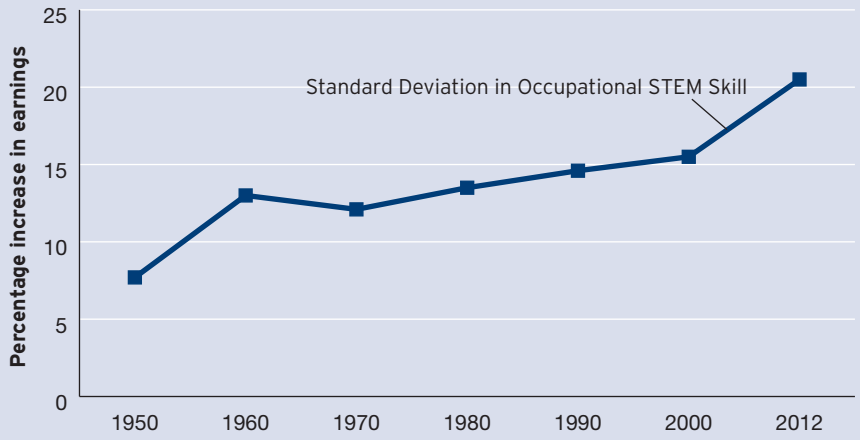
At another level, this report presents a new and powerful tool to examine relative supply and demand imbalances across occupations and skills. A handful of states are currently conducting similar analyses (see box), but their reliance on either survey data or alternative data sources limits the details that can be extracted for research or policy purposes. For students and educators, the detailed information on the value and labor market demand for specific skills could prove useful for motivation or funding. Moreover, regional-level statistics can be used to assess strengths and weaknesses in the area's workforce pipeline. The goal of all of these efforts should be to expand opportunities for people to pursue and enter rewarding careers, many of which have large social benefits.

Appendix

One can quantify STEM knowledge by asking workers about the level of STEM skills needed to do their jobs. The Department of Labor funds such a survey, called O*NET, which provides knowledge scores in various domains for every occupation in the economy. Occupations with extraordinarily high levels of knowledge in one or more STEM fields are classified as STEM occupations in this report, building off a method developed in previous Brookings research and updated with Version 18 of O*NET.

Using census microdata from IPUMS (the University of Minnesota's data series), one can project the current skill levels of occupations retrospectively and observe how earnings have changed for a given unit (a standard deviation) of STEM knowledge. To estimate a premium for STEM knowledge, one can use individual census data and regress a standardized STEM score on the log of earnings, controlling for a quartic in age (to account for experience at various life stages), a binary variable for sex (to account for the male earnings premium), and binary variables for each level of education. Appendix Figure 1 shows the results of this exercise.

Appendix Figure 1. The Earnings Premium for STEM Knowledge, 1950-2012



*Brookings analysis of U.S. Census and American Community Survey data from IPUMS. STEM knowledge was calculated using methods described in "The Hidden STEM Economy" (cited in references) and drawing on survey data from O*NET*

Analysis of Bias in Online Data Using Trends in Hiring Difficulty

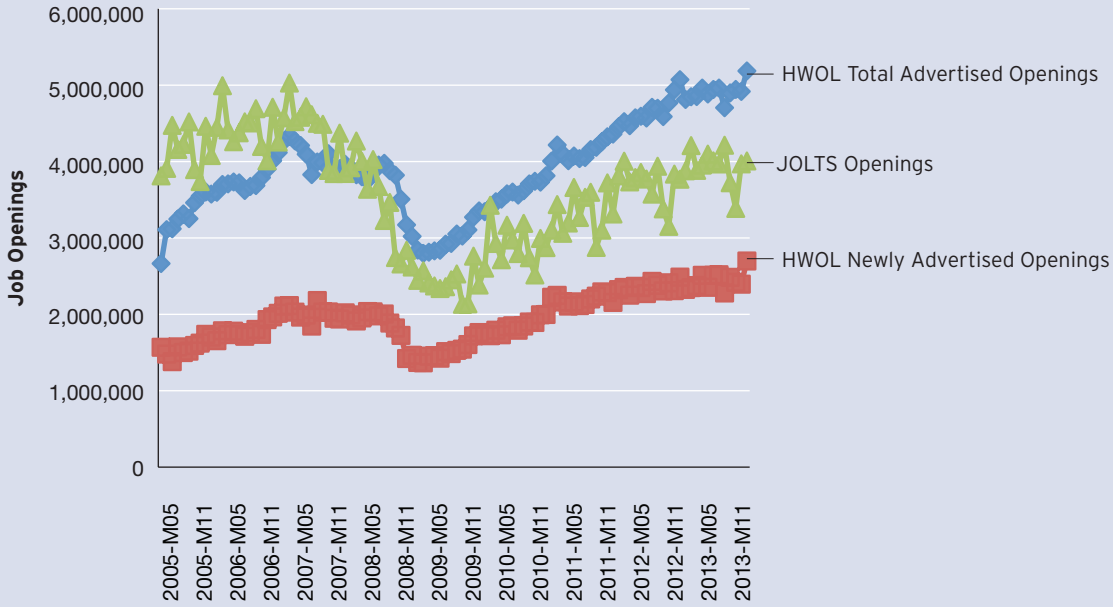
To investigate potential sources of bias between online job advertisements and those that use any kinds of recruiting (including posting a help wanted sign or using word-of-mouth), the appendix compares trends in vacancies and hiring difficulty between the Conference Board's HWOL and BLS's JOLTS. Because JOLTS relies on a direct survey of employers, it avoids any online-only bias and can be used to compare aggregate trends in the number and duration of vacancies. A comparison of total openings from JOLTS with total new openings from HWOL shows that HWOL seemed to capture about 60 percent of all job openings in recent years (since 2007)—assuming JOLTS is accurate—though only about 40 percent before the recession (2005 to 2006).

Since 2008, however, total HWOL ads have been larger than total JOLTS ads. This can be explained by the fact that HWOL also collects re-posted or unfilled advertisements, adding to monthly totals. Meanwhile, HWOL ad growth has exceeded JOLTS growth for what seems like methodological reasons: A higher percentage of ads are advertised online and captured by HWOL in recent years than in earlier years.

In both sources, the recession is clearly marked by a trough in job vacancies. Both sources show a major downturn around the beginning of 2008 that didn't reverse until the middle of 2009 (see

Appendix Figure 2). In fact, despite using very different methods, JOLTS and HWOL vacancy data are highly correlated, though the recession showed up earlier and lasted less time in HWOL. If one breaks up the data into before and after January 2008, the correlation between JOLTS and HWOL is 0.74 before and 0.81 after.

Appendix Figure 2. All U.S. Job Openings Advertised Online (HWOL) Compared to Those Reported by Businesses (JOLTS), 2005-2014



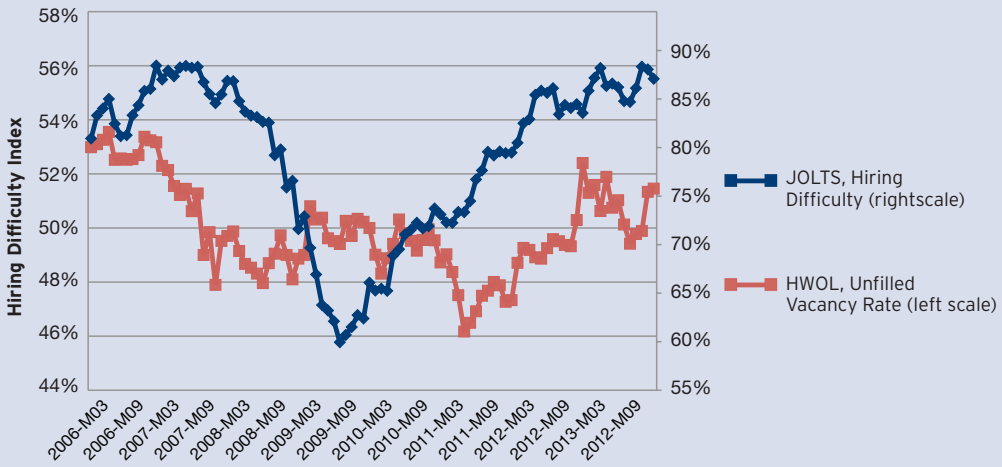
Brookings analysis of data from JOLTS and the Conference Board's HWOL Series.

Looking at only recent data, the major difference between the two surveys is informative. The JOLTS survey shows openings have not fully rebounded to their pre-recession levels, though recent openings are off by less than 10 percent. By contrast, HWOL vacancy data show that openings have more than recovered and are now roughly one-third higher. One explanation is that HWOL data are biased toward professional occupations and underrepresent jobs in food preparation and other positions with few skill requirements.

JOLTS data are not available by occupation, metropolitan area, or detailed industry, but they can be used to calculate *hiring difficulty*: the number of openings last month divided by the number of new hires this month. Little hiring relative to the number of openings suggests that vacancies are going unfilled at a higher rate. These data are generated through traditional survey methods, and, like the state surveys, do not require that companies post anything online. The major challenge with these data is the incongruity between how hires and vacancies are defined. The JOLTS definition of hires includes any worker who transfers from another establishment and workers who are re-hired after being laid off temporarily. These are not counted as advertised open positions, but there is no way to filter them out in the data when comparing hires to openings. Thus, hires always tend to exceed openings.

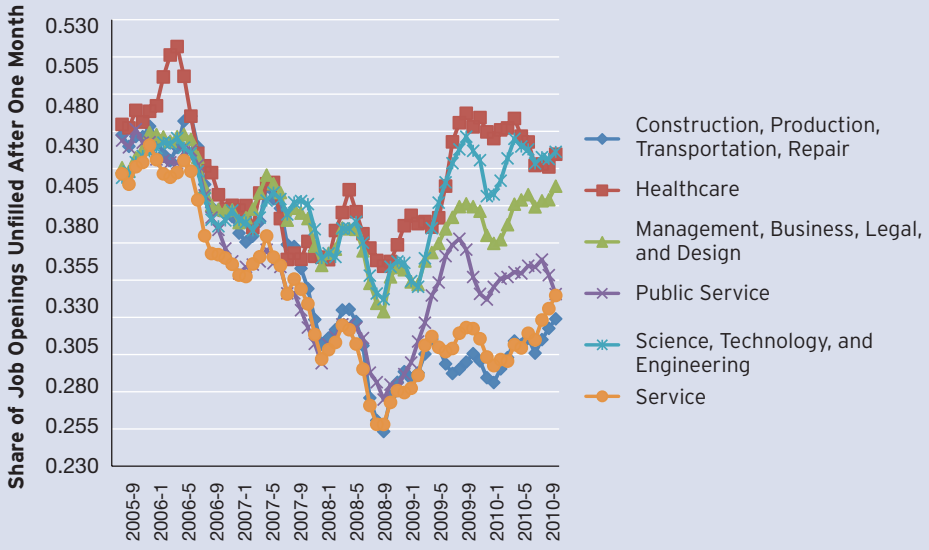
Both JOLTS and HWOL show a sharp decrease in hiring difficulty during the recession and a rebound thereafter (see Appendix Figure 3). The pattern is especially clear in the JOLTS data and is consistent with economic search theory, which predicts that an increase in vacancies and a decrease in unemployment will result in greater difficulty matching openings to workers. The intuition is simple: If there are fewer workers competing over the same job openings, as would be expected when more are employed, then firms will have to search longer to fill vacancies. These trends suggest that the relative difficulty of filling STEM positions is not just relative but actual, since hiring difficulty for the average job—which is much easier to fill than a typical STEM job—is high even compared to economic boom periods.

Appendix Figure 3. The difficulty of filling job vacancies advertised online (HWOL) compared to those reported by businesses (JOLTS), monthly, 2006-2014



Brookings analysis of data from JOLTS and the Conference Board's HWOL Series for 100 largest metropolitan areas.

Appendix Figure 4. Difficulty of Filling Job Vacancies in Largest Metropolitan Areas by Occupational Category, Three-Month Average, 2006-Q4 to 2012-Q1



Brookings analysis of Conference Board's HWOL Series for 100 largest metropolitan areas.

Appendix Figure 4 uses HWOL data to plot the changes in the unfilled job vacancy rate for large categories of occupations for occupations advertised in the 100 largest metropolitan areas.

Analysis of Bias in Online Data Using Level of Vacancy Duration

One might assume that online advertisements are biased toward professional job openings, especially those in computer occupations, and they are biased against jobs in food preparation and serving-related occupations. This section explores what that level of bias looks like in detail.

To better understand this bias, I collected data from state job vacancy surveys that do not rely upon online advertisements but rather ask employers directly about the number and characteristics of their job vacancies. About a dozen states publish job openings data, but not all of them publish those data at the metropolitan-area level, which is the aggregation I have available from Burning Glass (though Burning Glass also collects non-metropolitan data).

I put together six quarters of data from Minneapolis, three quarters from Boston, one from Seattle, and one from Portland, OR over the 2010 to 2013 time period, covering the 22 major occupational categories for each place and quarter. The degree of bias was calculated as the Burning Glass share of job openings by occupation less the state-survey share. This assumes that the state-survey share more accurately reflects the distribution of vacancies across occupations because it does not require that the employers advertise the positions online.

Appendix Table 1. Distribution of Job Openings Across Occupations in Metropolitan Areas by Data Collection Source: Online Versus Traditional Survey, 2010-2013

Occupation	State-Survey Share of Openings	Burning Glass Share of Openings	Weighted Average Difference
Computer and Mathematical Occupations	8.5%	18.1%	8.9%
Management Occupations	7.0%	13.8%	6.8%
Business and Financial Operations Occupations	6.7%	10.7%	3.8%
Architecture and Engineering Occupations	2.8%	4.1%	1.2%
Legal Occupations	0.5%	1.4%	1.1%
Health Care Practitioners and Technical Occupations	6.4%	7.4%	0.9%
Arts, Design, Entertainment, Sports, and Media	1.9%	2.6%	0.6%
Life, Physical, and Social Science	1.6%	2.1%	0.3%
Office and Administrative Support Occupations	10.1%	10.5%	0.2%
Protective Service	1.0%	0.7%	-0.3%
Production Occupations	2.9%	2.8%	-0.4%
Installation, Maintenance, and Repair Occupations	2.2%	2.2%	-0.5%
Farming, Fishing, and Forestry Occupations	0.2%	0.0%	-0.6%
Construction and Extraction	1.3%	0.6%	-1.2%
Community and Social Services	2.5%	1.2%	-1.7%
Education, Training, and Library Occupations	4.5%	2.8%	-1.9%
Personal Care and Service Occupations	3.8%	2.1%	-1.9%
Health Care Support Occupations	3.6%	1.4%	-2.4%
Transportation and Material Moving Occupations	4.9%	2.5%	-2.7%
Building and Grounds Cleaning and Maintenance	3.0%	0.7%	-3.0%
Sales and Related Occupations	13.0%	10.0%	-3.3%
Food Preparation and Serving Related	11.7%	2.3%	-10.1%

Source: Brookings analysis of Burning Glass data and various state surveys for vacancies in Boston, Minneapolis-St. Paul, Portland-Vancouver-Hillsboro, and Seattle-King County metropolitan areas over the 2010-2013 period.

As Appendix Table 1 shows, the weighted-average difference in the occupational share of vacancies across the two methods is largest for computer and mathematical occupations, at 8.9 percent. To put this in perspective, these results imply that, for any sample of 100 job vacancies advertised online, an extra nine will be in computer occupations. Management and business occupations are the only other groups with differences above 1 percent after rounding. Overrepresentation in one occupational group implies underrepresentation in another. The only group grossly underrepresented seems to be food preparation and serving occupations, which represent a much larger share (10.1 percent) of state-surveyed vacancies compared to online vacancies. Only a small percentage of these jobs, apparently, are advertised online, possibly because many are "always open" and filled through social network and neighborhood recruitment. Sales (including retail cashiers) and building cleaning are other groups underrepresented by more than 1 percent.

The two methods largely agree on the distribution of jobs for health care practitioners, arts and design occupations, scientists, office workers, and a variety of blue-collar occupations. Evidently, a high percentage of these jobs are advertised online. Even construction occupations, which one might think unlikely to be advertised online in high percentages, appear well represented by the Burning Glass database.

Duration Bias From Online Sources

To check if job fill duration data are similar in more traditional surveys to what they are in online surveys, I obtained data from the Washington State Employment Security Department's job vacancy survey for the second quarter of 2013 for Seattle. For two-digit occupational categories, there is a very similar ranking between the Burning Glass measure of vacancy duration and Washington State's measure. For 2013 data, the department publishes data on the probability of filling a vacancy by major occupation for Seattle. The correlation was -0.4 between these data and the average days an ad was posted as compiled by Burning Glass, using all ads from the first three quarters of 2013. Likewise, the hard-to-fill occupations tended to be similar in both surveys. For the Seattle survey-based data, the five hardest occupations to fill were computer and mathematical, architecture and engineering, health care practitioners and technical, transportation and material moving, and personal care and service. With Burning Glass data, the five were education, training, and library; computer and mathematical; architecture and engineering; management; and personal care and service; health care was sixth. So, four of the five hardest occupations according to the Seattle survey also showed up in the top six on the Burning Glass list.

To further check the relationship between Burning Glass duration statistics and duration measures derived from traditional surveys, I analyzed data from the Oregon Employment Department that were provided to me by the department's research staff. At the two-digit level, the correlation between the share of jobs taking 30 or more days to fill and median duration (from Burning Glass) was 0.47. This is further evidence that relative duration statistics are valid across both Internet-only and traditional surveys. Moreover, this and the above suggest that advertisement duration is closely related to vacancy duration.

Finally, does vacancy duration indicate supply-side hiring difficulty? The answer can be partly obtained from looking at data from the Oregon Employment Department. Oregon's vacancy surveys are unique in asking employers to report whether a job is difficult to fill and why. Working with six-digit vacancy data provided by research staff at the department reveals a strong correlation (0.43 for all occupations or 0.56 for the 85 occupations with at least 100 ads) between vacancy duration and the percentage of total ads rated difficult to fill for supply-side reasons (e.g., lack of qualified candidates, experience, or technical skills). At the two-digit level, the correlation is even higher: 0.69. In both cases, vacancy duration is measured as percentage of ads vacant for at least 30 days. So, vacancy duration does seem to indicate supply-side shortage issues.

The results are similar using Burning Glass vacancy duration data and comparing the data directly to the percentage of occupations deemed difficult to fill for supply-side reasons by employers in Oregon. The correlation is 0.36 using average duration and 0.51 using median duration. Oregon state survey data show architecture and engineering jobs are rated the hardest to fill for supply-side reasons, followed by jobs in business, installation, transportation, computers, and health care. Among these jobs, the average vacancy duration using Burning Glass data for Oregon was 35 days, compared to 29 days

for the five occupations with the fewest supply-side hiring difficulties. The Burning Glass median was 14 compared to six for the jobs with the least supply-side hiring difficulties. Clearly, the Burning Glass measure of vacancy duration is capturing some aspects of supply-related hiring difficulty as expressed by employers, even among different employers at slightly different periods of the year.

Always-Open Vacancies

When the vacancy data are aggregated to the two-digit major occupation level, it is clear that occupations that take longer to fill are harder to fill, and are harder to fill primarily because of a lack of qualified candidates. There were nine major occupational categories in Oregon for which at least 35 percent of vacancies took longer than 30 days to fill. In these occupational categories, 29 percent of openings were deemed difficult to fill by employers for demand reasons, such as lack of qualified candidates. By contrast, there is another group of 12 occupational categories in which fewer than 35 percent of vacancies go unfilled after 30 days. In this group, only 14 percent of openings were deemed difficult to fill for demand reasons. Overall, there is a very high correlation of 0.69 between the share of openings deemed hard to fill for demand reasons and the share going unfilled for 30 days or longer. Moreover, there is a negative correlation between ad duration and the share of employers reporting supply reasons, such as harsh working conditions or low wage offers, for a vacancy going unfilled. This is evidence that openings that take a long time to fill reflect a lack of supply relative to demand.

Appendix Table 2. Percent of Workers in Occupations for Less Than One Year, Percent of Vacancies Always Open, and Percent of Vacancies That Are Very Hard to Fill by Major Occupation, for the United States and Washington State

	USA Survey (O*NET)	Washington Survey	
	Percent in job less than 1 year	Percent always open	Percent open 60 days or longer (excluding always open)
Food Preparation and Serving Related	18%	27%	3%
Sales and Related	17%	15%	7%
Personal Care and Service	13%	17%	11%
Building and Grounds Cleaning and Maintenance	12%	12%	5%
Community and Social Services	12%	10%	13%
Office and Administrative Support	12%	6%	7%
Farming, Fishing, and Forestry	12%	7%	8%
Transportation and Material Moving	10%	22%	4%
Arts, Design, Entertainment, Sports, and Media	9%	9%	10%
Education, Training, and Library	9%	19%	27%
Health Care Support	9%	22%	4%
Legal	9%	2%	7%
Protective Service	8%	15%	10%
Computer and Mathematical Science	8%	1%	23%
Production	8%	11%	8%
Construction and Extraction	7%	7%	5%
Life, Physical, and Social Science	5%	4%	18%
Installation, Maintenance, and Repair	5%	7%	7%
Architecture and Engineering	5%	4%	15%
Health Care Practitioner and Technical	5%	4%	12%
Business and Financial Operations	4%	5%	12%
Management	4%	1%	13%

*Source: Spring 2011 Job Vacancy Survey Report, Washington State Employment Security Department, Labor Market and Economic Analysis, and O*NET.*

Of relevance to interpreting Burning Glass vacancy duration data is the issue of constant recruitment for positions with high turnover, which does not apply to most STEM jobs. A long advertisement duration for high-turnover (and mostly entry-level, low-skill) occupations does not necessarily indicate hiring difficulty in the Burning Glass database or those similar to it, like HWOL, since recruitment is ongoing to fill the void left by workers who quit after a few months. National data from O*NET show that 18 percent of workers in food preparation and serving and 17 percent of workers in sales occupations have been in their jobs for less than one year (Appendix Table 2). This compares to just 8 percent of computer occupations and 5 percent of engineering and science occupations. This high-turnover metric is highly correlated with the share of ads listed by employers as always open in a Washington State survey from 2011. Meanwhile, occupations with a high percentage of positions that are always open are unlikely to have long vacancy durations, once those that are always open are excluded.

One implication is that the results presented in this report likely understate the true relative difficulty of filling STEM and other highly skilled positions, because ad duration for non-STEM and other low-skilled positions is artificially extended by always-open positions.

Detailed Econometric Analysis of Duration

The findings discussed in the body of this report are meant to summarize statistical analysis described below to a general audience in a relatively straightforward and non-technical manner. The findings are robust to a much more powerful and systematic analysis. The skeptical reader, however, may wonder about various associations between variables that would bias the foregoing analysis. This section is intended for that reader.

The statistical or econometric technique of multivariable regression allows researchers to examine correlations between variables while adjusting for (or "controlling for") the average effects of other variables. To simplify the discussion, consider the following equation, which predicts or "models" the duration of a job vacancy as a function of demand, supply, and employer characteristics:

$$\text{Duration of vacancy} = C + B1(\text{Demand for Job Requirements}) + B2(\text{Labor Supply}) + B3(\text{Industry or Company Effects}) + E$$

Demand refers to job requirements. In this analysis, I take two approaches. The most comprehensive uses publicly available survey data on the characteristics of occupations. These data include the most frequent level of education required by the job nationally, average turnover, average years of experience, and level of skill in knowledge domains such as STEM, management, law, English/language, economics and finance, and all non-professional skills combined (e.g., production, construction). The hypothesis is that occupations that are more skilled and require more years of education will be harder to fill for two reasons: Employers are willing to invest more effort in finding the right workers, and the right worker is harder to find because only "experts" or highly trained individuals can do the job. These variables are available from O*NET and BLS's Occupational Employment Statistics (OES) at the most detailed six-digit level for every advertisement, which is already classified by Burning Glass into six-digit standard occupational classifications (SOC). The average metropolitan wage is included at the six-digit level. Finally, net year-over-year employment growth at the three-digit industry level for the metropolitan area was also included. This step uses data from Moody's Analytics, which is aggregated from government payroll records.

One other demand-side variable warrants a more detailed description. Burning Glass provided the author a list of "skills" requested by each advertisement. To quantify the value of these skills, the skill database was merged with a database of salaries. Then the average salary associated with each skill was calculated. The large sample size (4.7 million observations in total) meant that even though many ads were missing salary data, there were still a large number of salary observations per skill. The average value of each ad's set of skills was then merged back into the duration database. This allows the researcher to take into account that a computer software job at Google may require more valuable skills than, say, a computer software job at Target, even though both may have the same SOC code.

The other approach to measuring labor demand is to use the actual experience, education, and salary information listed on the job advertisement. The problem with this approach is that only half

of ads explicitly list experience or educational requirements and only 7 percent list salary. Thus, this approach "throws out" over 90 percent of observations. Moreover, not all jobs are equally likely to include these characteristics. Controlling for education, salary, and experience requirements, lower-paying jobs are more likely to include salary or other specific information. This can be partially corrected by using an econometric technique attributed to James Heckman that controls for the probability of ad-specific information in a final equation, after first estimating that probability in a probit model. One model, discussed below, will do this.

As for labor supply, the three most relevant variables are the unemployment rate (at the three-digit level) for both metropolitan-area workers and all U.S. workers in that minor occupation. These data are available from the 2012 American Community Survey, which is a 1 percent sample of the United States population. Using IPUMS, the data can be calculated at both the metropolitan and U.S. scales. The other most relevant supply variable is the actual number of workers with that six-digit occupation in the metropolitan area. This acknowledges that the labor supply is not limited to unemployed workers but also employed workers willing to switch jobs.

The third set of variables used in the econometric approach described above relates to industry and company effects. For the former, three-digit industry-level dummy variables were included in at least one model. This adjusts for the fact that, for example, universities or non-profits may have different recruitment and advertising practices than the federal government or manufacturing firms. Company effects were included directly as dummy variables to account directly for human-resource-specific practices. Additionally, the total number of company advertisements was included to adjust for firm size (though it may also capture expansion). The analysis also included year-over-year growth in metropolitan-specific ads for that six-digit occupation using the larger Burning Glass database (which has information on all ads, not just those on company websites, but lacks duration).

The results from four different models are shown in Appendix Table 3. The analysis starts with the broadest sample size that contains all metropolitan and occupational data (2.7 million observations) for the first three quarters of 2013 (not including September). Then, after adding ad-specific variables, it ends with a much smaller sample of roughly 40,000 in the fourth model. The first model does not control for industry or company effects; the second controls for industry effects; the third controls for company effects; and the fourth controls for company effects and uses ad-specific job requirements for salary, experience, and education rather than those imputed based on occupation.

There are a number of common findings that are robust across models. Most importantly, skill is highly predictive of longer advertisement duration. The clearest evidence comes from seeing that the log of average skill value is strongly correlated with longer duration (this is for skills requested on the advertisement using dollar values derived from all advertisements that list salary). A standard deviation increase in skill value increases duration by 1.5 to three days, with the smaller estimate coming from the smallest sample size that uses only ad-specific data. It is remarkable that skills add any value in this final estimate because the regression already controls for the actual salary specified in the ad within the same company. For example, if two computer science vacancies both advertise salaries of $80,000 at the same corporate website, but one lists Ruby on Rails and the other lists Microsoft Access, the job listing Ruby on Rails will take a few days longer to fill.

STEM knowledge, another measure of skill, is also highly predictive of longer duration in the three main models. This is powerful evidence that STEM skills are in shortage. A standard deviation of STEM knowledge adds just over a day to the ad duration, even after controlling for many things correlated with high STEM knowledge, such as average salary, educational requirements, and low unemployment rates. The effect even holds within the same industry and within the same company. Thus, the presence of many unfilled STEM vacancies cannot be attributed to the higher marginal productivity of STEM workers. The STEM variable becomes insignificant only in the fourth model, once ad-specific skills and salaries have been considered within the same company and the sample size has been cut by millions.

On the supply side, higher national and metropolitan-area unemployment rates predict lower duration. A standard deviation in the metropolitan statistical area (MSA) unemployment rates lowers duration by 0.1 to 0.7 days, depending on the model. The national rate has a larger effect (over one day for a standard deviation), but becomes positive and then insignificant in the models that control

Appendix Table 3. Regression of Vacancy Duration on Various Demand, Supply, and Company Characteristics for 2013 Vacancies in Metropolitan Areas

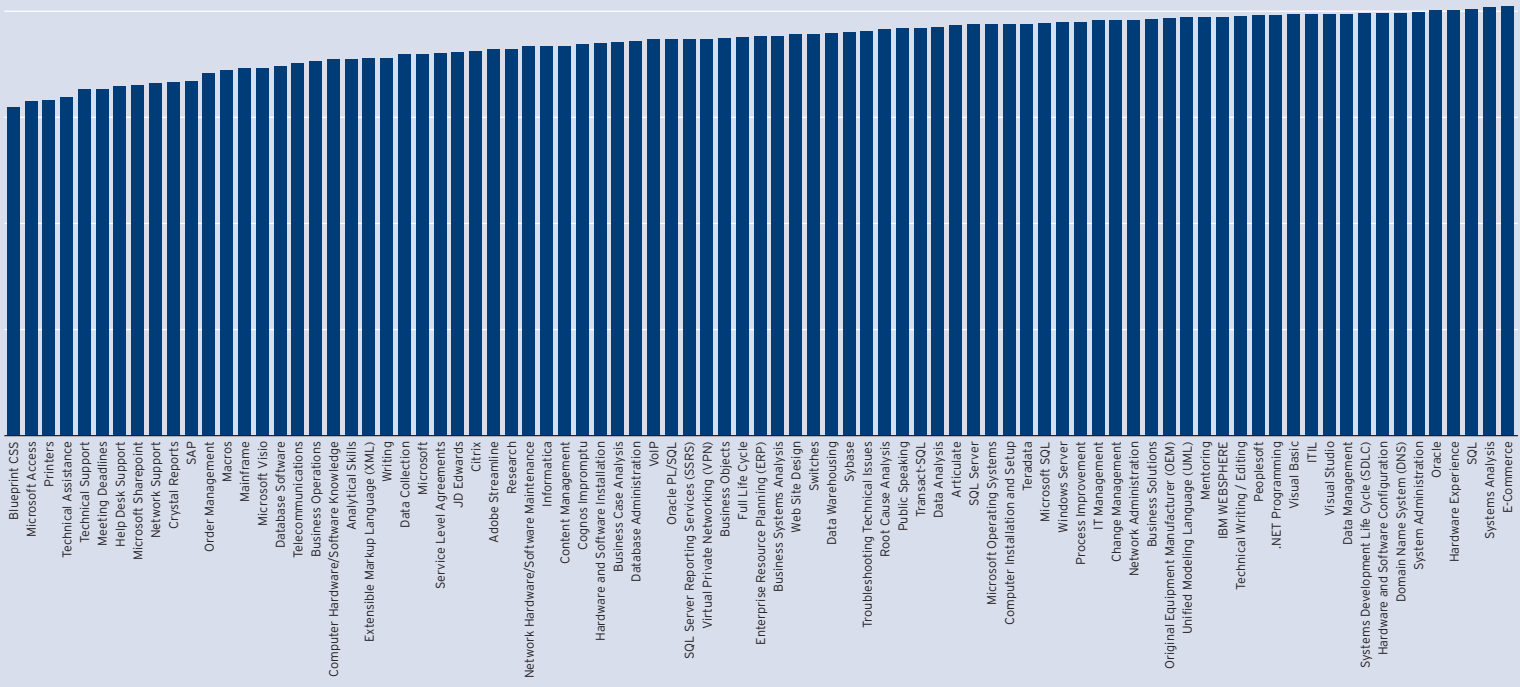
	Duration of vacancy in days			
	1	2	3	4
Ln of average value of skills advertised in vacancy	13.79***	12.52***	9.367***	6.869***
	-0.145	-0.17	-0.179	-1.688
STEM knowledge, standardized score (6-digit level)	1.057***	1.125***	1.310***	-0.175
	-0.0378	-0.044	-0.0435	-0.318
Management knowledge, standardized score (6-digit level)	-0.299***	-1.672***	-1.283***	-0.24
	-0.0585	-0.0686	-0.0664	-0.469
Economics knowledge, standardized score (6-digit level)	0.0129	0.781***	-0.0356	-1.208***
	-0.0396	-0.0473	-0.0467	-0.366
Legal knowledge, standardized score (6-digit level)	-0.543***	0.0908*	0.174***	-0.0361
	-0.0409	-0.0467	-0.046	-0.346
English knowledge, standardized score (6-digit level)	-1.252***	-0.701***	-1.394***	-2.801***
	-0.0451	-0.0519	-0.052	-0.342
Non-professional knowledge, standardized score (6-digit level)	0.532***	0.0908*	0.215***	0.704**
	-0.0471	-0.0549	-0.053	-0.353
Average years workers stay in jobs (6-digit level)	0.170***	0.0752***	0.284***	0.533***
	-0.0197	-0.0222	-0.0214	-0.152
Percentage of workers remaining in jobs less than one year (6-digit level)	-0.104***	-0.103***	0.000833	0.0665
	-0.00626	-0.00714	-0.00703	-0.0514
Average years of on-the-job training required (6-digit level)	0.239***	0.417***	0.0265	-0.392*
	-0.029	-0.0334	-0.0324	-0.206
Average years of experience required (6-digit level)	-0.191***	-0.101***	-0.0814***	0.00129
	-0.0149	-0.0168	-0.0163	-0.138
Occupation-specific metropolitan area unemployment rate (3-digit level)	-2.928***	-3.019***	-6.123***	-14.60***
	-0.754	-0.86	-0.842	-5.184
Occupation-specific metropolitan area average years of education (3-digit level)	0.229***	0.469***	0.423***	0.279
	-0.0395	-0.0445	-0.0439	-0.274
Occupation-specific metropolitan area average age (3-digit level)	-0.244***	-0.132***	-0.171***	-0.0873
	-0.00768	-0.00882	-0.00877	-0.0546
U.S. occupation-specific unemployment rate (3-digit level)	-52.83***	-34.71***	9.143***	0.617
	-2.332	-2.775	-2.793	-18.54
Metropolitan area occupation-specific location quotient (6-digit)	0.434***	0.385***	0.275***	-0.0433
	-0.0271	-0.0313	-0.0292	-0.245
Ln of metropolitan area occupation-specific employment (6-digit level)	-0.242***	-0.408***	-0.343***	-0.545***
	-0.0203	-0.0233	-0.0232	-0.163
Metropolitan area unemployment rate, 2013	0.908***	0.645***	0.272***	-0.294*
	-0.018	-0.0203	-0.0223	-0.164
Metropolitan area size of labor force, 2013	-1.11e-07***	-1.36E-08	-1.18E-08	5.04e-07***
	-1.41E-08	-1.61E-08	-1.72E-08	-1.32E-07
Mode education is doctorate or professional degree (6-digit level)	2.228***	-2.955***	1.511***	
	-0.285	-0.308	-0.308	
Mode education is master's degree (6-digit level)	2.007***	3.604***	4.291***	
	-0.175	-0.196	-0.193	
Mode education is bachelor's degree (6-digit level)	-0.333***	0.808***	2.527***	
	-0.115	-0.131	-0.128	
Mode education is associate's degree (6-digit level)	-0.653***	0.542***	1.426***	
	-0.132	-0.152	-0.147	
Mode education is some college or certification (6-digit level)	-1.211***	-0.604***	0.644***	
	-0.125	-0.144	-0.145	
Mode education is less than high school (6-digit level)	8.143***	6.305***	1.682***	
	-0.158	-0.176	-0.175	
Ln average occupation-specific metropolitan area salary (6-digit level)	-4.813***	-6.019***	-5.017***	
	-0.286	-0.323	-0.32	
Average occupation-specific MSA salary (6-digit level) divided by average MSA salary	4.439***	5.208***	5.258***	
	-0.17	-0.188	-0.186	
Ln of average metropolitan area salary	13.40***	11.96***	12.41***	
	-0.324	-0.362	-0.37	
Advertisement requests specific education	2.169***	1.341***	1.194***	
	-0.0554	-0.0648	-0.0707	

Appendix Table 3. Regression of Vacancy Duration on Various Demand, Supply, and Company Characteristics for 2013 Vacancies in Metropolitan Areas (continued)

	Duration of vacancy in days			
	1	2	3	4
Advertisement mentions salary	-1.867***	-0.711***	0.921***	
	-0.102	-0.127	-0.167	
Advertisement mentions experience requirement	0.650***	1.397***	1.559***	
	-0.0544	-0.0621	-0.0662	
Ad is missing company name	-1.539***	-1.400***		
	-0.0613	-0.1		
Ln of ad specific salary				4.200***
				-0.624
Average years of experience requested by ad				0.00885
				-0.0079
Average years of education requested by ad				1.151**
				-0.453
Ad-specific salary divided by average occupational specific metropolitan area salary				-2.123***
				-0.349
Ad-specific education in years less occupation-specific mode years of education				-0.128
				-0.173
Ad requires high school diploma				2.743
				-3.097
Ad requires associate's degree				2.547
				-2.227
Ad requires bachelor's degree				0.578
				-1.508
Ad requires master's degree				4.302***
				-1.382
Probability of ad including experience, education, and salary				73.47
				-59.6
Advertisement first posted in the second quarter	-10.62***	-10.65***	-11.50***	-6.556***
	-0.0577	-0.0646	-0.0635	-0.423
Advertisement first posted in the third quarter	-15.69***	-16.88***	-18.31***	-12.66***
	-0.0636	-0.0718	-0.0714	-0.476
Constant	-208.2***	-172.4***	-153.4***	-105.5***
	-2.719	-3.141	-3.424	-22.09
Additional controls	None	3-digit NAICS	Company effects	Company effects
Observations	2,798,116	2,196,936	2,120,462	39,889
Adjusted R-squared	0.041	0.074	0.227	0.286

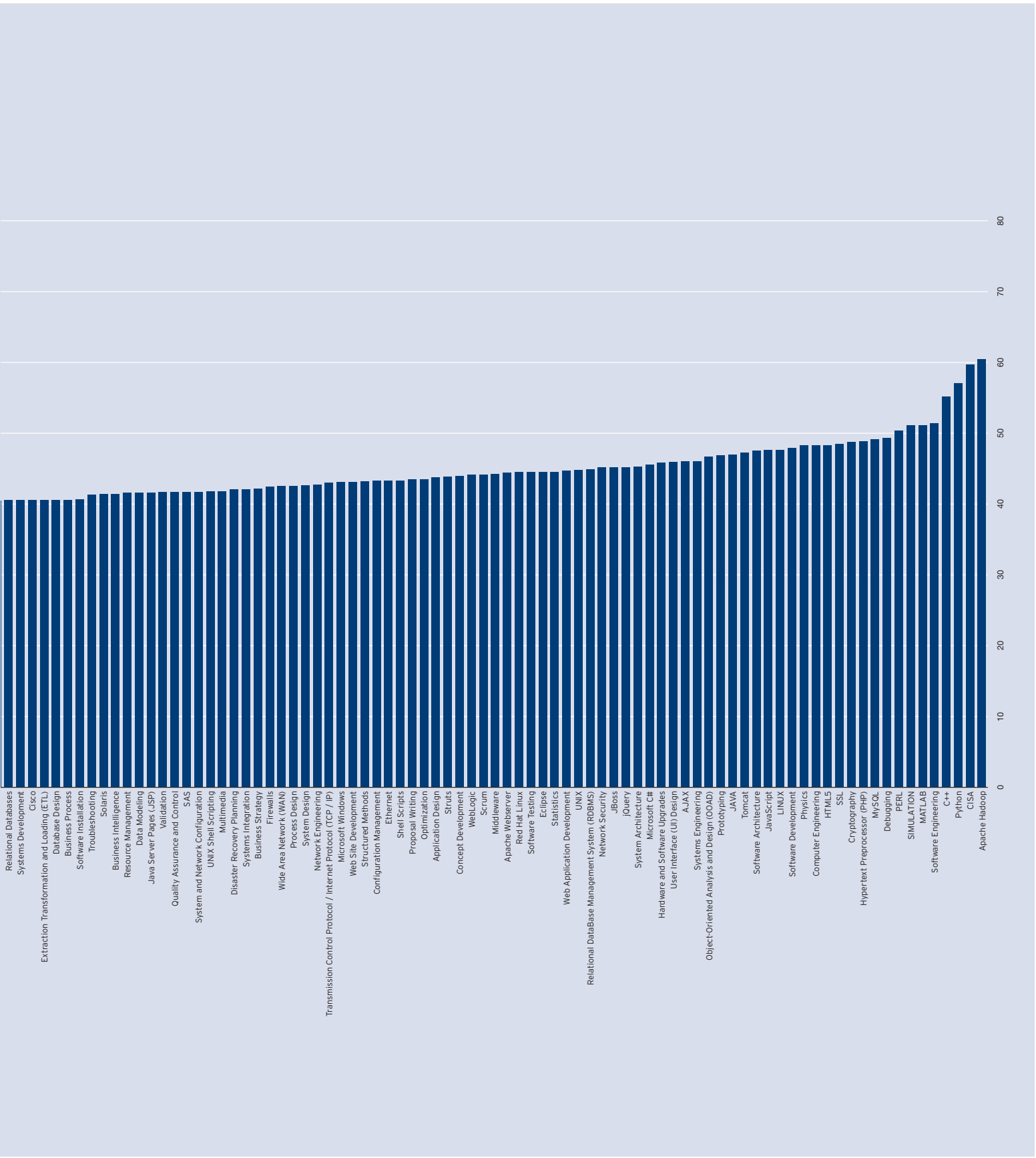
Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Figure 5. Average Duration of Job Advertisements Requiring Specific Computer Skills



Source: Brookings analysis of data from Burning Glass

Note: For skills advertised in at least 5000 ads


0
10
20
30
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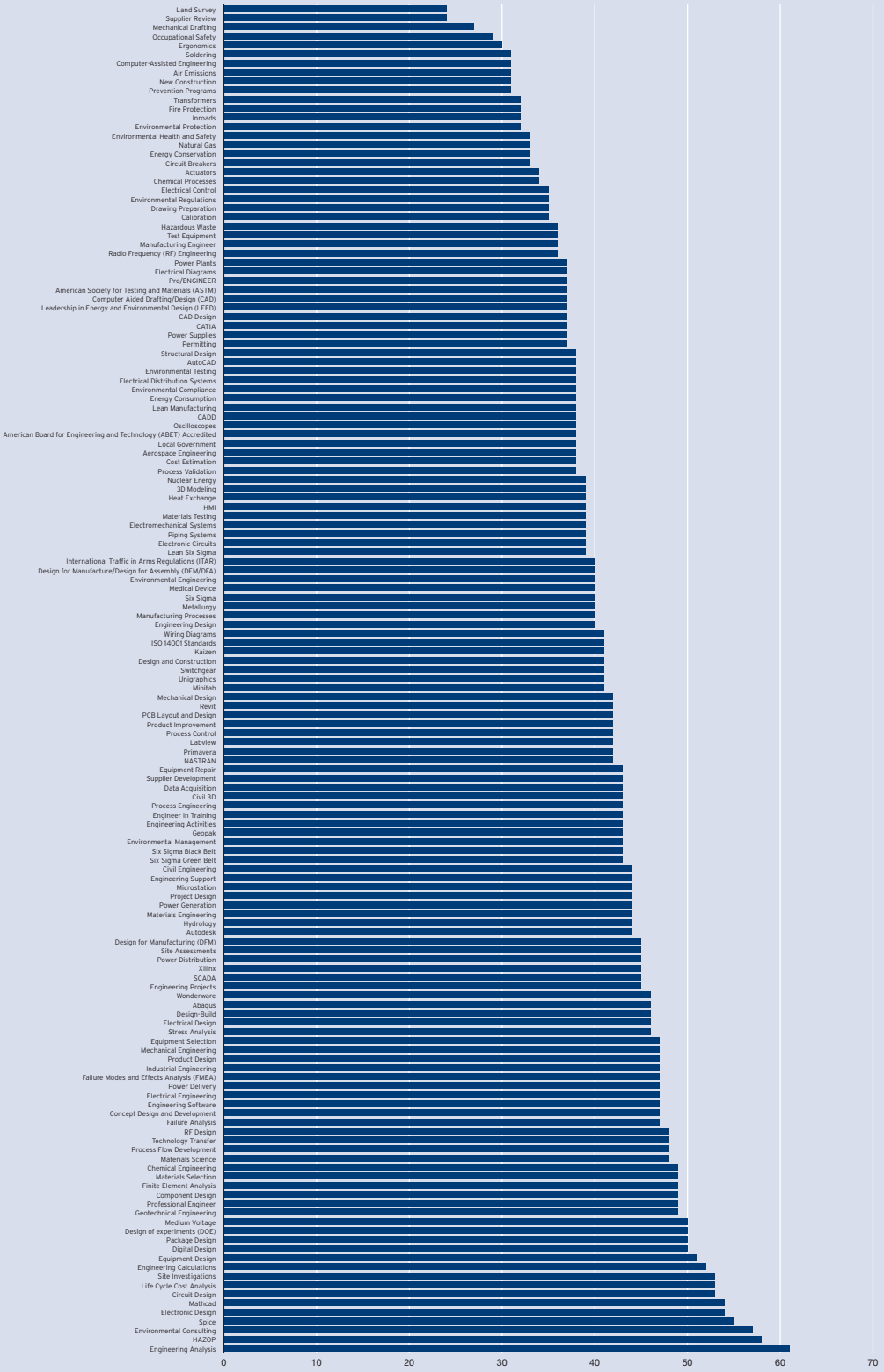
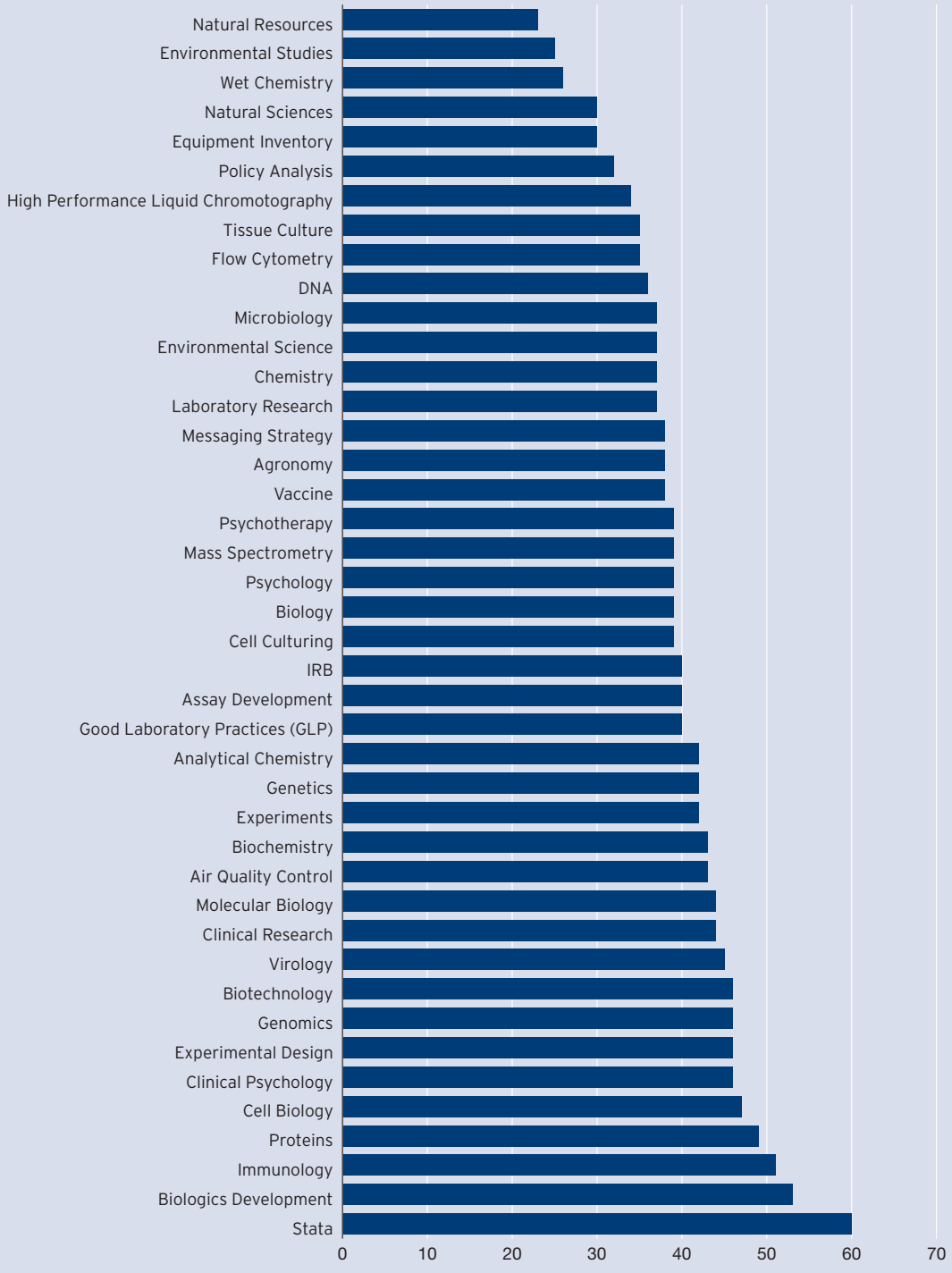
80
Relational Databases
Systems Development
Cisco
Extraction Transformation and Loading (ETL)
Database Design
Business Process
Software Installation
Troubleshooting
Solaris
Business Intelligence
Resource Management
Data Modeling
Java Server Pages (JSP)
Validation
Quality Assurance and Control
SAS
System and Network Configuration
UNIX Shell Scripting
Multimedia
Disaster Recovery Planning
Systems Integration
Business Strategy
Firewalls
Wide Area Network (WAN)
Process Design
System Design
Network Engineering
Transmission Control Protocol / Internet Protocol (TCP / IP)
Microsoft Windows
Web Site Development
Structured Methods
Configuration Management
Ethernet
Shell Scripts
Proposal Writing
Optimization
Application Design
Struts
Concept Development
WebLogic
Scrum
Middleware
Apache Webserver
Red Hat Linux
Software Testing
Eclipse
Statistics
Web Application Development
UNIX
Relational DataBase Management System (RDBMS)
Network Security
JBoss
jQuery
System Architecture
Microsoft C#
Hardware and Software Upgrades
User Interface (UI) Design
AJAX
Systems Engineering
Object-Oriented Analysis and Design (OOAD)
Prototyping
JAVA
Tomcat
Software Architecture
JavaScript
LINUX
Software Development
Physics
Computer Engineering
HTML5
SSL
Cryptography
Hypertext Preprocessor (PHP)
MySQL
Debugging
PERL
SIMULATION
MATLAB
Software Engineering
C++
Python
CISA
Apache Hadoop

Appendix Figure 6. Average Duration of Job Advertisements Requiring Engineering Skills



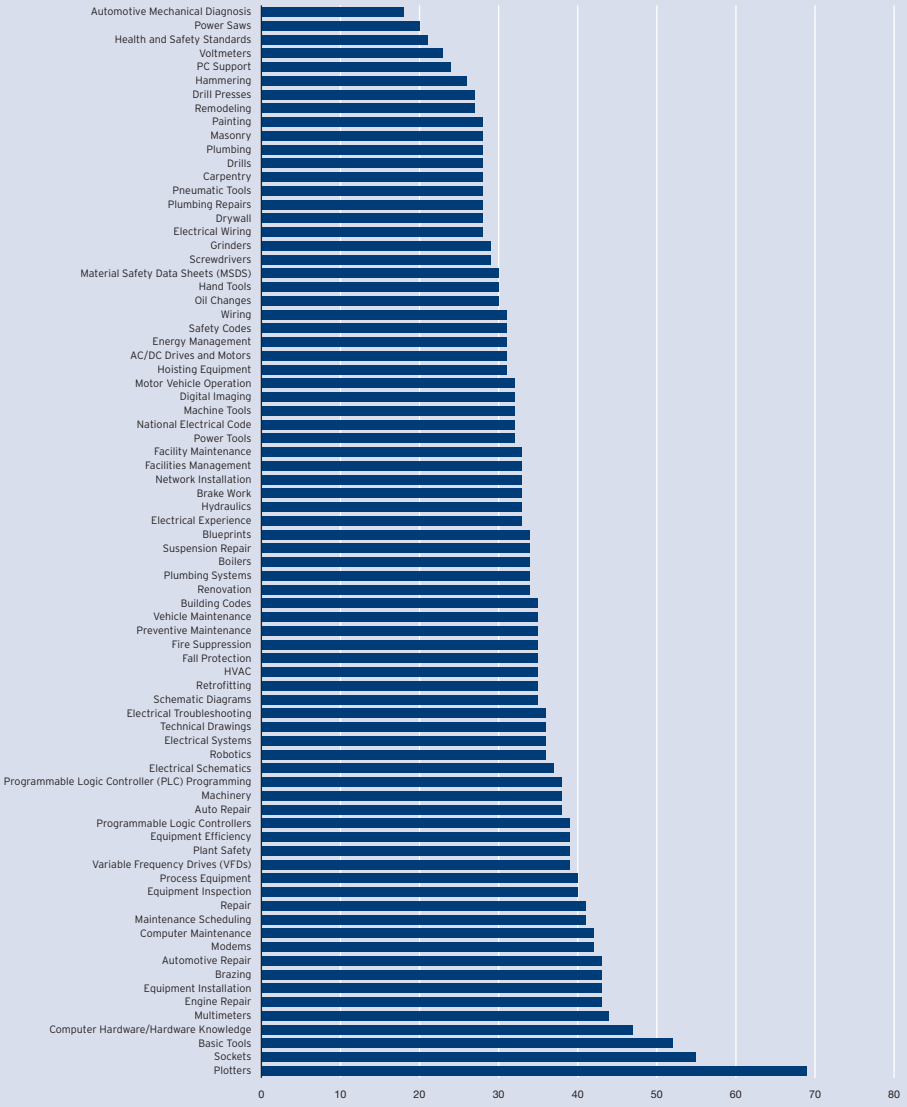
Source: Brookings analysis of data from Burning Glass

Appendix Figure 7. Average Duration of Job Advertisements Requiring Specific Life and Social Science Skills



Source: Brookings analysis of data from Burning Glass

Appendix Figure 8. Average Duration of Job Advertisements Requiring Specific Installation and Repair Skills



Source: Brookings analysis of data from Burning Glass

for company-specific effects. This implies that companies that rely on workers with low unemployment rates tend to have longer average vacancy durations, but the real causal effect is operating at the metropolitan scale. A large occupation-specific employment base in the MSA also lowers duration (by half a day to one day for a standard deviation), but highly clustered occupational concentrations in smaller metropolitan areas tend to extend duration times. Areas with high location quotients for a particular occupation also tend to have very specialized workers, which could explain the extension of duration.

Finally, in results not shown (to conserve space and because it lowers the sample size), the analysis also tests the hypothesis that firm-specific employment growth extends ad duration. The results are consistent with this. Year-over-year occupational growth within the metropolitan area had a significant and positive effect on ad duration, as did year-over-year industry-level metropolitan area growth. Meanwhile, companies with many advertisements tended to take down their ads sooner, suggesting benefits of scale when it comes to recruiting—possibly because there are more internal candidates.

Endnotes

1. Jonathan Rothwell et al., "Patenting Prosperity: Invention and Economic Performance in the United States and Its Metropolitan Areas" (Washington: Brookings Institution, 2013); Committee on Prospering in the Global Economy of the 21st Century, et al., *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington: 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: National Academies Press, 2010).

2. Jonathan Rothwell, "The Hidden STEM Economy" (Washington: Brookings Institution, 2013).

3. Economics and Statistics Administration, "STEM: Good Jobs Now and for the Future" (Washington: 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): 439-57; Paolo Buonanno and Dario Pozzoli, "Early Labor Market Returns to College Subject," *Labour* 23 (4) (2009): 559–88 ; 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): 161-84; Peter Arcidiacono, "Ability Sorting and the Returns to College Major," *Journal of Econometrics* 121 (1-2) (2004): 343-75.

4. 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**

5. Claudia Goldin and Lawrence Katz, *The Race Between Education and Technology* (Cambridge, MA: Harvard University Press, 2008); Clifford Winston, Robert W. Crandall, and Vikram Maheshri, *First Thing We Do, Let's Deregulate All the Lawyers* (Washington: Brookings Institution, 2011); Daron Acemoglu and David Autor, "Skills, Tasks and Technologies: Implications for Employment and Earnings," Working Paper No. 16082 (Cambridge, MA: National Bureau of Economic Research, 2010); Philip Oreopoulos and Uros Petronijevic, "Making College Worth It: A Review of Research on the Returns to Higher Education," Working Paper No. 19053 (Cambridge, MA: National Bureau of Economics Research, 2013).

6. A standard deviation in STEM knowledge is the difference between a medical scientist and an engineering technician, an engineering technician and a computer-support specialist, a computer-support specialist and a truck driver, and a truck driver and a security guard.

7. Engineering and computer science majors both experienced 2.9 percent growth in nominal earnings from 2009 to 2012, the highest among all fields and just ahead of other STEM fields: health care sciences and biology and life sciences. Meanwhile, salaries for undergraduate law majors fell 8.1 percent. This sample was 21- to 30-year-olds with bachelor's degrees. The American Community Survey data were analyzed via IPUMS, which allows researchers access to microdata.

8. Data from Conference Board Help Wanted Online Series, press release (**http://www.conference-board.org/pdf_free/press/PressPDF_5114_1394013935.pdf**).

9. That figure includes at least some part of human resource staff salaries and comes from Karen O'Leonard, "The Talent Acquisition Factbook 2011" (Oakland, CA: Bersin & Associates, 2011). Estimates from the United Kingdom are comparable at about $2,700 per hire for entry-level college graduates; CFE Research, "The AGR Graduate Recruitment Survey 2013" (Leicester, U.K., 2013).

10. Steven J. Davis, R. Jason Faberman, and John C. Haltiwanger, "The Establishment-Level Behavior of Vacancies and Hiring," *The Quarterly Journal of Economics* (2013) 128 (2): 581-622.Considering that there are roughly 4 million job vacancies in a given month and the average worker is paid $46,000 per year, a back-of-the-envelope estimate suggests that unfilled vacancies cost employers $6 billion per year in direct lost value. Assuming that workers in the same company complement each other, it is likely that missing workers will also degrade the value of their colleagues.

11. Careerbuilder, "Companies Losing Money to the Skills Gap, According to CareerBuilder Study," available at **http://www.careerbuilder.com/share/aboutus/pressreleasesdetail.aspx?sd=3%2f6%2f2014&siteid=cbpr&sc_cmp1=cb_pr807_&id=pr807&ed=12%2f31%2f2014** (March 2014).

12. Brookings analysis of Bureau of Labor Statistics' Job Openings and Labor Turnover Survey (JOLTS).

13. For example, in December 2013, 4.4 million workers were hired, but only 113,000 net jobs were created. Net job changes come from the Bureau of Labor Statistics' Current Employment Survey.

14. Dale Mortensen and Christopher Pissarides, "New Developments in Models of Search in the Labor Market," *Handbook of Labor Economics*, 3, edited by O. Ashenfelter and D. Card (Elsevier, 1999); Olivier Jean Blanchard and Peter Diamond, "The Beveridge Curve," *Brookings Papers on Economic Activity* 1 (1989): 1-76.

15. Blanchard and Diamond, "The Beveridge Curve."

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17. Kenneth J. Arrow and William M. Capron, "Dynamic Shortages and Price Rises: The Engineer-Scientist," *Quarterly Journal of Economics* 73 (2) (1959): 292-308.

18. Roland G. Fryer, Jr. "Financial Incentives and Student Achievement: Evidence from Randomized Trials," *The Quarterly Journal of Economics* (2011) 126 (4): 1755-1798.

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

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21. M. J. Andrews, S. Bradley, D. Stott, and R. Upward, "Successful Employer Search? An Empirical Analysis of Vacancy Duration Using Micro Data," *Economica* 75 (2008): 455-80; Jonathan Haskel and Christopher Martin, "The Causes of Skill Shortages in Britain," *Oxford Economic Papers* 45 (4) (1993): 573-88; Andrea Weber, "Vacancy Durations: A Model of Employer Search," *Applied Economics* 32 (2000): 1069-75.

22. Weber, "Vacancy Durations."

23. Haskel and Martin, "The Causes of Skill Shortages in Britain."

24. Ibid.

25. Jonathan Haskel and Christopher Martin, "Technology, Wages, and Skill Shortages: Evidence From UK Micro," *Oxford Economic Papers*, 53 (4) (2001): 642-58.

26. Penny Mok, Geoff Mason, Philip Stevens, and Jason Timmins, "A Good Worker Is Hard to Find: Skills Shortages in New Zealand Firms," New Zealand Ministry of Economic Development, Occasional Paper 12/05 (2012).

27. Philip Andrew Stevens, "Skill Shortages and Firms' Employment Behavior," *Labour Economics* 14 (2) (2007): 231-49; Jonathan Haskel and Christopher Martin, "Do Skill Shortages Reduce Productivity: Theory and Evidence From the United Kingdom," *Economic Journal* 103 (1993): 386-94.

28. Peter Cappelli, "Why Good People Can't Get Jobs: The Skills Gap and What Companies Can Do About It" (Wharton Digital Press, 2012).

29. ManpowerGroup, "2013 Talent Shortage Survey Research Results" (http://www.manpowergroup.us/campaigns/talent-shortage-2013/).

30. 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); Michael S. Teitelbaum, *Falling Behind? Boom, Bust & the Global Race for Scientific Talent* (Princeton, NJ: Princeton University Press, 2014).

31. Robert D. Atkinson and Luke A. Stewart, " The Real Story on Guestworkers in the High-Skill U.S. Labor Market" (Washington: Information Technology and Innovation Foundation, 2013).

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33. For example, the Great Recession began in late 2007, according to the National Bureau of Economic Research, but wages grew throughout 2008 and peaked in 2009, even as unemployment increased quickly. Despite job growth and falling unemployment from 2010 to 2013, wages fell during this period. Finally, wages look to be growing over the year ending in the first quarter of 2014 for the first time since 2008, according to data from the Current Population Survey. Meanwhile, median wages for computer workers and other professional STEM occupations were significantly higher in 2013 than in 2000, despite the recession and no wage growth for the median worker.

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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) (**http://www.jvsinfo.org/downloadFiles/aboutjvs.pdf**).

36. Colorado Department of Labor and Employment, "Mesa County Job Vacancy Survey 2005" (2005); Idaho Department of Labor, "Idaho Job Vacancy Survey Report, Spring 2010" (2010); Oklahoma Employment Security Commission, "Oklahoma Job Vacancy Survey: 1st Half 2006" (2006); Minnesota Department of Economic Security, "Help Wanted 2000 Report: Twin Cities Job Vacancy Survey" (Minneapolis: Metropolitan Workforce Investment Board, 2000).

37. ManpowerGroup, "2012 Talent Shortage Survey Results" (http://www.manpowergroup.us/campaigns/talent-shortage-2012/pdf/2012_Talent_Shortage_Survey_Results_US_FINALFINAL.pdf).

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40. William C. Dunkelberg and Holly Wade, "NFIB Small Business Economic Trends" (Washington: National Federation of Independent Business, 2014).

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42. There does not appear to be any bias in using the company website-only ads for skill salaries. Comparing the Burning Glass duration database, which uses only company websites, to the Burning Glass full database of openings, there is a very high correlation between the number of openings per skill (0.92) and a fairly high correlation between the average salaries advertised with each skill (0.51). This is across 24,123 different skills. The salary correlation increases with the number of observations. For skills with at least 50 vacancies, the correlation is 0.69, across 7,924 skills.

43. Rothwell, "The Hidden STEM Economy."

44. Steven Ruggles, J. Trent Alexander, Katie Genadek, Ronald Goeken, Matthew B. Schroeder, and Matthew Sobek, Integrated Public Use Microdata Series: Version 5.0 [Machine-readable database]. Minneapolis: University of Minnesota, 2010.

45. Andrews et al., "Successful Employer Search?"

46. An analysis of these single-day ads reveals that they are somewhat less likely to be in highly skilled, STEM-intensive, and highly educated occupations. They are more likely in large companies, but less likely in companies with high average skill or STEM requirements for their vacancies. They are most common in the public sector—in which 62 percent of ads are posted for one day or less. Transportation and construction sectors have single-day advertisement rates of 55 and 56 percent, which are the second and third highest. Single-day advertisement rates are lowest in information, professional services, and retail, with rates of 37, 36, and 33 percent, respectively.

47. Weber, "Vacancy Durations."

48. According to data collected annually from legal associations, students graduating from law school faced much lower starting salaries in 2012 compared to 2008 (a 15 percent decline in nominal salaries) and a much lower percentage are practicing law (a fall of 10 percentage points). Data from the National Association for Law Placement.

49. Even among production workers, unfilled rate trends vary distinctly. The unfilled rate for construction workers fell from over 36 percent in 2006-Q4 to 20 percent in 2008-Q3 and 16 percent in early 2012. Installation, maintenance, and repair occupations were just as easy to fill in 2012-Q1 as 2008-Q3. By contrast, the manufacturing sector rebound made production and transportation jobs harder to fill, with the latter experiencing the sharpest rebound—from 25 percent to 31 percent. Yet, the unfilled rate for transportation vacancies was still down eight percentage points from 2006-Q4, when it was 39 percent.

50. Bureau of Labor Statistics, Current Population Survey. 2014 data are for March, unemployed persons by occupation and sex: http://www.bls.gov/cps/aa2007/aat25.txt

(2007); http://www.bls.gov/web/empsit/cpseea30.htm (2014); employment http://www.bls.gov/cps/aa2007/aat39.txt (2007); http://www.bls.gov/web/empsit/cpseea19.htm (2014)

51. This is a very simple approach in that it does not make any adjustments for differences in occupation, education, experience, company, or the combination of skills requested. It merely asks: What is the average pay associated with each skill? Additional complications may be addressed in future research.

52. The states (and federal districts) with the longest median duration times include Vermont, Delaware (both with 20 days), Michigan, the District of Columbia, Illinois, Rhode Island, Connecticut, Maryland, Virginia, New York, Kentucky, Oregon, and North Carolina, each with over 12 days for the median vacancy. By contrast, nine states have median vacancies of just one day: Idaho, Ohio, Colorado, Montana, Wisconsin, Alaska, Minnesota, Maine, and South Dakota. Using the average number of days, Michigan and California have the highest durations at 47 days each. South Dakota has the shortest at 18 days.

53. Jonathan Rothwell, "Education, Job Openings, and Unemployment in Metropolitan America" (Washington: Brookings Institution, 2012).

54. The underlying cause of those earnings differences are complex, but three explanations can broadly account for why professional jobs tend to earn such high wages: (1) the high level of skill and therefore productivity of high-wage earners; (2) differences in industry profits, competitiveness, and regulation—which may reward skilled workers in the financial and health care sectors disproportionately; and (3) the relative scarcity of skills, which pushes up the price.

55. Rothwell, "The Hidden STEM Economy."

56. Rothwell, "The Hidden STEM Economy."

57. The author thanks Jessica Nelson of the Workforce and Economic Research division of the Oregon Employment Department for providing the occupational-level data used in this analysis.

58. The author thanks Jessica Nelson of the Workforce and Economic Research division.

59. James Heckman, "Sample Selection Bias as a Specification Error," *Econometrica* 47 (1) (1979): 153–61.

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