The Slow Adjustment in Tech Labor: Why Do High-Paying Tech Jobs Go Unfilled?

The Center for Growth and Opportunity at Utah State University

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Policy Paper

The Center for Growth and Opportunity at Utah State University is a university-based academic research center that explores the scientific foundations of the interaction between individuals, business, and government.

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Introduction

The technology industry in the United States has faced a challenge in recruiting talent. Though wages are above average, there are many unfilled jobs. In 2019, over 7.5 million positions were vacant, and the tech sector made up roughly 918,000 of those job openings.[1] In 2020 the median income of computer occupations was $91,350, which is more than twice as large as the median income of all occupations in the United States.[2] In 2017, the unemployment rate for software developers was only 1.9 percent.[3] Meanwhile, some estimate that 44 percent of American workers have low-wage jobs.[4] This presents a puzzle. What prevents more Americans from entering tech, considering that it pays well and does not have the drawbacks of some other in-demand jobs, such as the travel schedule of a truck driver or the physically taxing labor required in oil fields? In this paper, we present the current facts about employment in the technology industry and possible answers to that puzzle. However, there are limited data available to make definite conclusions, and this paper will describe some of the questions that should be addressed in future research.

We define work in tech as the jobs recognized by the US Bureau of Labor Statistics under the umbrella of Computer and Information Technology Occupations.[5] Collectively, these jobs are predicted by the BLS to grow at a rate of 11 percent over the next decade and add 531,200 new positions.

Lessons drawn from this study are applicable in any country where high-skilled workers are in demand, although some features of the US job market are unique to the American economy and culture. Policymakers in many cities invest with the hope of spurring innovation and growing a high-tech sector. Lee and Clarke demonstrate that when new high-tech jobs are created, it not only benefits high-skill workers, but it also creates new jobs for low-skill workers.[6]

Both private companies and policymakers lament the persistent shortage of Americans who can fill the demand for labor in computer occupations. In 2016, President Obama's Council of Advisors on Science and Technology warned that there would be a shortfall of 1 million STEM graduates by 2022.[7] In the PwC's Global Digital IQ Survey, only 52 percent of organizations rated the digital IQ of their companies as "strong."[8]

These findings have led industry and political leaders to encourage the public to consider careers in tech. Many of these messages underscore how accessible a career in tech can be. Former

1 Angus Loten, "America's Got Talent, Just Not Enough in IT," *Wall Street Journal*, October 15, 2019, https://www.wsj.com/articles/americas-got-talent-just-not-enough-in-it-11571168626.

2 According to the Bureau of Labor Statistics the median annual wage in 2020 for all occupations is $39,810. "Computer and Mathematical Occupations," accessed October 24, 2022, https://www.bls.gov/oes/2020/may/oes150000.htm.

3 Craig Torres, "Demand for Programmers Hits Full Boil as US Job Market Simmers," *Bloomberg*, March 8, 2018, https://www.bloomberg.com/news/articles/2018-03-08/demand-for-programmers-hits-full-boil-as-u-s-job-market-simmers.

4 Marcela Escobari, Ian Seyal, and Michael J. Meaney, "Realism about Reskilling: Upgrading the Career Prospects of America's Low-wage Workers," *Brookings*, November 7, 2019, https://www.brookings.edu/research/realism-about-reskilling/.

5 These roles include computer science researchers, network architects, computer support specialists, systems analysts, database administrators, information security analysts, and software and web developers.

6 Neil Lee and Stephen Clarke, "Do Low-Skilled Workers Gain from High-Tech Employment Growth? High-Technology Multipliers, Employment and Wages in Britain," *Research Policy* 48, no. 9 (2019): 103803, https://doi.org/10.1016/j.respol.2019.05.012.

7 Jo Handelsman and Megan Smith, "STEM for All," Whitehouse.gov, February 11, 2016, https://obamawhitehouse.archives.gov/blog/2016/02/11/stem-all.

8 PricewaterhouseCoopers (PwC), "Global Digital IQ® Survey: 10th Anniversary Edition," 2017, https://www.pwc.com/ee/et/publications/pub/pwc-digital-iq-report.pdf

President Barack Obama made a concerted effort to promote STEM and computer science education. As part of a White House Hour of Code campaign, he delivered a speech saying, "Don't just buy a new video game. Make one. Don't just download the latest app. Help design it. Don't just play on your phone. Program it. No one is born a computer scientist. But with a little hard work and some math and science, just about anyone can become one."[9] The Trump Administration has also put forward a tech-facing workforce development initiative. Promoting an executive order in 2018, Ivanka Trump wrote an op-ed for the *Wall Street Journal* saying, "Many of these jobs require skills training, but not a college degree. Yet for too long, both the public and the private sectors have failed to develop innovative and effective training programs."[10] We investigate that claim.

A lack of access to training is likely not the most serious barrier to tech careers. A wide strata of education programs are available, from free training initiatives to coding bootcamps, community college, bachelor's degrees, and beyond. Though jobs in tech can put workers in similar income brackets as veterinarians or nurse practitioners, they require less formal training. In most cases, a bachelor's degree in computer science is more than sufficient to enter the tech workforce.[11]

Research indicates that other forces prevent many communities from entering the tech workforce. Despite the promise of a high income and a growing number of job vacancies, just a small percentage of Americans choose to train for and enter these fields. The jobs are sometimes touted as a guarantee of having a comfortable and rewarding career, but the reality is not that simple. Women, Latino, and Black Americans enter computer science education programs and the tech sector at significantly lower rates than other groups.[12] These communities are often limited by a lack of access and role models.[13] Those who do enter the field may face a toxic workspace that is difficult to navigate. These issues must be addressed if leaders and policymakers are serious about closing the skills gap.

In this paper we propose an additional set of factors that have been overlooked and apply broadly to the tech sector. They may affect women or Black and Latino Americans to greater degrees, but they also encompass other demographics. We examine whether jobs in tech are more difficult than policymakers realize or advertise. For the women who do enter the tech workforce, their attrition rate is significantly higher than those in other fields. After 12 years in their career, over half of women quit their jobs. Of these, over half abandon their STEM training altogether for other

9 Barack Obama, "President Obama Asks America to Learn Computer Science," Code.org, December 8, 2013, https://www.youtube.com/watch?v=6XvmhE1J9PY.

10 Ivanka Trump, "Training for the Jobs of Tomorrow," *Wall Street Journal*, July 17, 2018, https://www.wsj.com/articles/training-for-the-jobs-of-tomorrow-1531868131.

11 Q. Burke and C. S. Bailey, "Camp or College?," in *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (New York: ACM, 2019), 345–50. https://doi.org/10.1145/3287324.3287373.

12 Maria Ong, Carol Wright, Lorelle Espinosa, and Gary Orfield, "Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering, and Mathematics," *Harvard Educational Review* 81, no. 2 (2011): 172–209, https://doi.org/10.17763/haer.81.2.t022245n7x4752v2; Pamela Holland Obiomon, Virginia Cook Tickles, Adrienne Holland Wowo, and Shirley Holland-Hunt, "Advancement of Women of Color in Science, Technology, Engineering, and Math (STEM) Disciplines" (paper presented at Advancing Women and the Underrepresented in the Academy [symposium], Johnson C. Smith University Charlotte, NC, November 16–17, 2007); M. Muro, A. Berube, and J. Whiton, " Black and Hispanic Underrepresentation in Tech: It's Time to Change the Equation," *Brookings*, March 28, 2018, https://www.brookings.edu/research/black-and-hispanic-underrepresentation-in-tech-its-time-to-change-the-equation/.

13 Google and Gallup, *Searching for Computer Science: Access and Barriers in US K-12 Education*, 2015, http://services.google.com/fh/files/misc/searching-for-computer-science_report.pdf; Janet Abbate, *Recoding Gender: Women's Changing Participation in Computing* (Cambridge, MA: MIT Press, 2012); Hala Annabi and Sarah Lebovitz, "Improving the Retention of Women in the IT Workforce: An Investigation of Gender Diversity Interventions in the USA," *Information Systems Journal* 28, no. 6 (2018): 1049–81, https://doi.org/10.1111/isj.12182; Jane Margolis, *Stuck in the Shallow End: Education, Race, and Computing* (Cambridge, MA: MIT Press, 2010).

work.[14] In addition to a workplace that is stressful for some individuals, tech workers experience high rates of mental health issues.[15]

Although some leaders advocate the claim that anyone can train for work in tech and that these jobs do not necessarily require college degrees, the data do not support these statements. Tech recruiters demonstrate a strong preference for computer science degree holders.[16] According to the Bureau of Labor Statistics, most computer programmers have attained a bachelor's degree or higher.

To alleviate the perceived shortage of Americans with these skills, wages may need to be even higher to compensate workers and attract competent people. Alternatively, changes to the nonpecuniary aspects to these jobs could increase recruitment and retention, especially for women. An insight from this study is that better management practices might significantly alleviate the perceived shortage of talent. We present relevant data and current research so that readers can see both the available information and unanswered questions in this area. First, we present public data on wages and the increase in the number of workers. Next, we discuss reasons for slow convergence based on a review of studies and surveys. Finally, we conclude with recommendations.

Official Data on the Supply and Demand for Technology Workers

Warnings are issued every decade that the United States is falling behind in the global talent pool and that a "skills gap" is looming. Before the outbreak of COVID-19, this gap stood at a historic high of 7.5 million unfilled jobs, of which 918,000 involved work in tech.[17] The internet and computers have become increasingly integral to all industries. In response to this pressure, there has been some change in the observable price and quantity of workers, as classified by the Bureau of Labor Statistics (BLS).

In computer and mathematical occupations (SOC code 15), employment has risen from approximately 2.9 million in 2000 to 4.2 million in 2017. Figure 1 shows this steady but slow growth in the past decade. Official data may underestimate the number of workers participating in the IT workforce because these data do not count self-employed workers.[18] Other sources place the number much higher. The Computing Technology Industry Association (CompTIA) counts 12.1 million net tech employees in the United States. The report states that the industry added 2.3 million jobs between 2010 and 2019.[19] BLS analysts in 2014 put the number of "high-tech

14 Catherine Ashcraft, Brad McLain, and Elizabeth Eger, *Women in Tech: The Facts* (Boulder, CO: NCWIT, 2016).

15 Rachel Johnson, "Major Study Finds Diverse Members of the Tech Sector Experience Discrimination and Stress," BIMA, April 9, 2019, https://bima.co.uk/major-study-finds-diverse-members-of-the-tech-sector-experience-discrimination-and-stress-2/; V. Padma, N. N. Anand, S. S. Gurukul, S. S., Javid, A. Prasad, and S. Arun, "Health Problems and Stress in Information Technology and Business Process Outsourcing Employees," *Journal of Pharmacy and BioAllied Sciences* 7, no. 5 (2015): 9–13, https://doi.org/10.4103/0975-7406.155764.

16 Burke and Bailey, "Camp or College?," Melissa Butcher and Johanna Wadsley, *Young People's Participation in TechCity: Opportunities and Barriers* (Milton Keynes, UK: The Open University, 2015), https://doi.org/10.13140/RG.2.1.4848.8483.

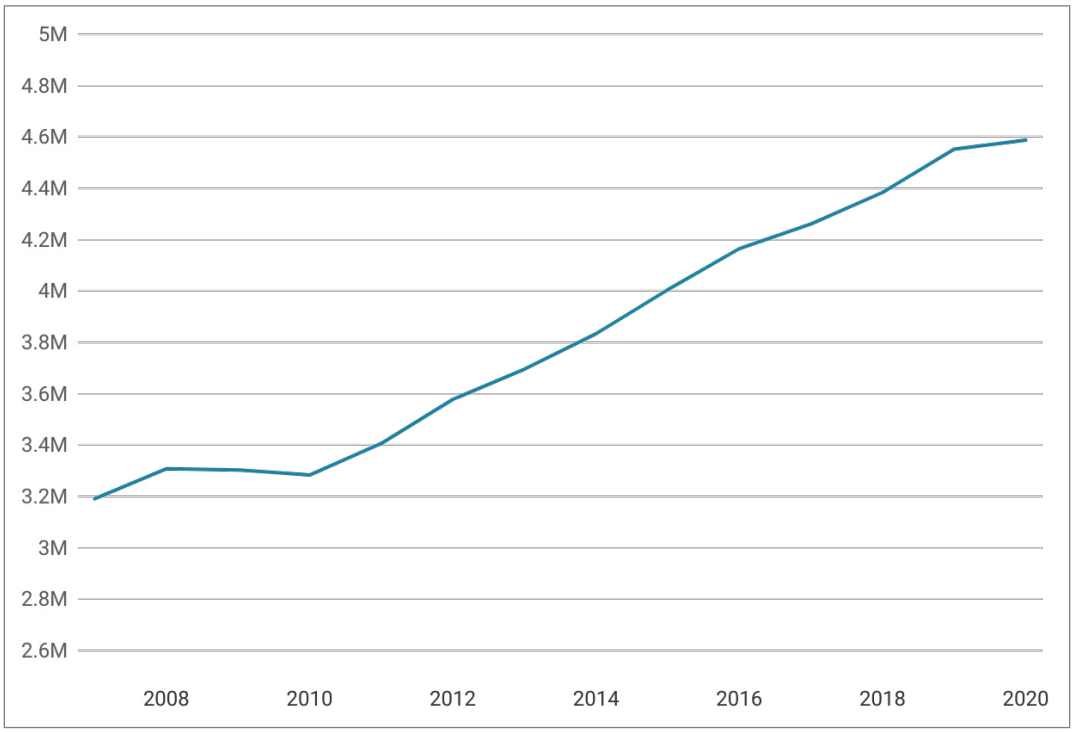
17 Loten, "America's Got Talent."

18 Taylor and Joshi detail the rise of IT workers who prefer short-term contracts in online crowdsourcing platforms. Joseph Taylor and K. D. Joshi, "Joining the Crowd: The Career Anchors of Information Technology Workers Participating in Crowdsourcing," *Information Systems Journal* 29, no. 3 (2019): 641–73, https://doi.org/10.1111/isj.12225.

19 Chris Curran, Dan Garrett, and Tom Puthiyamadam, "CompTIA 2020 Tech Industry Job Market and Salary Trends Analysis," in *Cyberstates Report*, November 2019, https://www.comptia.org/content/research/it-industry-outlook-2020.

workers" or "those having high concentrations of workers in STEM occupations" at 17 million.[20] However, the official BLS number of workers has not even doubled in two decades.

Figure 1. Total Employment for All Computer Occupations by Year.



Source: BLS Occupation Statistics Survey

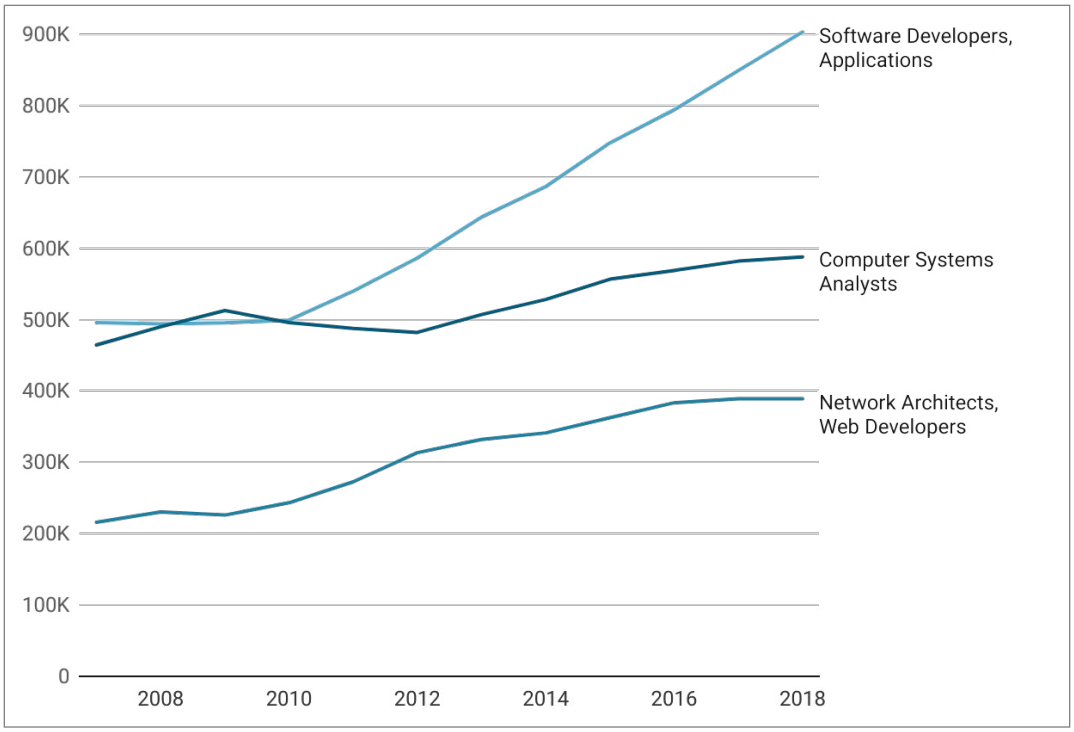
The trend in figure 1 hides the volatility of subfields within computer occupations. Bessen argues that the "skills gap" exists because shortages are most acute for the newest skills to operate the most recent technologies.[21] Figure 2 indicates that the number of software developers has grown by more than the number of computer systems analysts. Bessen argued that employers "aren't just whining—the skills gap is real." However, analyzing job posting databases across industries, Modestino, Shoag, and Ballance indicate that employers have partially overstated the shortage.[22] Their analysis shows that during and following the Great Recession employers increased the stated skill requirements for jobs in terms of both education and experience. This led to a slackening of what the authors call "recruiting intensity." When unemployment began to fall, employers neither relaxed their hiring standards nor increased their recruiting intensity to pre-recession levels. Workers on the job hunt now, therefore, must clear higher hurdles.

20 Michael Wolf and Dalton Terrell, "The High-Tech Industry, What Is It and Why It Matters to Our Economic Future," *BLS, Beyond the Numbers* 5, no. 8 (May 2016), https://www.bls.gov/opub/btn/volume-5/the-high-tech-industry-what-is-it-and-why-it-matters-to-our-economic-future.htm.

21 James Bessen, "Employers Aren't Just Whining – The 'Skills Gap' Is Real," *Harvard Business Review*, August 25, 2014.

22 Alicia S. Modestino, Daniel Shoag, and Joshua Ballance, "Upskilling: Do Employers Demand Greater Skill When Workers Are Plentiful?," *Review of Economics and Statistics* 102, no. 4 (2020): 793–805, https://doi.org/10.1162/rest_a_00835.

Figure 2. Total Employment by Occupation per Year.



Source: BLS Occupation Statistics Survey

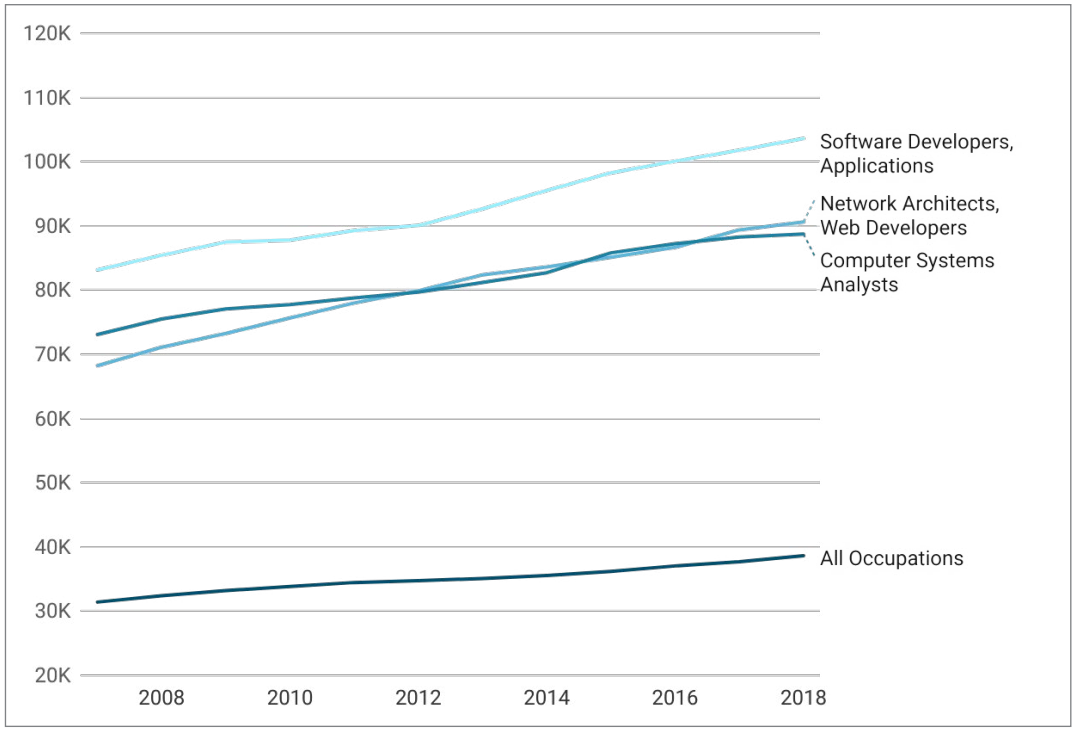
Based on the number of unfilled positions, it appears that there is a shortage of high-skilled talent in computer-related occupations.[23] Classical economic theory suggests that a shortage should be met with an increase in wages until the quantity demanded meets with the quantity supplied. The pattern of wage growth is even less dramatic than the moderate increase in the number of workers. Annually, the nominal median wages of computer and mathematical occupations has grown by about 2 percent, barely outpacing inflation. This supports the positions of some scholars that no skills gap exists within the technology industry.[24] Figure 3 shows the change in wages in the decade before 2018, for three of the subcategories within computer occupations. Note that they are all well above the median wage for all of the occupations recorded by the BLS.[25]

23 Burning Glass Technologies published a study comparing job openings and workers available to fill jobs. They estimate that the demand for computer occupations exceeds supply by 17 percent. They found that there were 3.5 million job openings in computer and mathematical occupations. Dan Restuccia, Bledi Taska, and Scott Bittle, *Different Skills, Different Gaps: Measuring and Closing the Skills Gap* (Boston, MA: Burning Glass Technologies, 2018), 24. The recent increase in demand is largely driven by growth in data analytics and information security. In the public sector, the Department of Homeland Security's cyber security division posted a vacancy rate of 22 percent for cyber security positions. Rebecca Vogel, "Closing the Cybersecurity Skills Gap," *Salus Journal* 4, no. 2 (2016): 32.

24 Gary Burtless, "Unemployment and the 'Skills Mismatch' Story: Overblown and Unpersuasive," *Brookings* (blog), November 30, 2001, https://www.brookings.edu/opinions/unemployment-and-the-skills-mismatch-story-overblown-and-unpersuasive/; Paul Krugman, "Jobs and Skills and Zombies," *New York Times*, March 31, 2014, https://www.nytimes.com/2014/03/31/opinion/krugman-jobs-and-skills-and-zombies.html.

25 The more commonly discussed "median household income" is higher than the median annual wage of all occupations. More details can be found at the BLS technical OES note for May 2017 at https://www.bls.gov/oes/2017/may/oes_tec.htm.

Figure 3. Annual Median Nominal Wage by Occupation per Year.



Source: BLS Occupation Statistics Survey and Current Population Survey

Restuccia, Taska, and Bittle found that jobs like computer engineering had a shortage of workers even during the Great Recession when most professions had excess workers.[26] While wages for the All Occupations category were not growing during the Great Recession from 2007 to 2012, figure 3 indicates that there were increases in wages for the most in-demand high-skill jobs, like software development. The gap between supply and demand has decreased slightly because of an increase in the number of people training for jobs in fields like cybersecurity. However, the gap has persisted for many years, both during the Great Recession, when workers outside of tech faced an oversupply of labor in most fields, and today.

Workers with exceptional skills in tech have seen larger wage increases than what is reflected in the median wage chart in figure 3. Employers increasingly value top talent and workers who already have experience. The wage for workers in the 90th salary percentile is almost double the wage for median workers in computer occupations.[27] Instead of trending toward consolidation, the wage for top workers is growing at a faster rate than the wage for average workers. Compounded from 2012 to 2017, there was a 15 percent increase in the 90th percentile wage and only a 10.9 percent increase in the median wage for computer and mathematical occupations. Figure 4 shows that the growth rate for top performers has exceeded the growth rate of the median wage since 2011. The change in the median wage for computer occupations is a 22 percent increase, which is higher than the inflation rate of 18.2 percent over the same 10-year period. The change for the 90th percentile

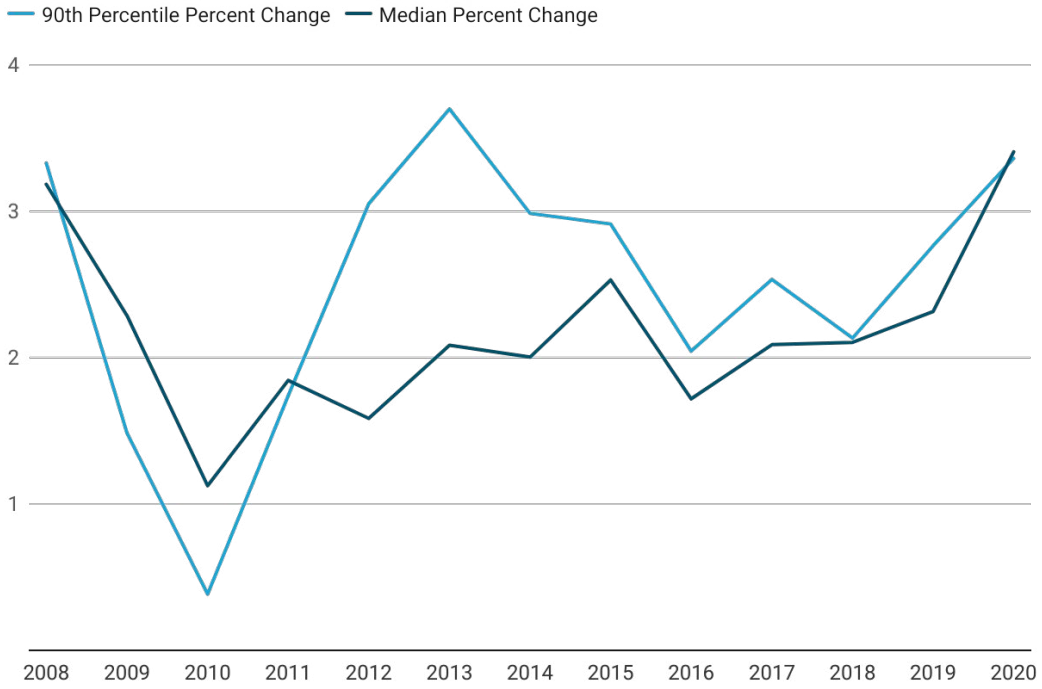
26 Restuccia, Taska, and Bittle, *Different Skills, Different Gaps.*

27 According to the BLS OES, in 2017, the median wage for computer occupations was $84,500 and the 90th percentile wage was $145,000.

wage is larger, a 27 percent increase in 10 years. The demand for superstars grew fastest in 2013, and the median wage change has not overtaken the rising top talent wage.[28]

Within niche subfields, like software development in applications and network architecture, these wages rise on average nearly 3 percent within the 90th percentile. Wage inequality within the tech industry is rising as employers favor highly skilled workers over the "median" worker. This is due to the nature of the tech industry. On the cutting edge, technology changes rapidly. Lawrence-Fowler, Grabowski, and Reilly note in their study on bridging the skills gap that technical and scientific knowledge evolves so quickly that it is possible that a person's skills become obsolete within a few years.[29] To stay competitive, firms must adapt to rising technological changes. Although technology changes quickly, companies prefer experienced workers, so that leaves a very small pool of workers who have experience in the in-demand fields to fill the positions.[30]

Figure 4. Year-to-Year Growth in Wages for All Math/Computer Occupations.



Source: Author's calculations from BLS survey data

28 The demand for superstars can grow even at a time when general wages are stagnating. Tyler Cowen, *Average Is Over: Powering America beyond the Age of the Great Stagnation* (New York: Penguin, 2013).

29 Wendy A. Lawrence-Fowler, Laura M. Grabowski, and Christine F. Reilly, "Bridging the Divide: Strategies for College to Career Readiness in Computer Science," in *2015 IEEE Frontiers in Education Conference* (El Paso, TX: IEEE, 2015), 1–8, http://ieeexplore.ieee.org/document/7344317/.

30 In Silicon Valley culture, employees debate the presence and value of "10x developers." These workers are so talented that they can supposedly accomplish the work of ten developers singlehandedly. Software engineers Timothy Lister and Tom DeMarco developed a coding productivity competition known as Coding War Games in 1977. In their 1999 text *Peopleware*, they describe how some teams performed 11.1x more efficiently than others. Tom DeMarco and Timothy Lister, *Peopleware: Productive Projects and Teams*, 2nd ed. (New York: Dorset House, 1999). More recent scholarship, however, problematizes the concept of the 10x developer as highly relative and conditional. See L. Prechelt, "The Mythical 10x Programmer," in *Rethinking Productivity in Software Engineering*, ed. C. Sadowski and T. Zimmermann (Berkeley: Apress, 2019), https://doi.org/10.1007/978-1-4842-4221-6_1. One might settle on the conclusion that some developers are more productive than others, and tech companies want to hire the most productive employees possible.

The exceptional tech employee possesses many skills. They have advanced specialized knowledge, but they are also creative and constantly learning.[31] Soft skills also form some of the most useful tools in their toolbox.[32] Very few workers can fulfill all of those requirements. Employers want workers who are on the high end of both hard and soft skills distribution. To find these employees, tech companies could raise wages. However, in the short run, that will not cause more superstars to appear. Until talent development pipelines get bigger, there will be a fixed limited supply of people who can fill technical jobs. It is also difficult for tech companies to accurately identify ex ante who among a group of candidates will perform well and become a high contributor, so paying high wages is risky.

In some documented cases, firms will invest significantly to recruit talent instead of simply raising the salary or delivering training. They will wait for months with unfilled positions and maintain a fleet of recruiters. For example, the software development company Mapbox has one recruiter for every 30 employees. That is a higher recruiter-to-employee ratio than most companies.[33] In 2013, Massachusetts-based firm HubSpot offered a $30,000 reward to individuals who could find software engineers and designers to hire.[34]

The problem of information asymmetry between employers and workers is a structural issue that can explain part of the perceived gap. It is risky to pay a worker what a superstar programmer is worth when employers do not know ahead of time who the superstars are.

More so than any other industry, tech has experienced a recent explosion in "certs" or certifications for specific skills to alleviate this problem. This has been a nimble response from the private sector that helps more people match with companies. Some have cast doubt on whether there is a

31 A report from the Pew Research Center finds that employment is rising faster in occupations which require higher levels of expertise through education and training. Anna Brown, "Key Findings about the American Workforce and the Changing Job Market," *Pew Research Center* (blog), October 6, 2016, http://www.pewresearch.org/fact-tank/2016/10/06/key-findings-about-the-american-workforce-and-the-changing-job-market/.

32 A large body of research indicates that soft skills gaps may be wider and more harmful than hard skills gaps. Burke and Bailey, "Camp or College?" Researchers have established that soft skills are a key aspect of employability across business sectors and global regions. See Geana W. Mitchell, Leane B. Skinner, and Bonnie J. White, "Essential Soft Skills for Success in the 21st Century Workforce as Perceived by Business Educators," *Delta Pi Epsilon Journal* 52, no. 1 (2010): 43–53; M. M. Robles, "Executive Perceptions of the Top 10 Soft Skills Needed in Today's Workplace," *Business Communication Quarterly* 75, no. 4 (2012): 453–65; Narendra M. Agrawal and Mohan Thite, "Nature and Importance of Soft Skills in Software Project Leaders" (IIM Bangalore Research Paper No. 214, September 2003), https://doi.org/10.2139/ssrn.2159692. Some evidence suggests soft skills are more important to employers than hard skills. Hart Research Associates, *Falling Short? College Learning and Career Success* (Washington, DC: AAC&U, 2015), https://www.aacu.org/research/falling-short-college-learning-and-career-success; Agrawal and Thite "Nature and Importance." A 2020 survey identified soft skills as the most in demand among cybersecurity applicants. In addition, 73 percent of respondents rated prior cybersecurity experience as "very important" in determining the merit of an applicant. Prior experience was rated significantly higher than credentials, hands-on training, and a university degree. International Systems Audit and Control Association (ISACA), *State of Cyber 2020, Part 1: Workforce Efforts and Resources* (Schaumburg, IL: ISACA, 2020). Colombo, Mercorio, and Mezzanzanica (2019) confirm this using detailed analysis of the Italian labor market. They found that soft skills are highly demanded in computer and mathematical occupations (along with hard technical skills). Emilio Colombo, Fabio Mercorio, and Mario Mezzanzanica, "AI Meets Labor Market: Exploring the Link between Automation and Skills," *Information Economics and Policy* 47 (June 2019): 27–37, https://doi.org/10.1016/j.infoecopol.2019.05.003.

33 Torres, "Demand for Programmers."

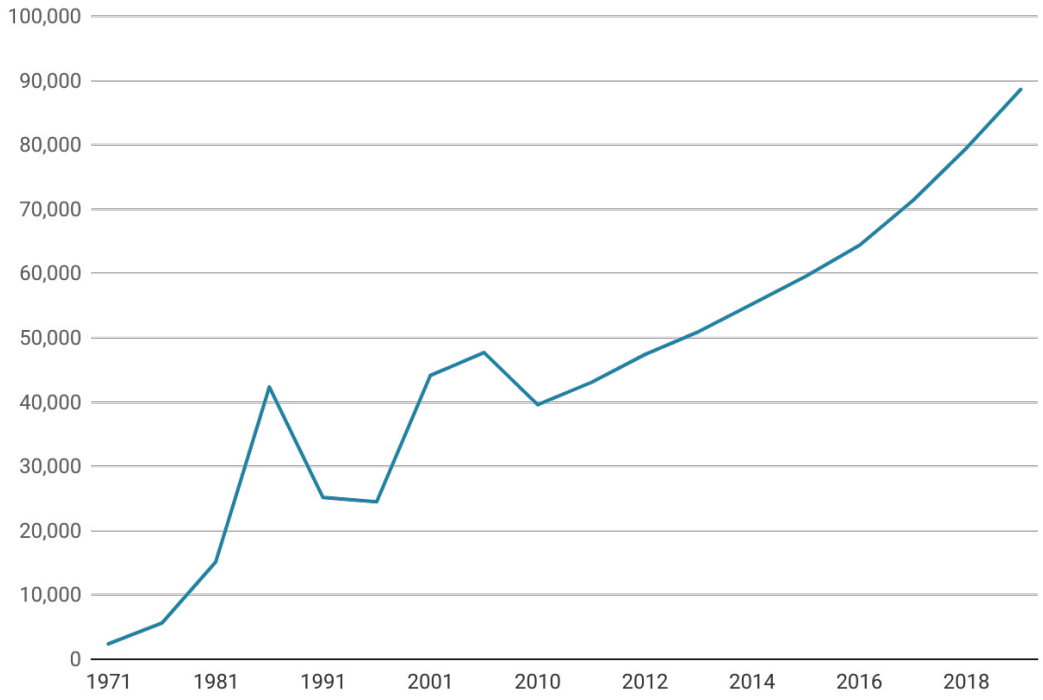
34 John Dodge, "The War for Tech Talent Escalates," *Boston Globe*, February 19, 2016, https://www.bostonglobe.com/business/2016/02/19/the-war-for-tech-talent-escalates/ejUSbuPCjPLCMRY1RZIKoJ/story.html.

relationship between certifications and skills.[35] But evidence suggests that certifications do improve performance in fields that maintain certification standards.[36]

Employers could provide in-house training for the skills that they value. However, since they are generally without legal means of contracting into the future with workers, most employers do not want to run the risk of investing in their own employees just to lose them to a competitor. Talent poaching is common. The 2020 ISACA report found that 59 percent of cybersecurity workers who left their jobs were recruited by another company, the highest source of attrition mentioned.[37] The cost of training is borne by workers, so high wages are needed to compensate for the time and expense.

There are methods besides earning certs for an inexperienced worker to signal quality. They can independently develop a successful application that users buy or contribute to the open-source software community. These accomplishments are a strong signal of talent and work ethic. However, the four-year college degree remains a popular route to a career in tech.

Figure 5. Computer and Information Sciences Bachelor's Degrees Conferred by Postsecondary Institutions, 1970–71 through 2018–19.



Source: Table 322.10 of US Department of Education, National Center for Education Statistics, Higher Education General Information Survey (HEGIS)

Figure 5 indicates that computer science has been a growing field of study at American colleges, and it continues to grow. The percentage of bachelor's degrees granted for computer science increased from about 2.5 percent to almost 3.5 percent in a decade (see table 1). The fields

35 James, Jason E., and Jennifer Callen. "Cybersecurity Certifications Matter." *Issues in Information Systems* 19.3 (2018).

36 Joan M. Heise, "Professional Certifications versus Skills: A Study of Professional Certifications from the Perspective of the Certified and Their Employers" (PhD diss., Capella University, 2009).

37 ISACA, *State of Cyber 2020*.

experiencing declines are the ones that promise a less clear path to a high-paying career, such as education and the humanities. High future wages and perhaps STEM-related messaging to youth are exerting some pull on students' choices. Among people with the opportunity to get a bachelor's degree, it is a small but growing minority that choose computer science or math.

The "skills gap" does not only exist for jobs that require college degrees or jobs in the technology sector. Employers report shortages for labor in the "skilled trades," and that includes IT help desk staff and technicians who need to be conversant with computers.[38] The shortage implies that employers may be trying to get high-skill workers without paying the wages that an advanced degree would command. In the Manpower Group international survey, employers said they cannot fill jobs because candidates do not have the technical competencies required. Another reason cited was "lack of experience." In many places, employers' expectations were disappointed in the labor market.

Table 1. Bachelor's Degrees Conferred by Postsecondary Institutions, 1970–71 through 2018–19.

Year	Total College Degrees	Computer and Information Sciences Degrees	Percent Computer Degrees
1970–71	839,730	2,388	0%
1975–76	925,746	5,652	1%
1980–81	935,140	15,121	2%
1985–86	987,823	42,337	4%
1990–91	1,094,538	25,159	2%
1995–96	1,164,792	24,506	2%
2000–01	1,244,171	44,142	4%
2005–06	1,485,104	47,702	3%
2009–10	1,649,919	39,593	2%
2010–11	1,716,053	43,066	3%
2011–12	1,792,163	47,406	3%
2012–13	1,840,381	50,961	3%
2013–14	1,870,150	55,271	3%
2014–15	1,894,969	59,586	3%
2015–16	1,920,750	64,402	3%
2016–17	1,956,114	71,416	4%
2017–18	1,980,665	79,597	4%
2018–19	2,012,854	88,633	4%

Source: Table 322.10 of US Department of Education, National Center for Education Statistics, Higher Education General Information.

38 Manpower Group, *The Talent Shortage Continues* (Milwaukee, WI: Manpower Group, 2014), https://www.manpowergroup.com/wps/wcm/connect/c2ddd2bc-fa8f-4d7f-8281-6bd96071a160/2014_Talent_Shortage_WP_US2.pdf?MOD=AJPERES&CACHEID=c2ddd2bc-fa8f-4d7f-8281-6bd96071a160.

It is not only the technical hard skills that are lacking at current wages. In another survey of employers, the skills that polled as both most valued and hardest to find were communication skills, closely followed by problem solving.[39] The skills that a worker can demonstrate by completing a coding bootcamp are not the only skills needed to succeed in a collaborative workplace. Companies want more people in IT roles who excel at written and verbal communication, teamwork, creative problem solving, and other soft skills.

Closing this skills gap will require a bilateral shift. Workers should focus their training more on computer technology, without ignoring basic communication skills, and employers will need to pay more to attract talented people.

Google, which has a stake in the future tech workforce, funded a survey on the perception of computer science.[40] Students, parents, and teachers all have very positive views of careers in computer science. Some of the gains in the tech workforce over the past decade may have come from the growing awareness of opportunities in tech. The Google survey indicates that many stakeholders in education are aware that some people with the right qualifications and talents are enjoying great success. The stereotype revealed in the survey shows that students do not realize that there are mid-level opportunities in tech, such as IT help desk technicians, which do not require such extensive training.

The survey also indicates that many Americans see a career in tech to be out of reach. Only half of students report that they are "very confident" that they could learn computer science if they wanted to. Male students are more likely than females to report that they are very confident.[41] Although tech careers are perceived to be good destinations, most students indicate that they would not pursue one.

Although the pool of qualified applicants is small within the American population, there is a large international pool of talent that can access the American job market through the H-1B program. People who have a different set of opportunities abroad are choosing to train for these jobs. What are the important features of these high-paying jobs that make them unattractive or unattainable to most Americans?

39 These employers predict that workers in "skilled trades" IT functions will be in demand for a long time. Their recommendation, since hiring people with experience is proving difficult, is to hire people with "the desire and ability to develop in-demand skills." Manpower Group, *Robots Need Not Apply: Human Solutions for the Skills Revolution* (Milwaukee, WI: Manpower Group, 2018), https://www.manpowergroup.com/wps/wcm/connect/59db87a7-16c6-490d-ae70-1bd7a322c240/Robots_Need_Not_Apply.pdf?MOD=AJPERES.

40 Google and Gallup, *Searching for Computer Science*.

41 In an experiment with undergraduate students, one of us (Joy Buchanan) found that male and female students are equally willing to do a short-term computer programming job. Joy Buchanan, "Willingness to Be Paid: Who Trains for Tech Jobs?," *Labour Economics* 79 (December 1, 2022), 102267 https://doi.org/10.1016/j.labeco.2022.102267.

Dirty Jobs: What Makes Tech Work Unattractive?

The skills gap is a policy issue, predicated on the assumption that people want jobs. In the summer of 2018, President Trump signed an executive order to create a national council focused on job retraining.[42] As part of this initiative he asked companies to make a pledge to train their workers. President Trump also sought to increase access to STEM education in K–12 schools and promote job retraining and apprenticeships.[43] Although the issue of bringing jobs "back" to America loomed large in the 2016 political campaign rhetoric, there are currently many open jobs in the United States. At current wages, Americans cannot or will not fill them. In this section, we explore the connection between the shortage of workers in tech and other jobs that go unfilled.

Better than "Dirty Jobs"

The term "dirty jobs" was popularized by TV host and activist Mike Rowe. Rowe works to bring attention to the unpopular jobs in America that do not fit the high-status white-collar mold. Rowe says that Americans insist on a four-year college degree and have a culture that pushes people away from the skilled trades.[44] In contrast to the vital roles of maintaining a sewage treatment plant or catching rattlesnakes, tech jobs are comfortable in a physical sense and they are not low status.[45] Why are tech workers in short supply, along with plumbers?

The popular high-status conception of tech jobs might actually deter people from them. Although the "nerd" now occupies a lofty place in culture, there is still a stigma to computer jobs that turns away many people. This phenomenon has been shown to be stronger among women than men and may be a result of the "leaky pipeline"—cultural forces that have compelled women to participate in tech and computer science programs today at lower rates than they did during the 1960s and 1970s.[46]

Perks of tech jobs include being able to work remotely or indoors, although remote work is now available to a variety of professions. Some tech workers enjoy the analytical challenges of their work, but there are drawbacks that we will document below. In fact, the lonely hours spent inside staring at a computer screen might seem more unpleasant to some workers than opportunities to work with their hands in the mode of "dirty jobs."

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42 This recent policy initiative is not the first in the United States. In 2014, President Obama signed into law the Workforce Innovation and Opportunity Act designed to help job seekers access employment, education, retraining, and support programs. The purpose of the program was to consolidate the already numerous existing federal retraining programs under one banner with the aim to simplify the retraining process. The goal of the program was to increase worker retraining into in-demand fields such as niche manufacturing sectors, trades, and technology.

43 Trump, "Jobs of Tomorrow."

44 Kathy Caprino, "Dirtiest Man On TV Mike Rowe Takes On America's Skills Gap Problem," *Forbes*, August 30, 2018, https://www.forbes.com/sites/kathycaprino/2018/08/30/dirtiest-man-on-tv-mike-rowe-takes-on-americas-skills-gap-problem/.

45 A "dirty job," as defined by Mike Rowe, the host of the television show *Dirty Jobs*, is a job viewed poorly by society. These are the types of jobs that are looked down upon, degraded, and not sought after. Mike Rowe notes that these are not necessarily bad jobs, and, in fact, workers in these jobs do not mind the work they do. Mike Rowe, "Learning from Dirty Jobs," TED Best of the Web, 2008, video, 19:42, https://www.ted.com/talks/mike_rowe_celebrates_dirty_jobs. Rowe's foundation gives scholarships to students who study the skilled trades, many of whom go on to good paying jobs or even run their own businesses.

46 Joseph Appianing and Richard N. Van Eck, "Gender Differences in College Students' Perceptions of Technology-related Jobs in Computer Science," *International Journal of Gender, Science and Technology* 7.1 (2015): 28–56.

Worse than "Dirty Jobs"

Are tech jobs as unpleasant as picking watermelons in the summer heat? Perhaps not, but in both cases, the US government has decided that the need is so acute and the native pool of talent is so weak that foreign workers may take the jobs. Reasons that tech jobs are not attracting US workers include the dangers of skills obsolescence and the onerous nature of the work itself.

Threat of Becoming Obsolete, Outsourced, or Automated

One of the reasons that Rowe's "dirty jobs" provide stable employment in the United States today is that the work cannot be outsourced or automated. Unlike plumbers, tech workers who are in high demand must constantly re-skill and adapt to changing technology and protocols. Most specializations have a shelf life. It pays for workers to be attuned to current job opportunities; however, the particular skills that are in demand change overtime.[47]

Research indicates that new applied science graduates enjoy a large wage premium over their liberal arts peers at first. But as Deming and Noray demonstrate, tech specialists must constantly work to preserve this premium.[48] According to their model developed with job posting platforms, a specific technical skill can become obsolete in as little as five years.[49] Computer science graduates need to be adaptable. Most computer science undergraduate programs do not prepare learners for a specific job. In many cases, academia lags behind the private sector. Hollingsworth and Powell describe how, despite the fact that no major desktop-first software had been designed since 2004, Elon University did not require web or mobile programming courses until 2010.[50] Computer science curricula are generally designed to provide foundational knowledge upon which learners will need to build and specialize in order to enter the industry.[51]

This need to constantly re-skill presents a higher burden in tech than other industries. But research indicates that employees who are already entrenched in the industry successfully navigate changing development trends. For example, the industry's use of Adobe Flash—a suite of tools and platforms used to create multimedia, applications, games, and more—dropped steadily after Apple CEO Steve Jobs announced in 2010 that his company would no longer support it on iOS. Android

47 Filippetti and Guy suggest that job insecurity for high-tech workers slows innovation. They find among European countries that unemployment insurance is associated with more patents. Andrea Filippetti and Frederick Guy, "Labor Market Regulation, the Diversity of Knowledge and Skill, and National Innovation Performance," *Research Policy* 49, no. 1 (2020): 103867, https://doi.org/10.1016/j.respol.2019.103867.

48 David J. Deming and Kadeem L. Noray, "STEM Careers and the Changing Skill Requirements of Work" (NBER Working Paper 25065, National Bureau of Economic Research, Cambridge, MA, September 2018), https://doi.org/10.3386/w25065.

49 The model devised by Deming and Noray predicts that the higher the rate of skill change in an industry, the more workers will switch careers. See Deming and Noray, "STEM Careers." Available data relating to STEM careers, however, do not support this. Iammartino et al. show that the attrition rate among federal STEM workers ranged from about 0.45 and 0.7 percent between 2005 and 2015. In most years, it was lower than the total federal employee attrition rate. See R. Iammartino, J. Bischoff, C. Willy, and P. Shapiro, "Emergence in the US Science, Technology, Engineering, and Mathematics (STEM) Workforce: An Agent-based Model of Worker Attrition and Group Size in High-density STEM Organizations," *Complex and Intelligent Systems* 2, no. 1 (2016): 23–34. At NASA, it was significantly lower, especially among STEM workers. CompTIA's *Cyberstates Report* projects the average tech workforce "replacement" (those who either retired or left the industry) will be on average 8 percent between 2018 and 2028. Curran, Garrett, and Puthiyamadam, "CompTIA Analysis."

50 Joel Hollingsworth and David Powell, "Requiring Web-based Cloud and Mobile Computing in a Computer Science Undergraduate Curriculum," in *Proceedings of the 49th Annual Southeast Regional Conference* (New York: ACM, 2011), 19–24, https://doi.org/10.1145/2016039.2016054.

51 M. Sahami, A. Aiken, and J. Zelenski, "Expanding the Frontiers of Computer Science: Designing a Curriculum to Reflect a Diverse Field," in *SIGCSE: 41st ACM Technical Symposium on Computer Science Education* (New York: ACM, 2010), 47–51, https://doi.org/10.1145/1734263.1734279.

followed a year later, and Flash specialists began to face a negative demand shock. As Horton and Tambe detail, Flash-specific jobs had declined by roughly 80 percent by 2015.[52] Flash experts began exiting their jobs at higher rates as demand dropped, while fewer newcomers developed the professional skill. The average salary for Flash workers remained constant while the total hours worked on Flash jobs declined. The researchers surveyed those who exited the skill and found their main coping strategy was to learn new skills. Many elected to take an initially lower salary to "earn while they learn." In other words, tech workers proved adept at navigating a significant negative demand shock. But Horton and Tambe do not quantify the efforts and resources that were expended by these workers to retrain. Currently available data do not allow us to precisely estimate how costly it is for individuals to constantly retrain. This is an area where more research would be helpful.

In theory, tech jobs have low barriers to entry for someone who can learn how to perform the work to employers' standards. They do not have occupational licensing barriers, except for some cyber-security positions. By contrast, in 2006, 29 percent of the workforce required some form of legal occupational licensing.[53] Even hairdressers must get some kind of legal license in some states. Less than 10 percent of workers in computer and mathematical occupations hold some sort of license, and the licenses appear to not offer any competitive advantages.[54] Incidentally, individuals who hold a license in computer and mathematical occupations do not earn more than those without a license. Most programmers are to some degree self-taught from forums and free materials on the internet. Although employers prefer someone with a college degree and work experience, the need is so great that some people who complete a bootcamp can enter a job at above national median level wages.

In practice, a large majority of workers in tech have graduated from computer science degree programs. Some research points to a heavy bias to undergraduate degree holders for entry-level jobs.[55] According to the Bureau of Labor Statistics (BLS), in most tech positions, fewer than 20 percent of employees do not hold a bachelor's degree or higher. It is unclear, however, how well those who enter the tech industry via a bootcamp or other non-degree training path fare in the long run. It is possible that persistence in the industry is lower among this population. This would be a promising area for future research.

On the other hand, the rapidly changing nature of the tech industry may also serve to protect jobs from automation. In a 2018 survey of employers, workers in the "skilled trades" in IT were predicted to be in demand for a long time. In the same survey, employers predicted that traditional administrative or office functions would experience job loss due to automation.[56] It may be a boon to IT workers that their work is not more routine, since that would lead to automation, but it is also a burden to constantly be needing to learn new protocols and tools. As Diamond describes,

52 John J. Horton and Prasanna Tambe, "The Death of a Technical Skill" (working paper, October 17, 2020), https://john-joseph-horton.com/papers/schumpeter.pdf.

53 Morris M. Kleiner and Alan B. Krueger, "The Prevalence and Effects of Occupational Licensing," *British Journal of Industrial Relations* 48, no. 4 (2010): 676–87.

54 Ryan Nunn, "Occupational Licensing and American Workers," *Brookings*, June 21, 2016, https://www.brookings.edu/research/occupational-licensing-and-the-american-worker/.

55 Butcher and Wadsley, *Participation in TechCity*.

56 Manpower Group, *Robots Need Not Apply.*

most experts believe computer automation can replace human jobs only to a limited extent.[57] Risk of automation could be a minor factor in the attrition of tech workers.

The ability to learn has become a key advantage and necessary tool for survival in the workplace.[58] As Deming and Noray show, the rate at which new skills become sought-after in the tech marketplace is higher than other industries.[59] This does not, however, lead to high turnover in the workforce. The difficulty of keeping up can lead to our next topic: mental health stressors and burnout.

Burnout, Depression, Anxiety, and Boredom

More so than the need for lifelong learning, the challenge of the work itself is the greatest barrier to increasing the tech workforce. High wages do lure people into computer science college programs and tech careers. However, there is some attrition both for students in the pipeline and also for certain populations of workers who have been hired in the tech field, such as women and people of color.

There are more studies on traditional STEM fields, so we will again draw on those insights and assume that they also apply to rigorous computer science studies. Many students who initially choose to study in STEM fields in college leave for easier college majors. Students who performed well in high school find the work boring while other students find the math difficult.[60] In 2012, the President's Council of Advisors on Science and Technology expressed a belief that better teachers could be more inspiring and engage students creatively. The report implies that most students should want to pursue a technical field and merely lack the help to make the first step. However, this discounts the fact that this work may actually be difficult or unrewarding.

In fact, individuals with high-status tech jobs report burnout, anxiety, depression, and other mental health issues at significantly higher rates than the general population. While this body of literature is limited, the results are strikingly similar across countries. According to a survey completed by Blind, an anonymous social app for tech employees, 57 percent of US respondents reported currently experiencing burnout in their work.[61] A study of UK tech workers found that 52 percent had experienced symptoms of anxiety or depression—five times the UK national average.[62] A survey of tech workers in Chennai, India, recorded rates of depression, anxiety, or insomnia at 54 percent.[63] Some workers voluntarily turn down full-time employment and take short-term contracts through crowdsourcing platforms because they value autonomy and dislike the corporate tech work environment.[64] Research suggests that it is difficult to focus in an ever more distracting digital world.[65]

57 Arthur M. Diamond, "Robots and Computers Enhance Us More Than They Replace Us," *American Economist* 65, no. 1 (2020): 4–10, https://doi.org/10.1177/0569434518792674.

58 David A. Kolb and Bauback Yeganeh, "Deliberate Experiential Learning," in *Contemporary Organizational Behavior in Action*, ed. K. Elsbach, C. D. Kayes, and A. Kayes (Upper Saddle River, NJ: Pearson Education, 2012), 201.

59 Deming and Noray, "STEM Careers."

60 President's Council of Advisors on Science and Technology (PCAST), *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*, February 2012.

61 TeamBlind, "Close to 60 Percent of Surveyed Tech Workers Are Burnt Out—Credit Karma Tops the List for Most Employees Suffering From Burnout," *Blind Blog –Workplace Insights*, May 29, 2018, http://blog.teamblind.com/index.php/2018/05/29/close-to-60-percent-of-surveyed-tech-workers-are-burnt-out-credit-karma-tops-the-list-for-most-employees-suffering-from-burnout/.

62 Johnson, "Discrimination and Stress."

63 Padma et al., "Health Problems and Stress."

64 Taylor and Joshi, "Joining the Crowd."

65 For a summary of this research, see Cal Newport, *Deep Work: Rules for Focused Success in a Distracted World* (London: Hachette UK, 2016).

Psychology studies indicate that certain aspects of tech jobs are mentally taxing in ways that are not experienced in most "dirty jobs." Other studies on mental illness show that the prevalence of mental or emotional problems varies by occupation. Occupations with stress and low levels of physical activity (desk jobs) correlate with higher levels of depression.[66] Primary and secondary teachers consistently have high rates of anxiety and depression.[67] To the extent that those in computer occupations, including teachers, experience role conflict and effort-reward imbalance, they might find their job unrewarding or stressful.[68] Tech support workers and programmers often express feelings that they are undervalued and are placed in stressful situations by clients. Highly skilled and conscientious programmers are frustrated by a lack of appreciation from clients and the demands to cobble something together that works in the short run as opposed to creating good code. A person's occupation and daily routine have a significant effect on their overall satisfaction with their lives.

One study suggests the opposite effect on mental health. According to a study in the United Kingdom, occupations with lower rates of mental problems include what might be considered "dirty jobs" such as "plant and machine operatives" and also "computer analysts, programmers."[69] The confidence and security that comes from having valuable skills might lead to greater happiness. Others with low rates of mental health problems were "science and engineering professionals."

Feeling depressed is not the primary reason workers cite for leaving tech jobs. Those who do choose to leave their positions with a firm, or the profession entirely, often report dissatisfaction with their work and management. Unfairness or mistreatment was the most reported reason for leaving a tech job.[70] Businesses are failing to fill open jobs in tech and, in some cases, they are failing to manage and incentivize existing employees. Unfair treatment was more likely to be cited by women than men. More than half of job-leavers stated that they would have stayed if management had improved, so they were not necessarily leaving to pursue opportunities that paid better.[71] Digital technology creates new opportunities for work arrangement, and with that come management challenges.[72]

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66 Lawson Wulsin, Toni Alterman, P. Timothy Bushnell, Jia Li, and Rui Shen, "Prevalence Rates for Depression by Industry: A Claims Database Analysis," *Social Psychiatry and Psychiatric Epidemiology* 49, no. 11 (2014): 1805–21, https://doi.org/10.1007/s00127-014-0891-3.

67 Wulsin et al., "Prevalence Rates for Depression;" Stephen Alfred Stansfeld, F. R. Rasul, J. Head, and N. Singleton, "Occupation and Mental Health in a National UK Survey," *Social Psychiatry and Psychiatric Epidemiology* 46, no. 2 (2011): 101–10, https://doi.org/10.1007/s00127-009-0173-7.

68 Joanna Wieclaw, Esben Agerbo, Preben Bo Mortensen, and Jens Peter Bonde, "Occupational Risk of Affective and Stress-Related Disorders in the Danish Workforce," *Scandinavian Journal of Work, Environment and Health* 31, no. 5 (2005): 343–51.

69 Stansfeld, Rasul, Head, and Singleton, "Occupation and Mental Health."

70 Allison Scott, Freada Kapor Klein, and Uriridiakoghene Onovakpuri, *Tech Leavers Study* (Oakland, CA: Kapor Center for Social Impact, 2017), http://www.kaporcenter.org/wp-content/uploads/2017/04/KAPOR_Tech-Leavers-Final.pdf.

71 Watson-Manheim, Chudoba, and Crowston document the difficulties of working remotely and coordinating a team of workers who do not work in the same office and may not even live in the same time zone. Managers must respond to these challenges and implement creative solutions quickly, such as implementing mandatory regular phone meetings that allow workers to coordinate. Mary Beth Watson-Manheim, Katherine M. Chudoba, and Kevin Crowston, "Perceived Discontinuities and Constructed Continuities in Virtual Work," *Information Systems Journal* 22, no. 1 (2012): 29–52, https://doi.org/10.1111/j.1365-2575.2011.00371.x.

72 One way to combat the tedium of technical work which leads to attrition is "gamification" of the workplace. Suh et al. warn that some gamified information systems do not engage people long enough to be useful in the workplace. They find that beautiful aesthetics play an important role in engagement. Managers learn from trial and error, and therefore management is constantly behind the technology curve, perhaps further behind than most tech workers. Ayoung Suh, Christy M. K. Cheung, Manju Ahuja, and Christian Wagner, "Gamification in the Workplace: The Central Role of the Aesthetic Experience," *Journal of Management Information Systems* 34, no. 1 (2017): 268–305, https://doi.org/10.1080/07421222.2017.1297642.

While no evidence indicates that the attrition rate of tech workers across the industry is exceptionally high, that is not the case among women. Women leave the tech industry at startlingly high rates compared to men.[73] Annabi and Lebovitz conducted interviews with women to understand why many women leave IT within five years of starting a career. One interviewee said, "That's during the time I'm starting a family, you're having to juggle your children, and yet in IT, it's a very demanding career, right, you're on call, your project goes amuck, you're working late…"[74] This quote explains both why wages are high and why attrition is high. IT workers are very hard to replace. That means that they can command high wages, but it also means that clients expect them to personally do whatever it takes to resolve a problem quickly. For many Americans, the high pay does not offset the stressful environment.

Along with the labor shortage, the lack of women is noticeable in the tech workforce. Sometimes, discrimination and sexual harassment are barriers to female success. Unwanted sexual attention was reported by 10 percent of females and only 8 percent of males, and technology fields tend to have a higher incidence of sexual harassment claims than other industries.[75] Evidence from performance in school before college indicates that women are not less capable of performing technical work. A study based on the test scores of young people in many countries found that many female high school students are strong in math and science. The enduring STEM gap between men and women (that is, more men major in STEM fields and pursue STEM careers than women) was much larger than the gap in skills.[76] Some skilled women are not choosing to pursue STEM fields. If employers can find ways to structure tech jobs so that they are more flexible, they may be able to attract and retain more workers, and they would potentially not have to offer such high salaries. Also, tech companies must become places where women are free from harassment.

Investigating the Supply of International Workers for High-skilled Jobs in America

Some low-skilled, low-paying jobs within the United States are filled by workers from other countries.[77] Likewise, perhaps surprisingly, there are some positions that pay well and offer good working conditions that Americans do not fill. Although there are many people in the United States that studied a STEM field, certain jobs such as a big data analyst can be posted for months without getting a qualified American citizen who can fill the role.[78] STEM jobs accounted for nearly two-thirds of all H-1B visa requests between 2001 and 2011. During that period, the program

73 Jamin D. Speer, "Bye Bye Ms. American Sci: Women and the Leaky STEM Pipeline" (Discussion Paper No. 14676, IZA Institute of Labor Economics, Bonn, Germany, August 2021), https://ssrn.com/abstract=3913037.

74 Annabi and Lebovitz, "Retention of Women."

75 Scott, Kapor Klein, and Onovakpuri, *Tech Leavers Study*.

76 Gijsbert Stoet and David C. Geary, "The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education," *Psychological Science* 29, no. 4 (2018): 581–93, https://doi.org/10.1177/0956797617741719.

77 For example, consider a study in North Carolina in 2011. At a time when nearly 500,000 people were unemployed in the state, the North Carolina Growers Association listed 6,500 available jobs. They were able to hire only 245 North Carolinians, and on the first day of work only 163 of them showed up. The rest of the jobs were mostly filled by workers from Mexico. Michael Clemens, *International Harvest: A Case Study of How Foreign Workers Help American Farms Grow Crops – and the Economy* (New York: New American Economy, 2013).

78 Morgan Raux, "Looking for the Best and Brightest" (working paper, The Center for Growth and Opportunity at Utah State University, Logan, UT, 2022).

generated and distributed roughly $1 billion to skill development efforts in the United States.[79] American skilled workers complain that allowing in H-1B visa holders drives down the wages for native skilled workers. However, the process of recruiting a foreign worker for these positions is sufficiently prohibitive that companies are willing to pay high wages to a native worker if one could be found, as stated in section 2 of this paper.

Why is there a large pool of tech workers outside the United States in H-1B sending countries such as India? Young people in H-1B sending countries persevere through difficult coursework, partly because they have external pressure from peers and family. Google found evidence within the United States that young people who are encouraged to study computer science are more likely to do it.[80]

Tech companies, such as Facebook, lobbied to increase the number of H-1B visas to as many as 180,000.[81] In 2008, Bill Gates of Microsoft testified before Congress to raise the cap on H-1B visas to address the "deficit of Americans with computer science degrees."[82] We can conclude that tech companies would like a larger talent pool that will accept lower wages. We can also conclude that at least 180,000 people who did not grow up with the advantages enjoyed by Americans are qualified and ready to move across the world for these jobs. How should this fact affect the conception held by some Americans that only a very small number of people are capable of having a career in tech? Some people enjoy aspects of computer occupations more than others.[83]

The hundreds of thousands of H1-B workers, the majority of whom are Indian, are formally educated. To meet the strict requirements to work in the United States through this legal program, they cannot simply attend a coding bootcamp. H-1B holders are required to have a bachelor's degree or the equivalent in order to petition for H-1B status. By educational attainment in 2016, 44 percent of H-1B holders held a bachelor's degree, 45 percent a master's degree, and 7 percent a doctorate.[84]

On average, many of these individuals experienced high expectations from parents and peers to succeed in academics. Hyderabad, India, provides an example of how pressure to study engineering

79 Ruiz, N. G., Wilson, J. H., Choudhury, S. (2012). The Search for Skills: Demand for H-1B Immigrant Workers in U.S. Metropolitan Areas. Metropolitan Policy Program at The Brookings Institution: Washington, D.C. Retrieved from https://www.brookings.edu/research/the-search-for-skills-demand-for-h-1b-immigrant-workers-in-u-s-metropolitan-areas/

80 According to the report, among young women who are not pursuing a computer science (CS) degree, less than 20 percent of them were encouraged by a family member to try. Among young people pursuing CS, the majority were encouraged by family. Google, *Women Who Choose Computer Science—What Really Matters*, May 26, 2014, https://static.googleusercontent.com/media/edu.google.com/en//pdfs/women-who-choose-what-really.pdf.

81 Nicole Torres, "The H-1B Visa Debate, Explained," *Harvard Business Review*, May 4, 2017, https://hbr.org/2017/05/the-h-1b-visa-debate-explained.

82 NPR, "Bill Gates Targets Visa Rules for Tech Workers," *All Things Considered*, March 12, 2008, 4:00 p.m., https://www.npr.org/templates/story/story.php?storyId=88154016.

83 One of us (Joy Buchanan) found in an experiment that enjoyment was the most significant predictor of who is willing to do computer programming. Buchanan, "Willingness to Be Paid."

84 Out of all H-1b holders, 3 percent possessed a professional degree. Workers with less than a bachelor's degree must have documented experience or other certificates. US Department of Homeland Security, Citizenship and Immigration Services, Characteristics of H-1B Specialty Occupation Workers: Fiscal Year 2016 Annual Report to Congress, May 2017, https://www.uscis.gov/sites/default/files/USCIS/Resources/Reports%20and%20Studies/H-1B/h-1B-FY16.pdf.

can result in many more credentialed young people.[85] US employers receive a huge number of applications from this region. A fraction are accepted. Sometimes the language barrier is a problem, but there are also graduates of these programs who do not actually have the requisite skills. Native workers in the United States face a much lower bar for qualifying for tech jobs. For the United States to provide more native tech talent, some more technical credentialing is important, but not to the exclusion of developing critical thinking and soft skills.

To the H1-B visa holders who move (some attended college in the United States before getting hired), America promises a better quality of life and scope of opportunity for their ambitions. Foreign workers who fill H1-B jobs are highly educated, but the most important difference from native workers appears to be that they are more willing to do a hard job and move for work than Americans. Not only are there shortages of highly skilled American workers within specific fields but there are also shortages within geographic regions. Audit work has some commonalities with technology occupations, and a study of the audit industry found that H-1B workers who were educated at US schools were more likely than native workers to be hired by less prestigious audit companies that operate in less desirable locations within the United States.[86] Arguing for the merits of increasing the number of H-1B visas for tech jobs is outside of the scope of this paper. However, it is clearly the fastest and cheapest way for American companies and government agencies to gain access to more talent.[87]

Recommendations and Conclusion

Within the United States, the workforce in tech will continue to grow as more people become aware of the opportunities and growing subfields such as cybersecurity. From our analysis of current problems with recruitment and retention, some recommendations emerge. First, political and community leaders can provide more accurate messaging and work to revamp the tech education pipeline. Facing a shortfall of STEM talent, these figures tend to downplay the difficulty involved in entering the tech workforce. There is no doubt that encouraging young people to strive to achieve their potential is a positive thing. But mismanaging expectations can cause young Americans to enter college and take on debt only to drop out without a degree. In July 2020, 39 million Americans had attended some college but never obtained a credential.[88]

In addition, as things stand today, computer science education usually involves earning a bachelor's of science degree. Coding bootcamps have proliferated and have proven successful at onboarding certain people, but they alone have not managed to answer the increasing demand. Norm Augustine, former chairman and CEO of Lockheed Martin, said, "In my position as CEO of a firm employing over 80,000 engineers, I can testify that most were excellent engineers. But the

85 "As of October 2013, there were 6,214 engineering and technical institutes in India, with 2.9 million students enrolled. The region around Hyderabad has the highest concentration of these institutes, thanks in part to Naidu, who pushed to make Hyderabad a rival to Bangalore, India's Silicon Valley." The city was so monolithic in this respect that they were trying out a program where young people are intentionally exposed to careers other than engineering. Sarita Santoshini, "Growing Up in a City Where Everyone Goes into Engineering," *Bloomberg CityLab*, October 8, 2015, http://www.citylab.com/work/2015/10/growing-up-in-city-where-everyone-goes-into-engineering/409198/.

86 Daniel Aobdia, Anup Srivastava, and Erqiu Wang, "Are Immigrants Complements or Substitutes? Evidence from the Audit Industry," *Management Science* 64, no. 5 (2017): 1997–2012, https://doi.org/10.1287/mnsc.2016.2707.

87 For a discussion of trade-offs, see Gordon H. Hanson, William R. Kerr, and Sarah Turner, eds., *High-Skilled Migration to the United States and Its Economic Consequences* (Chicago: University of Chicago Press, 2018).

88 Causey, J., Kim, H., Ryu, M., Scheetz, A., & Shapiro, D. (May 2022), Some College, No Credential Student Outcomes, Annual Progress Report - Academic Year 2020/21, Herndon, VA: National Student Clearinghouse Research Center.

factor that most distinguished those who advanced in the organization was the ability to think broadly and read and write clearly."[89] The communication skills that an engineer needs cannot be learned in a three-month bootcamp. The tech industry could benefit from a higher degree of stratification of computer science education programs. Much could also be done to improve and promote computer education, starting before college. There are also promising policies that could help develop and retain the current tech workforce.

Communities such as Hyderabad, India, from whence come so many H1-B visa applicants, demonstrate that social pressure on young people to become software engineers can increase the supply of tech workers. We do not imagine a large-scale shift in American culture in that direction, but only a small shift is needed among Americans who already are oriented towards getting an advanced degree. Some Americans who value education are unhappy with their job prospects after getting, for example, a doctoral degree in history. A marginal shift toward computer engineering within that group would shrink the skills gap. American adults are already more educated than they were two decades ago, and the trend indicates that more undergraduates are choosing computer science.[90]

The narrative of what it means to have a successful career needs to change to reflect where innovation is happening in society. More so than any prior technical revolution, the innovations in information technology are hard to understand; computer science is abstract and data often go unnoticed. Teachers, parents, and tech companies can all find ways to inform young people at an age-appropriate level about opportunities. A survey by Google indicates that young people who have some exposure to computer science through a class or camp are more likely to become CS majors in college.[91]

In addition to encouraging young students, company leaders can improve their recruitment and development strategies to reflect the labor market realities. To fill development teams with talented workers, companies need to pay enough to compensate employees for the mental challenges of demanding technical work.[92] Since workers in tech are frequently required to retrain, companies can help alleviate their own talent shortages by investing in training and education. Finally, tech companies may be able to access talent pools of women and minorities through better scheduling and management practices. The disparity in the attrition rates between men and women in tech indicate a workplace that is not accommodating to women. Mike Rowe might not consider work in the tech industry to represent a dirty job, but these jobs do carry with them unique difficulties and challenges that are underappreciated.

To attract more educated workers who might have traditionally gone into law or social science, employers can improve the way that they describe jobs and manage workers. Recruitment procedures need to change as quickly as technology changes. There could be advances in role matching

89 Norm Augustine, "The Education Our Economy Needs," *Wall Street Journal*, September 21, 2011, https://www.wsj.com/articles/SB10001424053111904265504576568351324914730.

90 US Census Bureau, "Number of People with Master's and Doctoral Degrees Doubles since 2000," February 21, 2019, https://www.census.gov/library/stories/2019/02/number-of-people-with-masters-and-phd-degrees-double-since-2000.html.

91 Google, *Women Who Choose Computer Science*. The evidence of early intervention is confounded by selection bias. However, the following statement from the nonprofit group Girls Who Code is encouraging: "Our alumni who have already declared their majors are choosing to major in CS, or related fields, at a rate 15 times the national average." Girls Who Code, "About Us," accessed August 3, 2020, https://girlswhocode.com/about-us/.

92 Buchanan demonstrates that a compensating differential is needed to pay workers who do not enjoy technical tasks like computer programming. Buchanan, "Willingness to Be Paid." Who Trains for Tech Jobs?

that result in faster hiring and lower rates of attrition. Otherwise, if recruiting in tech is an intractable problem, then we can expect the gap to persist, and companies will continue to recruit within tight, established social networks that tend to be less diverse.

In addition to recruiting, the management of tech projects is an area where innovation can improve retention of qualified workers. This emerges as one of the most cost-effective solutions from the analysis in this paper. A surprising number of workers in tech quit and cite management as the reason. If managers can find better ways to coordinate the efforts of teams, then tech jobs can be more flexible and less stressful. Companies that succeed in defining and dividing tech work should be able to reduce frustration for employees. Better pay and management will probably do more for the workforce than a huge push in education.[93] New strategies may emerge to deal with information flow, such as that suggested by Cal Newport.[94]

It is difficult to forecast the change in tech salaries. The need for tech services continues to grow. However, constant innovation that allows individual employees to become more productive counters that trend in unpredictable ways. The wages of tech workers will remain above overall median wages because most people do not train for these jobs.

To address the skills gap, employers can become more involved in education. Fourie et al. suggest academia collaborate with the private sector to ensure ongoing relevance of the hard skills being taught in academia.[95] The private sector acts on the cutting-edge of development to discover which skills are most in demand and necessary to remain competitive.

Steven Miller observes a talent shortfall in university, professional, and executive education programs designed to produce the talent needed to fill the growing demand in computer science.[96] Programs designed to teach big data, software development, and cybersecurity skills often do not produce graduates with the hard skills necessary for post-graduate employment. If a clear line of communication is established between firms and academia, then firms can communicate which skills are most needed to those who will teach those skills to the next generation of workers.[97] Miller recommends creating formal definitions of priority jobs (e.g., data scientists, big data architect, etc.), set minimum standards for data and analytic literacy for students, partner with industry organizations to create strong internship programs to increase student exposure to data science and experience, "and foster the creation of textbooks and courseware to address both literacy and specialized skills."[98]

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93 Consider that high school students in the United States all take math classes, so no one could argue that there is a lack of exposure, and yet very few go on to major in math in college.

94 Cal Newport, *A World without Email: Reimagining Work in an Age of Communication Overload* (New York: Penguin, 2021).

95 Leon Fourie, Shaoning Pang, Tamsin Kingston, Hinne Hettema, Paul Watters, and Hossein Sarrafzadeh, "The Global Cyber Security Workforce: An Ongoing Human Capital Crisis," in *2014 Global Business and Technology Association Conference* (Huntington Station, NY: GBATA, 2014), 173–84.

96 Steven Miller, "Collaborative Approaches Needed to Close the Big Data Skills Gap," *Journal of Organization Design* 3, no. 1 (2014): 26, https://doi.org/10.7146/jod.9823.

97 Partnerships have already been established in several fields. In cybersecurity, the National Security Agency (NSA) launched a cyber operation program at select universities to enhance the cyber security curriculum at those schools. The program trains students in the skills required by the NSA and other intelligence agencies to become successful cybersecurity analysts. In 2014, this program expanded to include 44 institutions and was designated the National Centers of Academic Excellence in Information Assurance and Cyber Defense.

98 Miller, "Collaborative Approaches Needed," 26.

Tech companies can expect that workers train in school for tech jobs, but there will always be a role for on-the-job learning. Tech companies can meet more of their talent needs by affording workers a good quality of life and investing in their skills after hiring them. Employers cannot fight the laws of supply and demand and should not expect large government subsidies in their pursuit of talent. There is no single simple solution to addressing the skills gap and enhancing the prospects of human workers. It certainly takes more than one coding bootcamp, whether subsidized or not, to develop a competitive tech workforce.