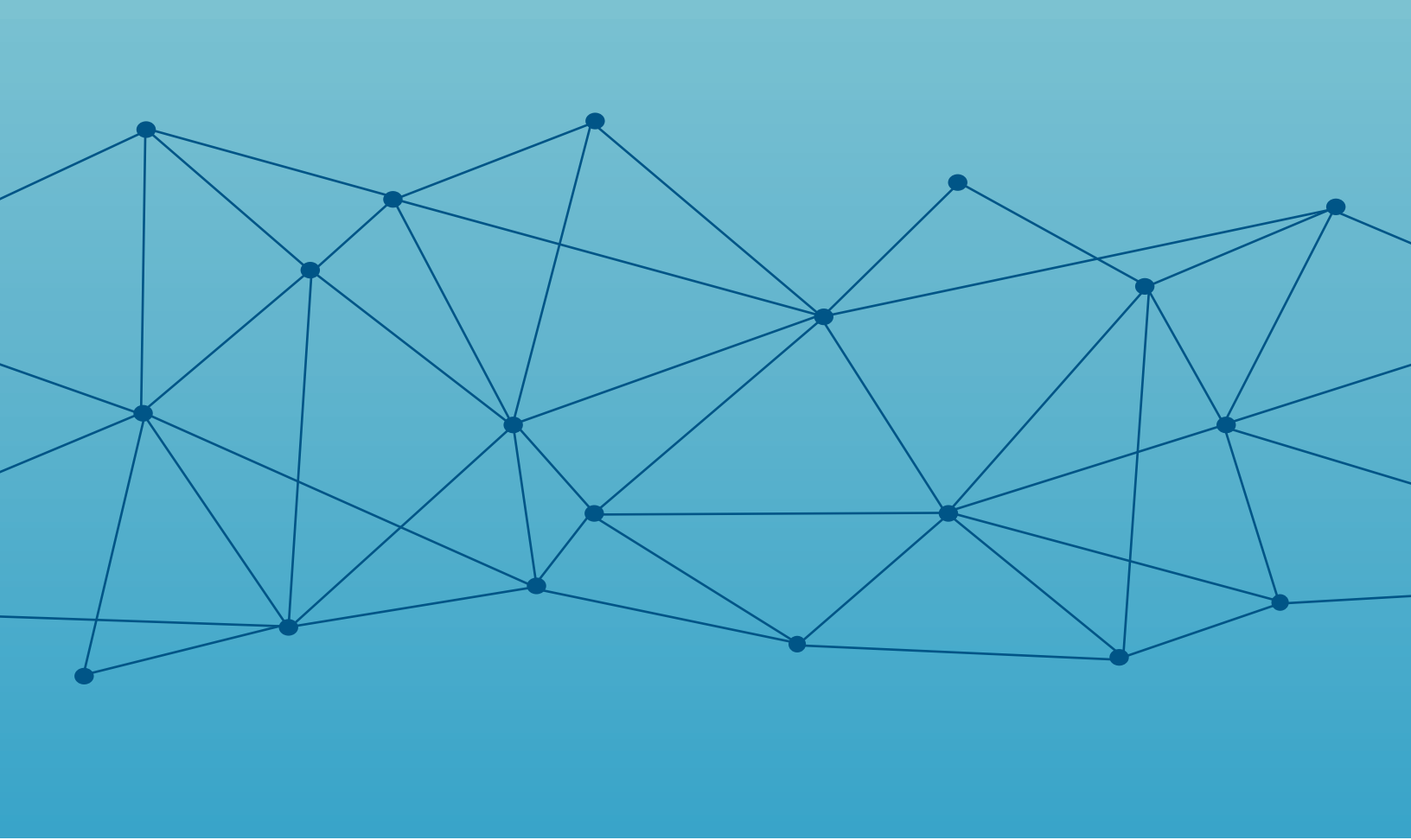


Automation and a Changing Economy

PART I: THE CASE FOR ACTION



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THE ASPEN INSTITUTE
FUTURE OF
WORK
INITIATIVE



About the Future of Work Initiative

The Aspen Institute Future of Work Initiative is a nonpartisan effort to identify concrete ways to address the challenges American workers and businesses face due to the changing nature of work in the 21st century. Established in 2015, the Initiative is driven by the leadership of Honorary Co-Chairs Senator Mark R. Warner and Purdue University President and former Governor of Indiana Mitch Daniels, and Co-Chairs John Bridgeland and Bruce Reed. Executive Director Alastair Fitzpayne leads an Aspen Institute staff, based in Washington, DC.

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Introduction

Technology fuels our economy, captures our collective imaginations, and promises extraordinary possibilities. It permeates almost all aspects of our lives. From electrification and the internal combustion engine, to search engines and smartphones, technology has changed how we travel, access information, buy products, and communicate with each other. As technology changes our personal lives, it also changes work. For generations, economic change has replaced products, jobs, and industries with innovative new models. The American economy has transitioned from agrarian to industrial, service to digital, and with each evolution, America has prospered even as it grappled with the profound challenges of change.

The American ideal embraces the promise that economic progress can create an inclusive society in which prosperity is broadly shared. Work is more than simply a way to earn a living. It gives structure, dignity, and purpose to our lives. For this reason, workers should not be treated as a cost of doing business but recognized for their productivity and creativity.

For too many Americans, the promise of work is not being kept. New technologies are creating great wealth for some, but we are simultaneously experiencing historic income and wealth inequality. Without robust policies and strong institutions, new innovations risk exacerbating the economic insecurity and political and civil divides that we are experiencing today.

Emerging technologies, including artificial intelligence, machine learning, and advanced robotics, have the potential to automate many tasks currently performed by workers. Historically, automation has been an important ingredient driving economic growth and progress. Automation has enabled us to feed a growing population while allowing workers to transition from subsistence farming to new forms of work. Automation helped move us from a craft system to mass production, from blue-collar to white-collar to “new-collar” work—with better work, higher wages, more jobs, and better living standards. Similar to past innovations, these new technologies offer the potential to help us meet human needs while supporting new jobs and industries never before imagined.

However, automation can also have negative effects on individuals and communities. Those who lose their jobs suffer economic, social, and psychological hardship. Communities that relied on single industries that have been automated have struggled to recover. New jobs are being created, but their geographic distribution and skill requirements often make them inaccessible to the individuals and the communities where those whose jobs were lost. This dislocation has played a role in exacerbating America’s economic, political, geographic, and social divides.

The answer to the dislocations that can result from automation should not be to stifle innovation. Policies and reforms should encourage both the development of new technologies and the promise of work. Workers need access to the opportunities technology creates. Policymakers and employers can help by providing access to skills training, ensuring the availability of good jobs, and improving the systems that are in place to help those who will transition from declining to growing occupations.

KEY TAKEAWAYS

- » Automation is an important ingredient driving economic growth and progress. Whether or not the benefits of automation are broadly shared will be dependent on the choices we make as a society.
- » Policies and institutions have played an important role in helping workers take advantage of the benefits of automation. However, without adequate support systems, automation can negatively impact many workers and communities.
- » To respond to the challenge and opportunity of automation, employers will need to lead with a human-centric approach to automation; workers will need access to skills training, good jobs, and new economic opportunities; communities will need targeted strategies to respond to the disruptive impact of automation; and new data systems are needed to help understand the impact and prepare for the changes automation will bring.

While there are many unanswered questions about what the future holds, this report attempts to explain how automation impacts the labor market and how to better prepare American workers to benefit from the changes to come.

The report is divided into two sections. Part I, *Automation and a Changing Economy: The Case for Action*, explores the history of automation and how it may impact the economic security and opportunity of the American worker in the future. This report reaches the following conclusions:

- » **While automation boosts economic growth, creates jobs, and improves living standards, it can also present serious challenges for workers and communities**, including job displacement, disruptions to local economies, changing skill needs, and rising inequality.
- » **Investments in education, training, and the social safety net, along with a social contract between employers and workers that provided workplace benefits and protections, have helped mitigate automation's negative impacts in the past** and helped workers succeed in the changing economy.
- » **Recent challenges highlight the consequences of limited supports for vulnerable workers.** Disinvestment in public and private sector training, a weakened public safety net, and reduced access to workplace benefits and protections have contributed to a slow and painful economic adjustment. Rising inequality and insecurity has left the country unprepared to weather future disruption.
- » **Artificial intelligence and other new technologies may lead to deeper, faster, broader, and more disruptive automation.** Automation need not be any more disruptive in the future than it has been in the past to warrant increased policy intervention, but action is particularly important because the U.S. economy could soon experience increased automation disruption.

Part II of this report, *Automation and a Changing Economy: Policies for Shared Prosperity*, outlines a program to address automation's challenges and opportunities. Success is achievable, but it requires an all-of-the-above approach, from targeted interventions to those with systems-level impact; from smaller place-based policies to reforms to national-level social safety net programs. While automation is one of the economic challenges facing American workers, potential solutions can address multiple problems including wage stagnation and income inequality.

Technology is not destiny—the impact of innovation on the American worker is mediated by policy choices and how institutions, such as employers, worker organizations, non-profits, and philanthropies respond to these challenges. By helping workers take advantage of new opportunities and assisting workers who are acutely impacted by automation return to stable work, we can promote greater opportunity and broadly shared prosperity for all.

Automation Increases Productivity and Boosts Job Growth—but Also Poses Challenges for Workers and Communities

Technological innovation should be embraced. Automation has been a largely positive economic and social force, and looking forward, automation will be necessary to feed, house, and raise the living standards of a growing and aging population.¹

But recent technological developments also have led to questions about automation's impact on workers. Recent studies projecting the disruptive potential of automation on the future workforce have yielded widely divergent results. It is therefore critical to begin any discussion of automation's future impact by looking at studies that have evaluated the actual impact of automation in the past.

WHAT IS AUTOMATION?

Automation generally refers to the use of technology to reduce the level of human activity needed to complete a particular task by replacing or augmenting labor. Key to this concept is that the task itself is still being performed, but with less human labor required as an input. Because automation occurs at the task level, it often changes jobs partially rather than eliminates them, though in limited cases, technology can automate an entire job.

Automation isn't the only way technology disrupts work. It also can reduce the need for certain types of work to be performed at all. For example, the economy lost 32,000 typewriter repair jobs between 1970 and 2015 not because a robot was created to repair typewriters, but because typewriters became obsolete.²

Technology also can change entire business structures, leading to automation as well as other impacts. For example, as more information becomes digitized and business activity shifts to the internet, online shopping platforms (e.g. Amazon) have become increasingly popular and have led to certain tasks being automated, such as order intake and customer checkout. But online shopping platforms also have had enormous effects on retail's entire business structure, shifting work away from brick and mortar stores and toward warehouses, delivery, and information technology. Physical stores require many tasks that online stores do not need, such as cleaning and security.

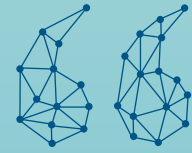
¹ For example, the United Nations Development Programme notes that "Limiting climate change requires a major shift in investment patterns towards low-carbon, climate-resilient development, including infrastructure estimated to cost US\$4 trillion a year until 2030." <http://www.sdfinance.undp.org/content/sdfinance/en/home/sdg/goal-13--climate-action.html>

² Manyika et al. 2017. "Jobs Lost, Jobs Gained." McKinsey Global Institute. <https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages>.

Overall, it is difficult to anticipate every disruptive impact technology can have. But the use of technology to automate work is easier to predict than other impacts because automation is based on machines doing currently identifiable tasks. For that reason, automation is the lens technologists, academics, and others use to project technology's future impact on work, with the understanding that the actual disruptive impact of technology could be broader and more unpredictable. Accordingly, this paper largely focuses on disruption from automation.

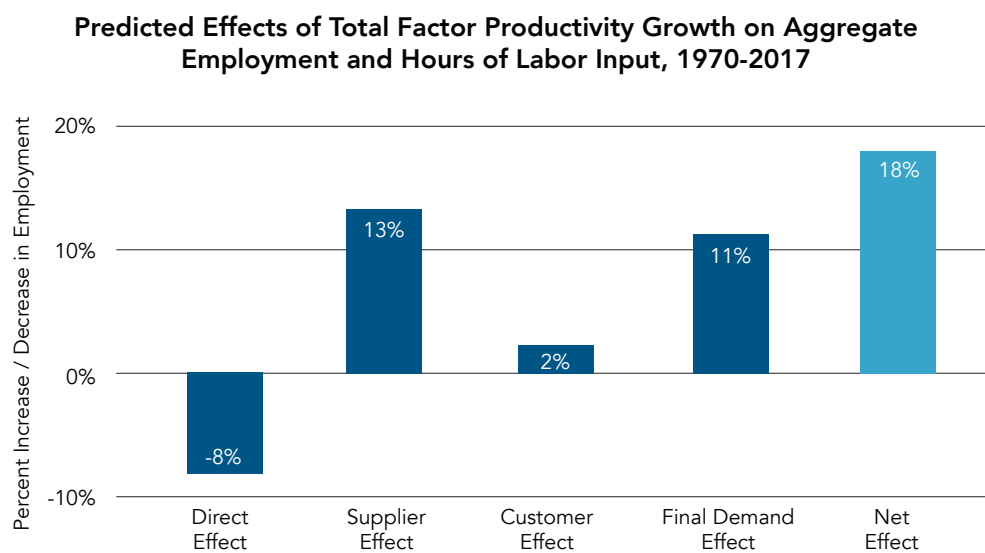
Historically, automation has created more jobs—directly and indirectly—than it has destroyed. By reducing the amount of human labor needed to complete particular tasks, automation increases labor productivity. Tasks cost less to perform, so the price for goods and services goes down. This can increase demand for those goods and services, free up income to be spent on other goods and services, and free up labor to be put to work on other productive tasks. Further, automation can create new tasks and jobs in industries that didn't previously exist.

The net impact of these forces has proven positive over the long-term. Studying data from 28 industries across 19 countries (Figure A),³ David Autor and Anna Salomons found that the net effects of total factor productivity growth, of which automation is a significant component, amounted to an 18 percent increase in overall employment from 1970 through 2007. As an example, the McKinsey Global Institute found that personal computers created nearly 16 million new jobs in the U.S. since 1970, despite displacing nearly 4 million jobs. Demand for typists, accountants, and secretaries declined due to word-processing and accounting software. But these declines were more than offset by new jobs in computer manufacturing and supplier industries, computer science and information technology, and e-commerce.⁴



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Figure A: Automation Creates Jobs, Even as Direct Industry May Lose Jobs



Source: Autor and Salomons. 2018. "Is automation labor-displacing?" Brookings Papers on Economic Activity. <https://www.brookings.edu/bpea-articles/is-automation-labor-displacing-productivity-growth-employment-and-the-labor-share/>.

³ Autor and Salomons. 2018. "Is automation labor-displacing?" Brookings Papers on Economic Activity. <https://www.brookings.edu/bpea-articles/is-automation-labor-displacing-productivity-growth-employment-and-the-labor-share/>.

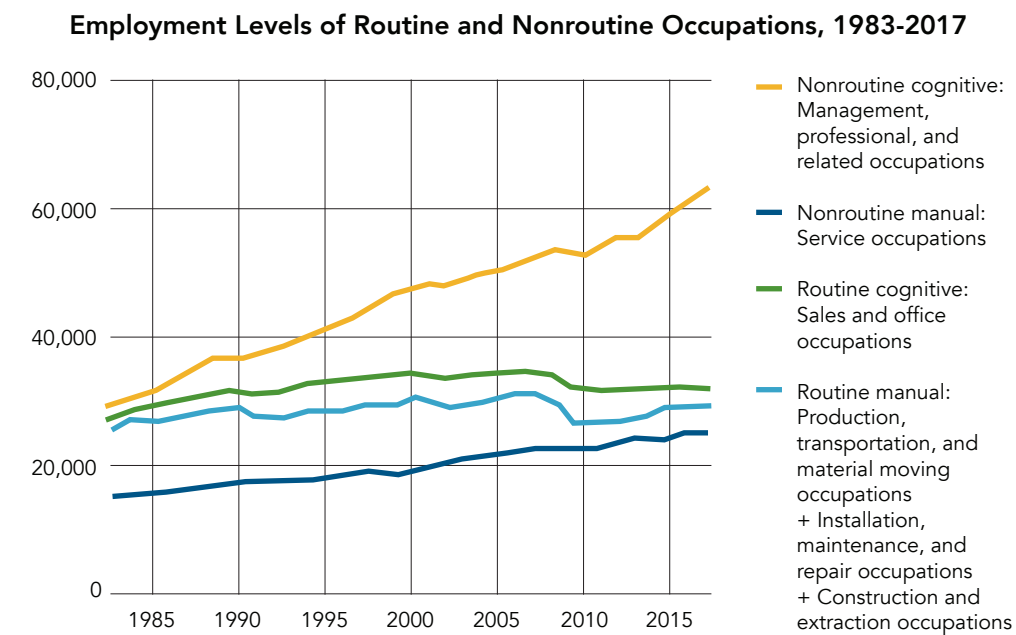
⁴ Manyika et al. 2017. "Jobs Lost, Jobs Gained." McKinsey Global Institute. <https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages>.

While it is important to note that automation’s overall, long-run effect on the economy has been positive—more jobs, more growth, higher living standards—this does not negate the disruptive impact of automation on individuals and communities, which results from displacements, changing skill needs, and income inequality.

Some Workers Will Be Displaced

Technology has and will continue to replace human labor with machine labor, causing the composition of jobs and tasks to change as some are eliminated and others are created. The jobs that appear most vulnerable are those that involve routine cognitive and manual tasks: repetitive, predictable activities like operating machinery, preparing fast food, and collecting and processing data. This is not a new trend. While employment in nonroutine cognitive and manual jobs has grown steadily since the 1980s, employment in routine jobs has remained flat despite a growing workforce (Figure B).⁵

Figure B: Nonroutine Jobs Growing While Routine Jobs (Both Cognitive and Manual) Remain Flat⁶



Source: Author’s analysis of Employment Level data, U.S. Bureau of Labor Statistics. Retrieved from Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/graph/?g=43U0#0>.

The McKinsey study estimates that up to 32 percent of workers may need to transition to entirely different occupations by 2030 as a result of automation.⁷ Most susceptible will be jobs performed in predictable physical environments (such as factory work, material moving machine operation, transportation, installation and repair, dishwashing, and food preparation).⁸ Declining occupations will also include those in customer interaction

⁵ Dvorkin. 2016. “Jobs Involving Routine Tasks Aren’t Growing.” Federal Reserve Bank of St. Louis. <https://www.stlouisfed.org/on-the-economy/2016/january/jobs-involving-routine-tasks-arent-growing>.

⁶ Ibid.

⁷ Manyika et al. 2017. “Jobs Lost, Jobs Gained.” McKinsey Global Institute. <https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages>.

⁸ Ibid.

(such as hotel workers, travel agents, and cafeteria workers), and office support (such as payroll processors and administrative assistants). Even occupations like commercial vehicle driving could eventually be automated—a recent analysis found that autonomous vehicle technology could eliminate between 1.3 and 2.3 million driving jobs over the next 30 years.⁹

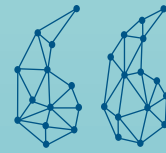
Displacements like these cause significant economic and social challenges for workers and for the communities in which they live. Displaced workers¹⁰ can experience long unemployment spells and significant earnings losses. According to a study by Henry Farber, on average, displaced workers who lose full-time jobs experience a 35 percent loss in earnings, largely due to unemployment or working fewer hours. Moreover, the longer they held their prior job, the greater the fall in earnings. On average, displaced workers with over 20 years of experience had a 10 percent greater earnings loss than those with one to three years of tenure.¹¹

These earnings losses can persist far into the future. Looking at mass layoff events from the early 1980s, Till Von Wachter, Jae Song, and Joyce Manchester found that people who had worked at least three years before becoming displaced had immediate losses of 30 percent in annual earnings compared to those who were not displaced. Earnings remained 15 to 20 percent lower 20 years later.¹² There is also evidence that displaced workers' earnings losses have increased since the mid-1990s.¹³

On top of reduced earnings, displaced workers also face increased job and earnings instability, with recurring spells of unemployment and more occupation and industry switches.¹⁴

But displacements do not just cause financial stress, they also contribute to significant non-monetary challenges. Research suggests that displaced workers face higher mortality rates and reduced life expectancy. Parental job loss and displacement have been linked to reduced educational achievement and cognitive development in children. Further, layoffs have been associated with lower rates of home ownership, increased incidence of divorce, and higher rates of entering disability insurance programs.¹⁵

Automation's disruptive impact is not limited to the individuals and families who are directly affected. In communities with large shares of impacted jobs, disruptions can spill over into other industries within a regional economy as income and aggregate demand falls, depressing the entire economic ecosystem. For instance, analyzing data from 1990 through 2007, Daron Acemoglu and Pascual Restrepo found that the use of industrial robots to automate manufacturing work resulted in significant, local jobs and earnings losses including beyond the industry being automated.¹⁶ For every additional industrial robot introduced into a local labor market, on average, 6.2 workers in that



In communities with large shares of impacted jobs, disruptions can spill over into other industries within a regional economy as income and aggregate demand falls, depressing the entire economic ecosystem.

9 Groshen et al. 2018. "Preparing U.S. Workers and Employers for an Autonomous Vehicle Future." Securing America's Future Energy. <https://aworkforce.secureenergy.org/wp-content/uploads/2018/06/Groshen-et-al-Report-June-2018-1.pdf>.

10 Displaced workers are those whose jobs were lost because of a plant closure, their position was eliminated, the business had insufficient work, or other similar reasons. This population—and in particular displaced workers who had long-tenure (i.e. greater than 3 years) in their job—has been shown to experience significant challenges that even differ from those experienced by other job losers.

11 Farber. 2017. "Employment, Hours, and Earnings Consequences of Job Loss." *Journal of Labor Economics*. <https://www.journals.uchicago.edu/doi/10.1086/692353>.

12 Von Wachter, Song, and Manchester. 2011. "Long-Term Earnings Losses due to Mass Layoffs During the 1982 Recession." Columbia University.

13 Farber. 2010. "Job Loss and the Decline in Job Security in the United States." In *Labor in the New Economy*. <https://www.nber.org/chapters/c10822.pdf>.

14 Davis and von Wachter. 2011. "Recessions and the Costs of Job Loss." *Brookings Papers on Economic Activity*. <https://www.brookings.edu/bpea-articles/recessions-and-the-costs-of-job-loss/>.

15 For a review of the relevant literature on these and other findings, see: Davis and von Wachter. 2011. "Recessions and the Costs of Job Loss." *Brookings Papers on Economic Activity*. <https://www.brookings.edu/bpea-articles/recessions-and-the-costs-of-job-loss/>.

16 Acemoglu and Restrepo. 2017. "Robots and Jobs." National Bureau of Economic Research. <http://www.nber.org/papers/w23285>.

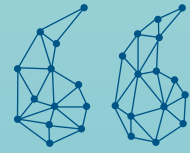
labor market lost their jobs. These losses include both direct factory job losses as well as indirect losses elsewhere, particularly in the construction, business services, wholesale, service, and retail industries. As a comparison, a recent study from George Borjas and Richard Freeman estimates that each industrial robot reduces employment and wages within the industry being automated by two to four workers.¹⁷

Many Jobs Will Change, and Workers Will Need to Adjust

While automation will eliminate some jobs, many more will change. Every job is made up of a series of different tasks, and as some tasks become automated, workers will instead be relied on to perform different ones. As with job loss, the tasks most vulnerable to automation are routine cognitive and physical tasks, while the least vulnerable are nonroutine, requiring core skills that are difficult to automate, such as critical thinking, social skills, management, decision making, planning, and innovation. The World Economic Forum estimates that more than 40 percent of the core skills required in 2022 will be different than those required in 2018.¹⁸ Nursing and medical and home health support, which are projected to be among the fastest growing occupations over the next decade¹⁹ are good examples of jobs with tasks that are difficult to automate because they involve large amounts of social and emotional interaction.

Humans will retain a competitive advantage over machines in nonroutine tasks for the foreseeable future. Ironically, automation may result in tomorrow's jobs being more "human." For example, with the introduction of self-service kiosks, workers who used to work behind a cash register are now expected to be more customer-facing, requiring more social skills and knowledge.²⁰ Similarly, when Electrolux, the world's second-largest manufacturer of home appliances, automated its production process, it asked its workers to focus on the creative task of designing and implementing changes to the factory floor and robot layout to maximize efficiency.²¹ Artificial intelligence can now be used to audit expense reports, freeing up auditors to conduct deeper investigations into questionable expenses and to educate workers about expense policies.²²

Automation also augments labor, helping humans do their jobs more effectively, efficiently, and productively. As automating technologies are adopted, workers will increasingly work alongside machines. To interact with new technologies, more workers will need technological and digital skills, ranging from basic digital literacy to advanced computer science. The Brookings Institution created a digitalization index to measure changes in the digital content of 545 occupations, which employ 90 percent of the workforce; it found that jobs are increasingly requiring digital skills, with the average digitalization index across all occupations rising 57 percent between 2002 and 2016 (Figure C).²³ Bartel, Ichinowski, and Shaw studied firms in the valve manufacturing



While automation will eliminate some jobs, many more will change. Every job is made up of a series of different tasks, and as some tasks become automated, workers will instead be relied on to perform different ones.

17 Borjas and Freeman. 2019. "From Immigrants to Robots." National Bureau of Economic Research. <https://www.nber.org/papers/w25438>.

18 World Economic Forum. 2018. "The Future of Jobs Report." <https://www.weforum.org/reports/the-future-of-jobs-report-2018>.

19 Bureau of Labor Statistics. 2018. "Fastest Growing Occupations." <https://www.bls.gov/ooh/fastest-growing.htm>.

20 D'Innocenzio. 2018. "Retail workers' jobs are transforming as shoppers' habits change." Chicago Tribune. <http://www.chicagotribune.com/business/ct-biz-retail-workers-tech-shoppers-habits-20180108-story.html>.

21 Wilkes. 2018. "How the World's Biggest Companies Are Fine-Tuning the Robot Revolution." *Wall Street Journal*. <https://www.wsj.com/articles/how-the-worlds-biggest-companies-are-fine-tuning-the-robot-revolution-1526307839>.

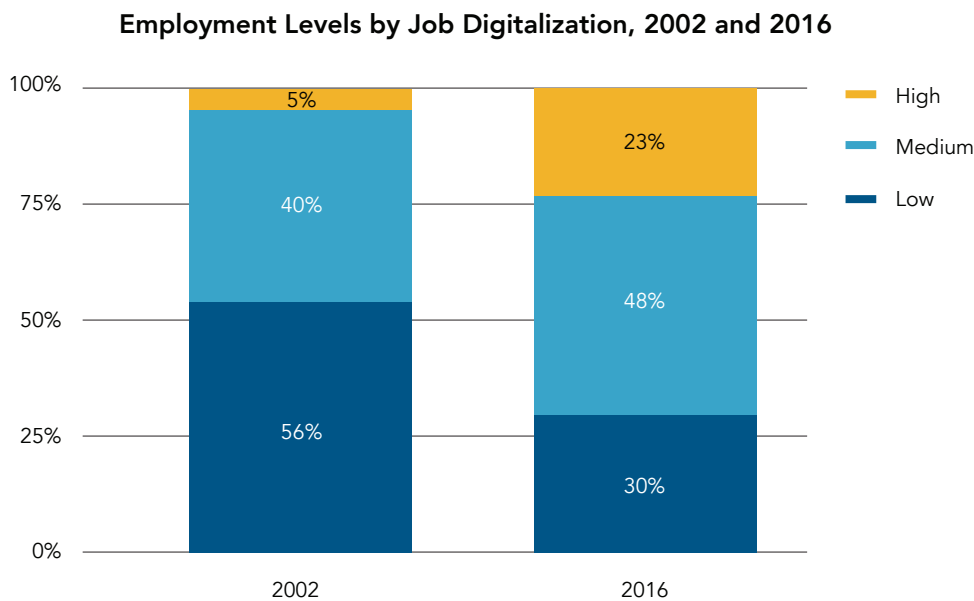
22 Loten. 2019. "AI Tool Helps Companies Detect Expense Account Fraud." *Wall Street Journal*. <https://www.wsj.com/articles/ai-tool-helps-companies-detect-expense-account-fraud-11551175200>.

23 The Brookings report on digitalization in the workforce provides examples, including nurses who now use portable vein finders for blood tests, auto mechanics who employ laptops to troubleshoot cars, and salespeople who use cloud-based, artificially intelligent software agents like Siri and Alexa to schedule meetings.

Muro et al. 2017. "Digitalization and the American workforce." Brookings Institution. <https://www.brookings.edu/research/digitalization-and-the-american-workforce/>.

industry, and showed that adoption of new IT-enhanced capital equipment coincided with increased skill requirements of machine operators, including technical and problem solving skills.²⁴ The McKinsey Global Institute projects that the largest growth in labor demand will be for technological skills, rising 55 percent by 2030 to represent 17 percent of hours worked, up from 11 percent today.²⁵

Figure C: Jobs Increasingly Require Digital Skills



Source: Muro et al. 2017. "Digitalization and the American workforce." Brookings Institution. <https://www.brookings.edu/research/digitalization-and-the-american-workforce/>.

Automation Changes the Distribution of Jobs and Income—Which Can Exacerbate Economic Inequalities

Automation can also impact workers by changing the wage and skills distributions of jobs. In the past, this effect contributed to rising income inequalities. Current research about the jobs most at risk of disruption indicates that existing inequalities could widen.

Over the past half century, automation has tended to displace middle-skill jobs because they involve a greater share of routine physical and cognitive tasks compared to high- and low-skill jobs whose tasks were more often nonroutine.^{26 27} This effect has been occurring across many countries (Figure D).

24 Bartel, Ichniowski, and Shaw. 2007. "How Does Information Technology Affect Productivity?" *The Quarterly Journal of Economics*. <https://academic.oup.com/qje/article-abstract/122/4/1721/1850517>.

25 Bughin et al. 2018. "Skill Shift." McKinsey Global Institute. <https://www.mckinsey.com/featured-insights/future-of-work/skill-shift-automation-and-the-future-of-the-workforce>.

26 Autor, Levy, and Murnane. 2003. "The Skill-Content of Recent Technological Change." *The Quarterly Journal of Economics*. <https://economics.mit.edu/files/11574>.

Autor, Katz, and Kearney. 2008. "Trends in U.S. Wage Inequality." *Review of Economics and Statistics*. <https://www.mitpressjournals.org/doi/abs/10.1162/rest.90.2.300>.

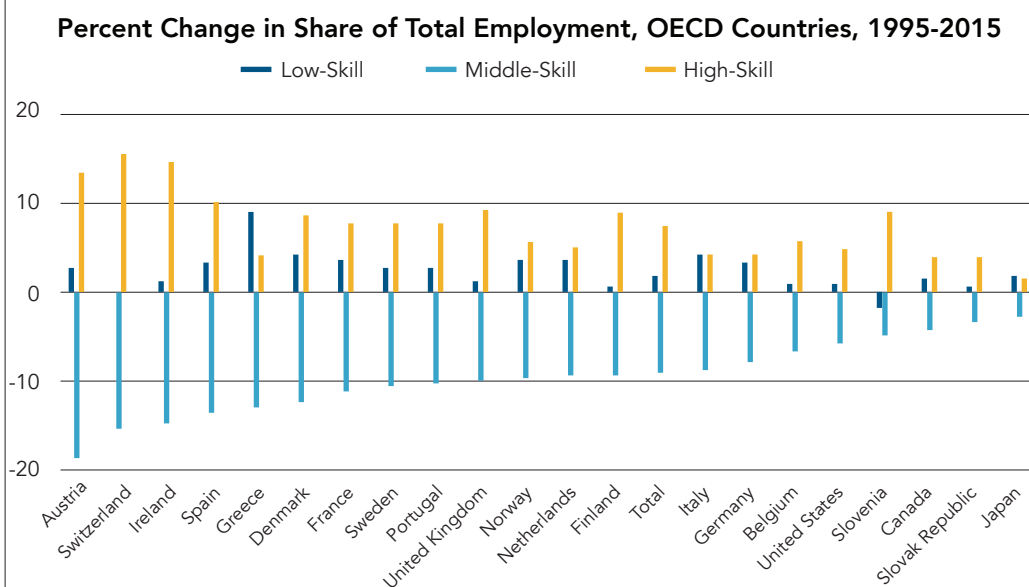
Autor, Katz, and Kearney. 2006. "The Polarization of the U.S. Labor Market." National Bureau of Economic Research. <https://www.nber.org/papers/w11986>.

Goos and Manning. 2007. "Lousy and Lovely Jobs." *Review of Economics and Statistics*. <https://www.mitpressjournals.org/doi/10.1162/rest.89.1.118>

Autor and Dorn. 2013. "The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market." *The American Economic Review*. <http://www.jstor.org/stable/42920623>.

27 In a recent paper, MIT's Frank Levy explains this hollowing-out effect as due to middle-skill jobs including a greater share of easily-automatable tasks: "Automation of the lowest wage jobs is hard because these jobs require unstructured physical activity and unstructured social interaction. Automation of the highest wage jobs is hard because these jobs (including many of the jobs AI creates) require unstructured cognitive activity and unstructured social interaction. Automation's impact is relatively larger in mid-wage, mid-skilled occupations because they involve relatively higher levels of structured physical and/or cognitive tasks." Levy. 2018. "Computers and Populism." MIT. <https://ssrn.com/abstract=3091867>.

Figure D: Middle-Skill Jobs Have Declined As a Share of Total Employment Across Many Countries, with Increasing Shares of High- and Low-Skill Jobs²⁸



Source: OECD. 2017. "Job polarisation by country." In *OECD Employment Outlook 2017*. https://www.oecd-ilibrary.org/employment/oecd-employment-outlook-2017/job-polarisation-by-country_empl_outlook-2017-graph39-en.

In 1979, middle-skill occupations accounted for 60 percent of U.S. employment. By 2007, this percentage fell to 49 percent, and to 46 percent by 2012. Over the same period, both high- and low-skilled occupations saw rapid growth.²⁹ This polarization contributed to rising inequality and the hollowing out of the middle class.³⁰ Many highly-educated workers moved from middle-skill to higher-skill jobs. For non-college educated workers, the shift was almost exclusively from middle-skill to low-skill work. In 1980, nearly the same percentage of non-college workers held low-skill (42 percent) and middle-skill jobs (43 percent). By 2016, almost twice as many were in low-skill (54 percent) compared to middle-skill work (29 percent). There was only a slight increase in the share of non-college workers in high-skill jobs (15.4 to 16.8 percent).³¹

Some middle-skill jobs have been replaced with low-skill jobs in the same industry, representing a deskilling of the occupation. For example, the introduction of Henry Ford's assembly line in the early 20th century led to the decline of the skilled craftsman and a rise in deskilled or unskilled specialized work.³² In a more modern example, a recent Barclays report notes that "the introduction of rear-view cameras, cruise control, automatic braking technology and radar all made it easier to drive a long-haul truck."³³

But automation also causes jobs to be upskilled, as workers increasingly interact with new technology. For example, office and administrative workers must now interact with

28 There is no universally accepted definition of "middle-skill jobs." A common definition is those that require more than a high school education but less than a college degree—for example, see Holzer and Lerman (2009). However, different studies and data sources rely on different definitions. For instance, the OECD study from which Figure D looks at jobs in ISCO-88 major categories 4 (clerks), 7 (craft and related trade workers), and 8 (plant and machine operators and assemblers).
Holzer and Lerman. 2009. "The Future of Middle-Skill Jobs." Brookings Institution. https://www.brookings.edu/wp-content/uploads/2016/06/02_middle_skill_jobs_holzer.pdf.
OECD. 2017. "OECD Employment Outlook 2017."

29 Autor. 2015. "Why Are There Still So Many Jobs?" *Journal of Economic Perspectives*. <https://economics.mit.edu/files/11563>.

30 Acemoglu and Autor. 2011. "Skills, Tasks and Technologies." *Handbook of Labor Economics*. <http://economics.mit.edu/files/5571>.

31 Autor. 2019. "Work of the Past, Work of the Future." National Bureau of Economic Research. <https://economics.mit.edu/files/16724?mod=djemCIO>.

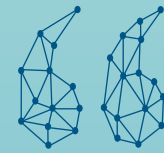
32 Meyer. 2004. "The Degradation of Work Revisited." *Automobile in American Life and Society*, University of Michigan. http://www.autolife.umd.umich.edu/Labor/L_Overview/L_Overview3.htm.

33 Barclays. 2018. "Robots at the Gate." <https://www.investmentbank.barclays.com/our-insights/robots-at-the-gate.html>.

computers and a variety of complex software systems, while a recent Deloitte study found that manufacturing jobs are increasingly relying on digital skills, robot programming, and critical thinking.³⁴

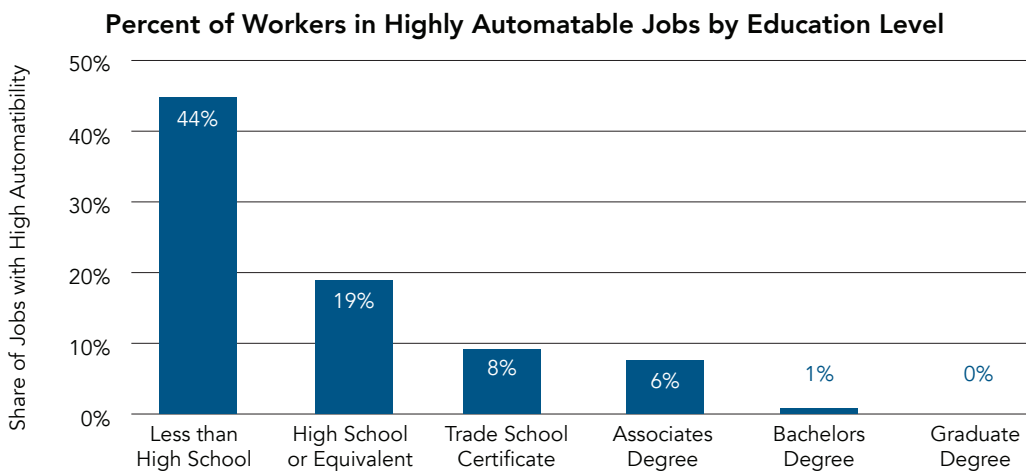
Which jobs are most at risk of automation going forward is more complex. Some research suggests the dramatic reduction in middle-skill occupations leveled off around 2000.³⁵ Others argue there are more middle-skill jobs today than workers to fill them.³⁶ There are also examples of higher-skill occupations which could soon be impacted by automation—such as the law³⁷ and hedge fund management.³⁸ Employers understandably have more incentive to automate positions that offer the highest cost savings.

Low-skill jobs, however, do appear to be at greatest risk of automation. Historically, these jobs have been less vulnerable due to the nonroutine physical and social activities that they entail, such as janitorial work. But new developments in artificial intelligence and robotics could lead to low-skill jobs being increasingly at risk of automation. For instance, a recent study³⁹ found that computer automation increases demand for high-skilled workers at the expense of low-skilled workers, and OECD researchers⁴⁰ recently found that 44 percent of workers with less than a high school degree are in jobs that are highly automatable, compared to less than 1 percent of jobs held by workers with a college degree (Figure E). Because low-skill jobs tend to be low-paying, those who are already the most economically vulnerable also face greater risk of seeing change in their jobs or facing displacements.



New developments in artificial intelligence and robotics could lead to low-skill jobs being increasingly at risk of automation.

Figure E: Workers with Less Education More Likely to Hold Automatable Jobs



Calculations based on the Survey of Adult Skills (PIAAC) 2012.

Source: Arntz, Gregory, and Zierahn. 2016. "The Risk of Automation for Jobs in OECD Countries." OECD Social, Employment and Migration Working Papers. https://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jz9h56dvq7-en.

34 Deloitte and The Manufacturing Institute. 2018. "2018 Skills Gap in Manufacturing Study." <https://www2.deloitte.com/us/en/pages/manufacturing/articles/future-of-manufacturing-skills-gap-study.html>.

35 Mishel, Schmitt, and Shierholz. 2013. "Assessing the job polarization explanation of growing wage inequality." Economic Policy Institute <https://www.epi.org/publication/wp295-assessing-job-polarization-explanation-wage-inequality/>.

36 National Skills Coalition. 2017. "United States' Forgotten Middle." <https://www.nationalskillscoalition.org/resources/publications/2017-middle-skills-fact-sheets/file/United-States-MiddleSkills.pdf>.

37 Dwoskin. 2017. "This Silicon Valley start-up wants to replace lawyers with robots." *Washington Post*. <https://www.washingtonpost.com/news/innovations/wp/2017/09/14/this-silicon-valley-startup-wants-to-replace-lawyers-with-robots/>.

38 *The Economist*. 2017. "Hedge funds embrace machine learning—up to a point." <https://www.economist.com/finance-and-economics/2017/12/09/hedge-funds-embrace-machine-learning-up-to-a-point>.

39 Bessen. 2016. "How computer automation affects occupations." Centre for Economic Policy Research. <https://voxeu.org/article/how-computer-automation-affects-occupations>.

40 Arntz, Gregory, and Zierahn. 2016. "The Risk of Automation for Jobs in OECD Countries." OECD Social, Employment and Migration Working Papers. https://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5jz9h56dvq7-en.

These changes can also exacerbate other inequalities, such as racial or gender wage disparities. Several recent studies show how jobs at highest risk of automation are disproportionately held by workers from traditionally marginalized populations.⁴¹ A recent study by the Joint Center for Political and Economic Studies found that larger shares of Latino (31 percent) and African American (27 percent) workers are employed in the 30 jobs identified as being at highest risk of automation, particularly cooking, cashiering, and food preparation, than are White (24 percent) or Asian American (20 percent) workers.⁴²

Similarly, a recent study by the Brookings Institution found that Hispanic, Native American, and African American workers on-average perform higher shares of automatable tasks (47, 45, and 44 percent, respectively) than do white (40 percent) and Asian American (39 percent) workers.⁴³ A McKinsey study shows that African American workers are more likely to be employed in “support” roles, such as administrative support, laborers, helpers, operatives, and service workers. These roles tend to be at a high risk of automation: 53 percent of time spent in support roles is potentially automatable. In contrast, African Americans are underrepresented in “directive” roles like executives, managers, professionals, craft workers, sales workers, and technicians, which are more resistant to automation.⁴⁴

Studies of jobs in Phoenix⁴⁵ and Indianapolis⁴⁶ show that women in certain markets may be more likely than men to be employed in jobs at highest risk of automation, such as cashier, office clerk, secretarial and administrative positions. The studies demonstrate how local or regional occupational mix affects how impacts are distributed within a given market.⁴⁷

A recent study by Source America shows that workers with disabilities are, on average, more likely to be employed in jobs at high risk of automation, such as in grounds and building maintenance, food service, retail, warehousing, and administrative work.⁴⁸

The Brookings Institution study examines several other potential impact disparities. It found that workers between the ages of 16 and 24 face a notably high average automation exposure due to their dramatic overrepresentation in automatable jobs, such as those in the food services.⁴⁹ The study also found that automation risk varies across U.S. regions, states, and cities. For example, the “American Heartland” states, which have a longstanding and continued specialization in the manufacturing and agricultural industries, are expected to face heightened automation risk.⁵⁰ This finding

41 These studies largely use data developed by Oxford researchers about the automation potential for hundreds of occupations. Frey and Osborne. 2013. “The Future of Employment” University of Oxford. https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.

42 Broady. 2017. “Race and Jobs at High Risk to Automation.” Joint Center for Political and Economic Studies. <https://jointcenter.org/blog/race-jobs-high-risk-automation>.

43 Muro, Maxim, and Whiton. 2019. “Automation and Artificial Intelligence.” Brookings Institution. <https://www.brookings.edu/research/automation-and-artificial-intelligence-how-machines-affect-people-and-places/>.

44 Baboolall et al. 2018. “Automation and the future of the African American workforce.” McKinsey & Company. <https://www.mckinsey.com/featured-insights/future-of-work/automation-and-the-future-of-the-african-american-workforce>.

45 Kinder. 2018. “Automation Potential for Jobs in Phoenix.” New America. <https://www.newamerica.org/work-workers-technology/reports/automation-potential-jobs-phoenix/>.

46 Kinder. 2018. “Automation Potential for Jobs in Indianapolis.” New America. <https://www.newamerica.org/work-workers-technology/reports/automation-potential-jobs-indianapolis/>.

47 A recent Brookings Institution study suggests that men may be slightly more exposed than women nationally, due to over-representation in manufacturing, construction, and transport industries.

Muro, Maxim, and Whiton. 2019. “Automation and Artificial Intelligence.” Brookings Institution. <https://www.brookings.edu/research/automation-and-artificial-intelligence-how-machines-affect-people-and-places/>.

48 Kanady. 2018. “The Future of Work and the Disability Community.” SourceAmerica. <https://www.sourceamerica.org/future-of-work>.

49 Muro, Maxim, and Whiton. 2019. “Automation and Artificial Intelligence.” Brookings Institution. <https://www.brookings.edu/research/automation-and-artificial-intelligence-how-machines-affect-people-and-places/>.

50 Ibid.

is supported by other research, which shows smaller cities at greater risk of automation disruption than larger cities, in part because larger cities have greater shares of difficult-to-automate technical and managerial professions.⁵¹

Automation Can Deliver Higher Returns to Capital Rather than Labor

Since the early 2000s, labor's share of the U.S. national income—the share of GDP paid in the form of wages, benefits, and other compensation—has declined 3.5 percentage points, as capital's share of income has grown. The result has been rising inequality as the gains from growth accrue more to capital owners (who tend to be higher income) and less to workers.⁵² Multiple studies have attributed much of the decline to technological advances and automation.⁵³

Economists Loukas Karabarbounis and Brent Neiman argue that the rapid pace at which communication and information technologies have improved and become cheaper, such as the availability of cheap and exceedingly fast computer microprocessors, have induced employers to automate and adopt a more capital-intensive production approach. The relative price of investment has fallen 25 percent since 1975, which they find accounts for about half of the 5 percentage point decline in labor's share of income globally.⁵⁴ Researchers at the International Monetary Fund found that automation of routine tasks contributed 44 to 57 percent of the decline in labor share within U.S. sectors and states.⁵⁵ Economists David Autor and Anna Salomons recently found that not only did total factor productivity growth reduce labor's share of national income—as mentioned earlier in this section—but that this effect grew over time and was most pronounced in the 2000s.⁵⁶ Implicit in these findings is that technology today is advancing more quickly than it did in prior generations, lowering the cost of automation while increasing its returns—thereby contributing to structural changes in the labor share.

51 Frank et al. 2018. "Small cities face greater impact from automation." *Journal of the Royal Society Interface*. <https://royalsocietypublishing.org/doi/full/10.1098/rsif.2017.0946>.

52 Abdih and Danninger. 2017. "What Explains the Decline of the U.S. Labor Share of Income?" International Monetary Fund. <https://www.imf.org/en/Publications/WP/Issues/2017/07/24/What-Explains-the-Divide-of-the-U-S-45086>.

53 Santacreu and Zhu. 2017. "How Income Inequality Is Affected by Labor Share." Federal Reserve Bank of St. Louis. <https://www.stlouisfed.org/on-the-economy/2017/july/income-inequality-affected-labor-share>.
Abdih and Danninger. 2017. "What Explains the Decline of the U.S. Labor Share of Income?" International Monetary Fund. <https://www.imf.org/en/Publications/WP/Issues/2017/07/24/What-Explains-the-Divide-of-the-U-S-45086>.
Karabarbounis and Neiman. 2013. "The Global Decline of the Labor Share." National Bureau of Economic Research. <https://www.nber.org/papers/w19136>.

54 Karabarbounis and Neiman. 2013. "The Global Decline of the Labor Share." National Bureau of Economic Research. <https://www.nber.org/papers/w19136>.

55 Abdih and Danninger. 2017. "What Explains the Decline of the U.S. Labor Share of Income?" International Monetary Fund. <https://www.imf.org/en/Publications/WP/Issues/2017/07/24/What-Explains-the-Divide-of-the-U-S-45086>.

56 Autor and Salomons. 2018. "Is automation labor-displacing?" *Brookings Papers on Economic Activity*. <https://www.brookings.edu/bpea-articles/is-automation-labor-displacing-productivity-growth-employment-and-the-labor-share/>.

Historically, the Negative Impacts of Technological Disruption Have Been Mediated by Investments in Education, the Safety Net, and a Strong Social Contract

The U.S. has a long history of new technologies disrupting the labor market, contributing to large structural changes, but has avoided many of the dire scenarios that some contemporaneous experts and policymakers predicted. Though some might conclude that the lesson from history is to not worry about future disruption, that would be the wrong lens with which to look at the past. Historically, the severity of automation's disruptive impacts—displacements, changing skill needs, and widening inequality—have been mitigated by policy interventions to help workers transition. Federal, state and local investments in education and worker training, expansions of the social safety net, and a strong social contract between employers and workers that provided workplace benefits and protections helped ensure the benefits of progress were more broadly shared. Similar policy interventions are needed now.

Automation's Role in Large-Scale Industry and Occupational Shifts

The jobs in today's economy look very different from those of previous generations. The relative shares of employment in various industries and occupations has shifted significantly and continuously throughout U.S. history, as some grow, others decline, and even more change over time.

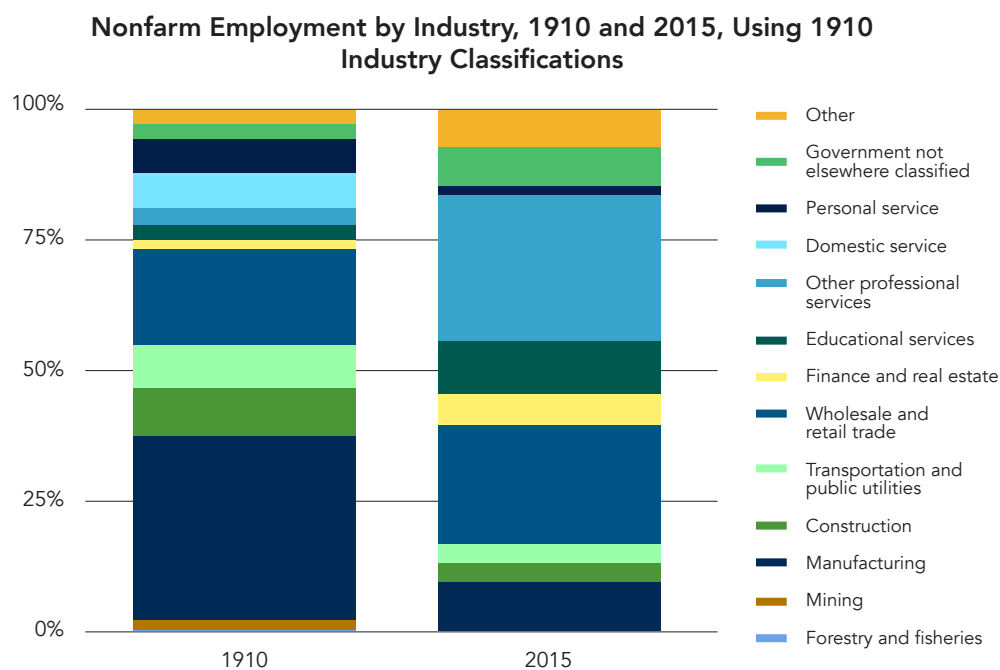
For instance, a recent Bureau of Labor Statistics study comparing U.S. employment in 1910 to that in 2015 shows significant long-term shifts away from manufacturing and agricultural employment and toward service industry jobs.⁵⁷ In 1910, 31 percent of the workforce was employed in agricultural jobs; by 2015, that share was less than 1 percent.⁵⁸ Manufacturing accounted for 32 percent of non-farm employment in 1910; by 2015, that share was just 9 percent. But these declining shares were replaced by growth in other sectors, particularly the service industry. Information services, professional and business services, and health care and social assistance together accounted for just 3 percent of non-farm employment in 1910, but by 2015, they accounted for 29 percent. Wholesale and retail jobs were 13 percent of nonfarm employment in 1910, and 23 percent in 2015.⁵⁹

57 Leon. 2016. "The life of American workers in 1915." Bureau of Labor Statistics. <https://www.bls.gov/opub/mlr/2016/article/the-life-of-american-workers-in-1915.htm>.

58 This includes various farm worker occupations, including farmers, managers, laborers, and foremen. See "Table 2. Employment, by occupation, 1910 and 2015, using 1910 occupational groups" *ibid.*

59 See "Table 3. Nonfarm employment, by major industry, 1910 and 2015, using 1910 industry classifications" *ibid.*

Figure F: Some Industries and Occupations Decline While Others Grow



Source: Leon. 2016. "The life of American workers in 1915." *Monthly Labor Review*, Bureau of Labor Statistics. <https://www.bls.gov/opub/mlr/2016/article/the-life-of-american-workers-in-1915.htm>.

Automation played a role in many of these structural shifts, contributing to occupational changes across and within industries. Automation’s ability to reduce employment within a specific industry or occupation can be seen clearly when looking at changes in agriculture and manufacturing. These industries have relied heavily on routine manual labor, much of which has since been replaced by automation, contributing to job losses and long-run declines in employment share.⁶⁰ But it is important to note that automation has not only impacted blue-collar and manual labor, and its impact is not only seen in displacements or industrial decline. The nature and distribution of white-collar work has undergone significant change from automation, too, despite long-term gains.

Tractors, Mechanical Harvesters, and the “Green Revolution” Disrupt Agriculture

The clearest example of automation’s capability to create large-scale displacements is the long-run decline in agricultural employment in the U.S. As noted above, in 1910, 31 percent of the workforce was employed in agricultural jobs; by 2015, that share was less than 1 percent, with much of the decline due to technology-fueled productivity gains. Productivity gains in agriculture have long outpaced the economy as a whole, even as employment in this sector has steadily declined.

In the late 19th to early 20th centuries, the introduction and adoption of tractors, made possible by the internal combustion engine, significantly reduced the need for manual and animal labor on farms. The share of agricultural employment subsequently fell dramatically, from 41 percent in 1900 to 16 percent in 1945, resulting from major

⁶⁰ Other factors may include disruptions from trade, changes in consumer preferences, and other technological innovations.

productivity gains.⁶¹ In the post-World War II period, new harvesting technologies, such as the self-propelled grain combine, tomato harvester, or cotton picker and stripper,⁶² further reduced the need for manual labor. And “Green Revolution” innovations, such as advancements in chemical fertilizers and pesticides and new high-yield crop varieties,⁶³ improved farm production significantly while further reducing the need for manual tasks such as weeding. From 1940 through 1980, agricultural occupations declined by nearly 4 percentage points per decade. More recently, advances in robotics, the use of big data analytics, and GPS technology in “precision agriculture” mean that today’s farmers spend less time on a tractor and more time in front of a computer. This change has resulted in productivity gains and rising output even as agricultural employment continues to fall. In a recent *New York Times* profile of John Moss, a Wisconsin cranberry farmer, Moss explains he had a successful career as a software engineer before returning home to work on his family farm. It was his interest in computer science that brought him back. He notes that operating the farm today is far less labor intensive than it was for his father or grandfather.⁶⁴

Mass Production, Assembly Lines, and the Rise of Robotics Disrupt Manufacturing

Manufacturing work has changed significantly since the Industrial Revolution. At the turn of the 20th century, electrification and the development of engine technology led to significant advances in manufacturing processes. Powered machines automated many manual production tasks, paving the way for assembly lines and mass production. Contemporaneously, a significant expansion of telegraph lines and railroads, along with new technologies such as telephones and the internal combustion engine, revolutionized communications and transportation. These innovations led to more interconnection and the conditions necessary for large business organizations and mass labor migration into urban centers. The result of these overlapping trends was a move away from decentralized, skilled craft work and toward centralized and hierarchical factory work with greater shares of both low-skilled work on assembly lines (augmented by machine labor) and higher-skilled managerial positions. For example, Henry Ford’s use of assembly lines shifted car manufacturing from a craft system, with complex skilled work in foundries, machine shops, and carriage making shops, to one built on repetitive low-skill tasks performed by assembly line workers, and overseen by line managers.⁶⁵ This trend was replicated in factories across the country, leading to cheaper manufactured consumer goods and factory equipment. Factory output per capita more than doubled between 1909 and 1930.⁶⁶

In the latter part of the 20th century, the introduction of robotics automated much of the remaining repetitive low-skilled assembly line work. This contributed to the



Automation has not only impacted blue-collar and manual labor, and its impact is not only seen in displacements or industrial decline. The nature and distribution of white-collar work has undergone significant change from automation, too, despite long-term gains.

61 Dimitri, Effland, and Conklin. 2005. “The 20th Century Transformation of U.S. Agriculture and Farm Policy.” U.S. Department of Agriculture. https://www.ers.usda.gov/webdocs/publications/44197/13566_eib3_1_.pdf.

62 Schmitz and Moss. 2015. “Mechanized Agriculture.” *AgBioForum*. <http://www.agbioforum.org/v18n3/v18n3a06-schmitz.htm>.

63 Dimitri, Effland, and Conklin. 2005. “The 20th Century Transformation of U.S. Agriculture and Farm Policy.” U.S. Department of Agriculture. https://www.ers.usda.gov/webdocs/publications/44197/13566_eib3_1_.pdf.

64 Olsen. 2018. “A Harvest That Requires Flooding, Floating and Pumping.” *New York Times*. <https://www.nytimes.com/2018/10/19/business/cranberry-harvest-wisconsin.html>.

65 Meyer. 2004. “The Degradation of Work Revisited.” *Automobile in American Life and Society*, University of Michigan. http://www.autolife.umd.umich.edu/Labor/L_Overview/L_Overview3.htm.

66 See Series D 213-217, Output Per Man-Hour, All Manufacturing. https://www2.census.gov/library/publications/1949/compendia/hist_stats_1789-1945/hist_stats_1789-1945-chD.pdf.

Stark. 1940. “Does Machine Displace Men in the Long Run?” *New York Times*. <https://timesmachine.nytimes.com/timesmachine/1940/02/25/109344698.pdf>.

displacement of millions of factory workers and caused significant disruptions to local economies. As discussed in Section I, looking at data from 1990 through 2007, Acemoglu and Restrepo⁶⁷ found significant job and earnings loss at the local level as a result of adoption of industrial robots—autonomous machines that can be programmed to perform many different manual tasks involved in production⁶⁸—with the largest effects on low-skilled manual jobs, and the manufacturing industry. They found that for every additional robot introduced in a local labor market, an average of 6.2 workers lost their jobs, and these job losses spread across industries in the local economy. These and other technological advancements, along with expanded global trade, contributed to a significant decline in manufacturing employment, even as industry output expanded.⁶⁹ From 1987 to today, manufacturing output grew by over 60 percent even as the sector lost nearly 5 million jobs, or more than 25 percent of its total employment.⁷⁰

Moreover, the advanced manufacturing jobs that do still exist have dramatically different skills requirements. In response to increased automation, American manufacturers are posting more jobs for coders and software developers than for production workers.⁷¹ A recent Deloitte study found that manufacturing jobs are increasingly relying on digital skills, robot programming, and critical thinking.⁷² A study by the Brookings Institution found that the average digitalization score for the basic goods manufacturing industry group increased from 15 to 33 between 2002 and 2016, while the digitalization score for advanced manufacturing increased from 24 to 39.⁷³ And a study by Larry Katz and Robert Margo found that the share of high-skill jobs within manufacturing grew from 6 percent in 1920 to 30 percent in 2010 while the share of low-skill jobs fell from 60 percent to 39 percent (Figure G).⁷⁴

67 Acemoglu and Restrepo. 2017. "Robots and Jobs." National Bureau of Economic Research. <http://www.nber.org/papers/w23285>.

68 Acemoglu and Restrepo. 2017. "Robots and jobs." Centre for Economic Policy Research. <https://voxeu.org/article/robots-and-jobs-evidence-us>.

69 There is some debate in the literature about the relative contribution of automation versus global trade on manufacturing job losses in recent decades. For instance, an often-cited study from Ball State University found that as much as 88 percent of manufacturing job losses in recent years are attributable to factory productivity increases. However, a more recent paper from economist Susan Houseman argues that productivity increases in manufacturing have been concentrated in computer production, not in the industries experiencing job loss—suggesting that trade shocks played a larger role than was previously understood. But this distinction may not matter in the long run: as economist Frank Levy notes in a recent paper, offshoring and automation tend to displace similar types of work—structured tasks that don't need to be performed onsite and in-person, and that can be described in instructions that can be automated (i.e. codable) or explained to foreign producers. In this way, even if we are unsure of the amount of automation in recent years, we might still learn a good deal about the impact that future automation might have by studying disruptions due to trade and offshoring.

Levy. 2018. "Computers and Populism." MIT. <https://ssrn.com/abstract=3091867>.

Hicks and Devaraj. 2015. "The Myth and the Reality of Manufacturing in America." Ball State University. <https://projects.cberdata.org/reports/MfgReality.pdf>.

Houseman. 2018. "Understanding the Decline of U.S. Manufacturing Employment." Upjohn Institute for Employment Research.

http://research.upjohn.org/up_workingpapers/287/.

Furman. 2017. "Should We Be Reassured If Automation in the Future Looks Like Automation in the Past?" Harvard Kennedy School and Peterson Institute for International Economics. <http://www.nber.org/chapters/c14031.pdf>.

70 Bureau of Labor Statistics. "Manufacturing Sector: Real Output [OUTMS]." Retrieved from Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/series/OUTMS>.

Bureau of Labor Statistics. "All Employees: Manufacturing [MANEMP]." Retrieved from Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/series/MANEMP>.

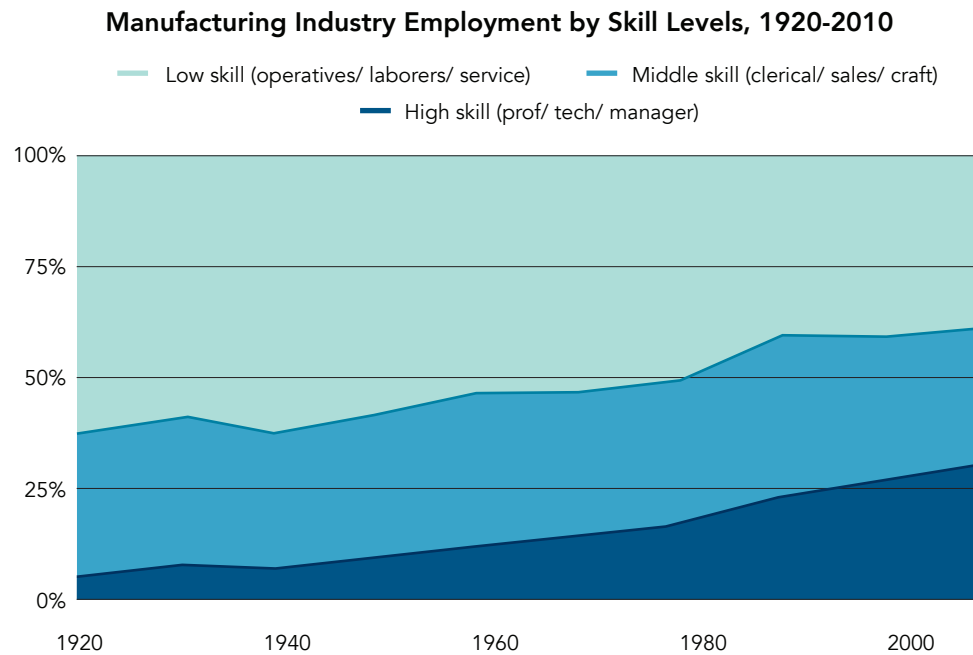
71 Burning Glass Technologies. 2017. "Manufacturing Shift." <https://www.burning-glass.com/blog/manufacturing-shift-software-jobs-now-outpace-production-openings/>.

72 Deloitte and The Manufacturing Institute. 2018. "2018 Skills Gap in Manufacturing Study." <https://www2.deloitte.com/us/en/pages/manufacturing/articles/future-of-manufacturing-skills-gap-study.html>.

73 Muro et al. 2017. "Digitalization and the American workforce." Brookings Institution. <https://www.brookings.edu/research/digitalization-and-the-american-workforce/>.

74 Katz and Margo. 2014. "Technical Change and the Relative Demand for Skilled Labor." In *Human Capital in History*. <https://www.nber.org/chapters/c12888.pdf>.

Figure G: Remaining Manufacturing Jobs Are Increasingly Higher-Skill Professional, Managerial, and Technical Jobs



Source: Katz and Margo. 2014. "Technical Change and the Relative Demand for Skilled Labor." In *Human Capital in History*. <https://www.nber.org/chapters/c12888.pdf>.

Importantly, the decline of manufacturing employment has had disproportionate impacts on communities of color. Historically, African American workers have been highly represented in manufacturing jobs, in part because these jobs were traditionally concentrated in urban areas in the Northeast and Midwest with large shares of African American workers, in cities such as Detroit, Philadelphia, and Pittsburgh. Research shows that the decline in manufacturing from 1960 through 2010 expanded racial gaps, including a 12 percent increase in the racial wage gap for men, a 3.4 percentage point increase in the racial employment gap for men, an 8 percentage point increase in the racial poverty gap for women, and a 5.4 percentage point increase in the racial poverty gap for children.⁷⁵

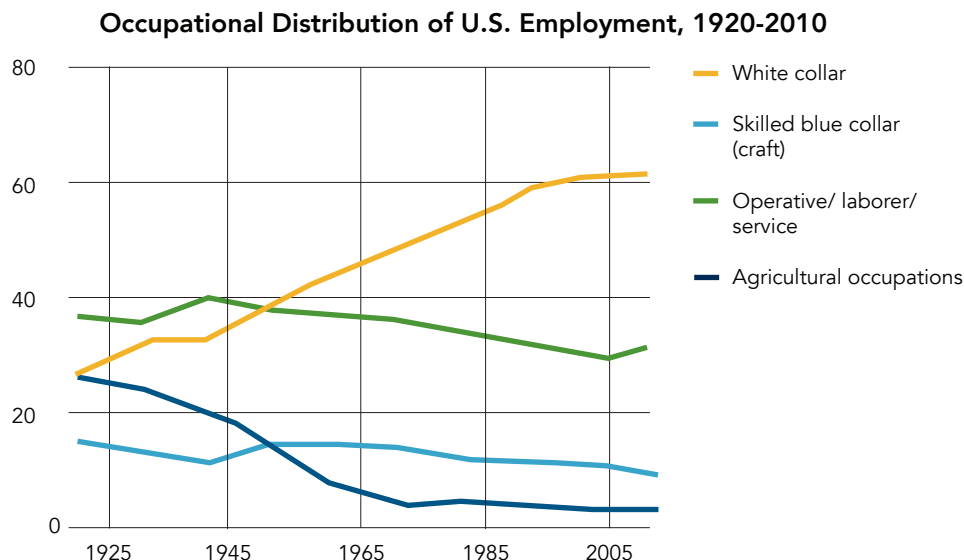
Information and Communications Technology Automates Middle-Skill White-Collar Work

The creation and spread of communications and information technologies in the middle of the 20th century enabled the creation and expansion of large multi-faceted business organizations and large expansions of white-collar office work, as employment shifted away from physically demanding manual labor. From 1940 through 1980, while low-wage agricultural occupations declined, white-collar work—middle-income clerical work and higher-wage managerial and professional work—grew from 32 percent to 54 percent of all employment (Figure H).⁷⁶

⁷⁵ Gould. 2018. "The impact of manufacturing employment decline on black and white Americans." Centre for Economic Policy Research. <https://voxeu.org/article/manufacturing-decline-has-hurt-black-americans-more>.

⁷⁶ Katz and Margo. 2014. "Technical Change and the Relative Demand for Skilled Labor." In *Human Capital in History*. <https://www.nber.org/chapters/c12888.pdf>.

Figure H: Good-Paying Middle- and High-Skilled White Collar Work Grew Significantly as a Share of All Jobs in the Mid-20th Century



Source: Katz and Margo. 2014. "Technical Change and the Relative Demand for Skilled Labor." In *Human Capital in History*. <https://www.nber.org/chapters/c12888.pdf>.

These trends combined to support relatively low measures of inequality and a growing middle class. Incomes rose broadly across all workers from the late 1940s through the early 1970s.⁷⁷

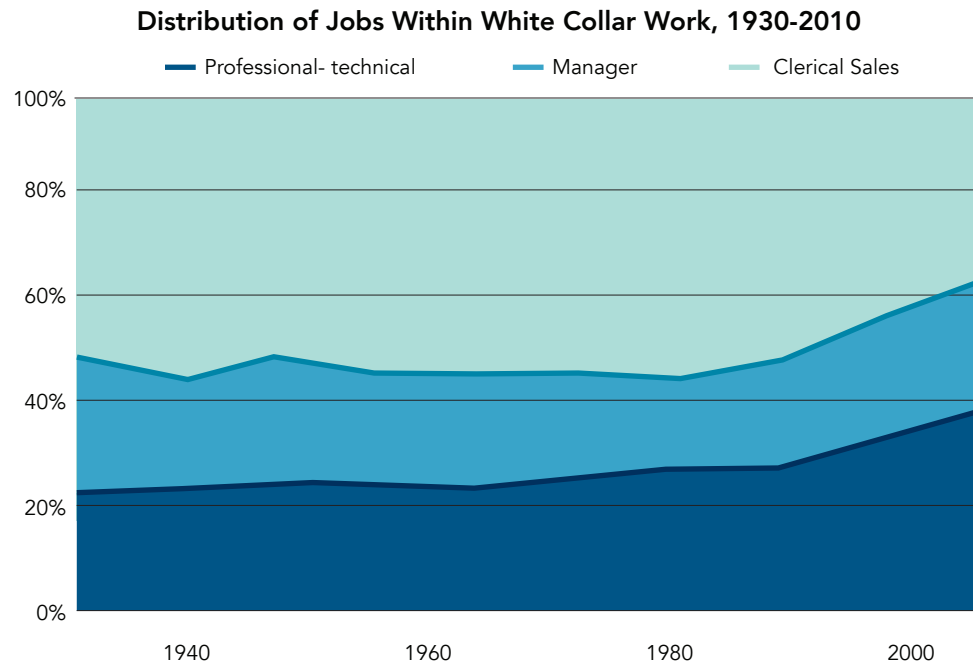
But just as technology helped create the conditions that led to these white-collar jobs, it also enabled the automation and displacement of much of those same jobs in the latter part of the 20th century and into the 21st century. Software such as spreadsheets and word processors automated many routine cognitive tasks, impacting accountants and clerical and administrative workers. The internet and communications technology also have greatly changed how businesses operate and organize labor, including by enabling the outsourcing of functions such as call center work, which can have a deskilling effect.

These technological changes played a significant role in the decline of middle-skill jobs, contributing to rising wage inequality and a hollowing out of the middle class.⁷⁸ From 1980 through 2010, high-paying professional, technical, and managerial work grew even more rapidly than in the prior period, but middle-skill, middle-income administrative and clerical jobs fell, so that even when white-collar work continued to expand as a share of all jobs (Figure H), the distribution within white-collar work was changing (Figure I).

⁷⁷ Stone et al. 2018. "A Guide to Statistics on Historical Trends in Income Inequality." Center on Budget and Policy Priorities. <https://www.cbpp.org/research/poverty-and-inequality/a-guide-to-statistics-on-historical-trends-in-income-inequality>.

⁷⁸ By no means was technological change the only factor in these trends—for instance, Mishel 2015 notes that a variety of other factors, including the decline in unionization, a de-emphasis of full employment policies, a fall in the real value of the minimum wage, and globalized trade also played a significant role. Mishel. 2015. "Causes of Wage Stagnation." Economic Policy Institute. <https://www.epi.org/publication/causes-of-wage-stagnation/>.

Figure I: Automation of Many Routine Office Tasks Has Contributed to Declining Share of Clerical and Sales Positions⁷⁹



Source: Katz and Margo. 2014. "Technical Change and the Relative Demand for Skilled Labor." In *Human Capital in History*. <https://www.nber.org/chapters/c12888.pdf>.

Investments in Education, Training, and Safety Net Supports Mediate Impacts of Disruption

Labor market disruption is not deterministic. The severity of disruption can be mitigated by the supports in place to help workers and communities transition, adjust, and share in the benefits of progress. Over the 20th century, new investments in public education, worker training, and the social safety net, as well as an ascendant labor union movement, helped smooth workforce transitions, acting as counterweights to the displacements, disruptions, and inequalities that could have resulted from technological changes generally, and automation specifically. But as these trends have reversed, economic prosperity has been more uneven and inequality has grown.

Rising Educational Attainment Reduces Skill Premiums and Inequality

In the early 20th century, grassroots movements to build and staff schools, paired with state policies that made education compulsory and child labor illegal, led to significant increases in Americans' average educational attainment. From 1910 to 1940, high school enrollment increased from 18 percent to 71 percent.⁸⁰ Research from Claudia Goldin and Lawrence Katz shows that the high school movement helped to significantly reduce

⁷⁹ Katz and Margo. 2014. "Technical Change and the Relative Demand for Skilled Labor." In *Human Capital in History*. <https://www.nber.org/chapters/c12888.pdf>.

⁸⁰ Goldin and Katz. 2011. "Mass Secondary Schooling and the State." In *Understanding Long-Run Economic Growth*. https://scholar.harvard.edu/files/lkatz/files/gk_mass_secondary.pdf.

inequality and compress the wage distribution by ensuring that the supply of skilled, educated workers met rising demand. In the late 19th and early 20th century, the wage premium for each additional year of education was very high. With the increase in high school attainment, this premium decreased, and wage inequality between high-skilled and low-skilled jobs shrank.⁸¹

In the mid-20th century, policymakers made even greater investments in education and training. The World War II and Korean War GI Bills significantly increased⁸² the share of workers with a college education. The Manpower Development Training Act in 1962 (the predecessor to today's Workforce Innovation and Opportunity Act) was a broad federal effort to support training and retraining for unemployed workers, including those displaced by technological change.⁸³ Large investments were made in public education with the Elementary and Secondary School Act (1965) and the Head Start program (1964), and access to traditional higher education was expanded with the Work Study program (1964) and the Higher Education Act (1965). These changes helped drive rising educational attainment through the 1970s that contributed to a period of high economic growth, broadly shared income gains, and an expanding middle class.

Safety Net Supports Help Workers Weather Displacements and Disruption

The early 20th century brought the creation of a strong public safety net to improve economic security for American workers and families. The New Deal launched by President Franklin Roosevelt established Unemployment Insurance, Social Security, the Works Progress Administration, Aid to Families with Dependent Children (now called "Temporary Assistance for Needy Families"), and more. Contemporaries argued that supports like these were important not just as a response to the Great Depression, but as key components of a strategy to help workers transition and adjust when displaced by technology.⁸⁴

The social safety net was significantly expanded in the mid-20th century with the creation of Medicare, Medicaid, and the food stamp program (now the "Supplemental Nutrition Assistance Program"). In 1964, President Lyndon Johnson launched the "Blue-Ribbon National Commission on Technology, Automation, and Economic Progress," whose recommendations included a negative income tax to provide financial support to out of work and low-paid workers to counteract technological disruption—an idea that was later adapted with creation of the Earned Income Tax Credit in 1975.

Labor Movement Raises Job Quality Standards

The early 20th century also saw the rise of a strong labor movement. As workers shifted from agriculture to manufacturing and other industries, unions leveraged their collective bargaining power to ensure many of those new jobs provided high pay,

81 Goldin and Katz. 2007. "The Race between Education and Technology." National Bureau of Economic Research. <http://www.nber.org/papers/w12984>.

82 Stanley. 2003. "College Education and the Midcentury GI Bills." *The Quarterly Journal of Economics*. <http://course.napla.copladigital.org/wp-content/uploads/2016/09/College-Education-and-the-Midcentury-GI-Bills-1.pdf>.

83 Kremen. 1974. "MDTA: The Origins of the Manpower Development and Training Act of 1962." U.S. Department of Labor. <https://www.dol.gov/general/aboutdol/history/mono-mdtatext>.

84 Stark. 1940. "Does Machine Displace Men in the Long Run?" *New York Times*. <https://timesmachine.nytimes.com/timesmachine/1940/02/25/109344698.pdf>.

comprehensive benefits, and training investments for workers.⁸⁵ These efforts were assisted by the passage of federal labor rights laws, including the right to organize, collectively bargain, and strike, and new job standards including the minimum wage and overtime protections.

The growing influence of labor also culminated in agreements between unions and automotive companies, which came to be known collectively as the Treaty of Detroit, to forego strikes in exchange for a variety of other benefits, such as rising wages, health coverage, vacation, and defined benefit pensions. This arrangement soon spread to industries throughout the economy.⁸⁶

85 Bivens et al. 2017. "How today's unions help working people." Economic Policy Institute. <https://www.epi.org/publication/how-todays-unions-help-working-people-giving-workers-the-power-to-improve-their-jobs-and-unrig-the-economy/>.

86 Aspen Institute Future of Work Initiative. 2017. "Toward a New Capitalism." <https://www.aspeninstitute.org/publications/the-promise-of-opportunity-and-the-future-of-work/>.

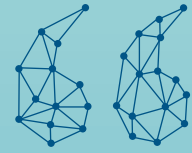
Recent Challenges Highlight Consequences of Limited Supports for Vulnerable Workers

Recent history, however, has been marked by a reversal of these efforts, with declining, rather than expanding investment in workforce development and critical safety net supports, and a fraying of the social contract. The result of this policy inaction has had negative consequences on the economic security and health of the country, and has left workers vulnerable to the downsides of automation. Policymakers and business leaders should heed these lessons and recognize that even if future automation is no more disruptive than it has been in the past, significant investments in education and training, expansions of safety net programs, and a revitalized social contract for the 21st century are necessary to help manage the resulting transitions.

Slowed Growth in Educational Attainment and Disinvestment in Worker Training

Driven by demographic shifts and slower growth in educational attainment, the 1980's brought a reduction in the expansion of the skilled labor force.⁸⁷ While demand for highly-skilled labor climbed significantly, growth in the supply of that labor did not meet rising demand, contributing to rising skill premiums and lower demand for lesser skilled workers.⁸⁸ In 1980, median earnings for high-school educated workers were 70 percent that of workers with at least a bachelor's degree; today, that ratio is 55 percent.⁸⁹ Meanwhile, the cost of higher education has skyrocketed, contributing to large amounts of outstanding student debt. The average rates for tuition, fees, room and board for full-time undergraduate students in degree-granting institutions rose 65 percent between 1995-96 and 2015-16 (in constant 2015-16 dollars).⁹⁰ As of December, 2018, outstanding student loan debt reached a record high of almost \$1.57 trillion, according to the Federal Reserve.⁹¹

At the same time, investments in worker training have declined in recent decades. Employers traditionally have been the largest source of funding for workforce training, but businesses are training fewer workers than in the past. From 1996 to 2008, the percentage of workers receiving employer-sponsored or on-the-job training fell 42



Employers traditionally have been the largest source of funding for workforce training, but businesses are training fewer workers than in the past. From 1996 to 2008, the percentage of workers receiving employer-sponsored or on-the-job training fell 42 percent and 36 percent, respectively.

87 Goldin and Katz. 2007. "The Race between Education and Technology." National Bureau of Economic Research. <http://www.nber.org/papers/w12984>.

88 Ibid.

89 Authors' calculations based on Bureau of Labor Statistics data series LEU0252917300 and LEU0252918500.

90 National Center for Education Statistics. 2018. "Tuition costs of colleges and universities." U.S. Department of Education. <https://nces.ed.gov/fastfacts/display.asp?id=76>.

91 Board of Governors of the Federal Reserve System. 2019. "Consumer Credit Outstanding (Levels)." https://www.federalreserve.gov/releases/g19/HIST/cc_hist_memo_levels.html.

percent and 36 percent, respectively.⁹² This decline was widespread across industries, occupations, and demographic groups.⁹³ Historically, unions played an important role in negotiating stronger pay, particularly for low- and middle-income workers,⁹⁴ and greater employer investment in training. But as unions have lost power and membership, income inequality has grown, and businesses have had a freer hand to hire already-trained external candidates, often leading to fewer within-firm career pathways and higher turnover.⁹⁵

Public sector investment has declined, too. For example, WIOA Title I state grants, which fund the core of the federal workforce development system, have been cut by over 40 percent since 2001. The program is currently underfunded by \$367 million relative to its authorized levels.⁹⁶ Government spending on training and other programs to help workers navigate job transitions is now just 0.1 percent of GDP, lower than all other OECD countries except for Mexico and Chile, and less than half of what it was 30 years ago.⁹⁷

Limited and Declining Access to Safety Net Supports and Workplace Benefits

The safety net for unemployed and displaced workers has also proven inadequate. Fewer unemployed workers receive Unemployment Insurance benefits today than ever before, in part due to reductions in benefit length in several states.⁹⁸ Following reforms to welfare programs and introductions of work requirements, much of the system of supports for out-of-work Americans have been curtailed in recent decades. And though some programs do offer additional support to displaced workers, they have limited eligibility, funding, and services.⁹⁹

Trade Adjustment Assistance (TAA) is only available to workers who can prove their jobs were displaced due to import competition and offshoring—leaving out workers disrupted by technology and other causes. The Dislocated Worker Program provides funding for career counseling and retraining support via Individual Training Accounts (ITA) for dislocated workers, but this funding is capped and distributed on a first-come, first-served basis, and lacks longer-term income support to help workers pursue training in lieu of work. National Dislocated Worker Grants give the Department of Labor the

92 Council of Economic Advisors. 2015. "Economic Report of the President." https://obamawhitehouse.archives.gov/sites/default/files/docs/cea_2015_erp_complete.pdf.

More recent data on employer-provided training has been mixed. Data from the Society for Human Resource Management suggests that employer-provided tuition assistance has been falling in recent years, from 66 percent of surveyed businesses offering tuition assistance benefits in 2008 down to 53 percent in 2017. Meanwhile, data from the Association for Training & Development suggests that employer training investments have been roughly flat over the last decade.

Society for Human Resource Management. 2017. "2017 Employee Benefits." <https://www.shrm.org/hr-today/trends-and-forecasting/research-and-surveys/pages/2017-employee-benefits.aspx>.

Association for Talent Development. 2017. "2017 State of the Industry." <https://www.td.org/research-reports/2017-state-of-the-industry>.

93 Waddoups. 2016. "Did Employers in the United States Back Away from Skills Training during the Early 2000s?" *ILR Review*. <http://ilr.sagepub.com/content/69/2/405>.

94 Bivens et al. 2017. "How today's unions help working people." Economic Policy Institute. <https://www.epi.org/publication/how-todays-unions-help-working-people-giving-workers-the-power-to-improve-their-jobs-and-unrig-the-economy/>.

95 Bidwell. 2013. "What Happened to Long-Term Employment?" *Organization Science*. https://repository.upenn.edu/mgmt_papers/124/.

96 National Skills Coalition. 2018. "America's workforce: We can't compete if we cut." <https://www.nationalskillscoalition.org/resources/publications/file/Americas-workforce-We-cant-compete-if-we-cut-1.pdf>.

Committee on Education and the Workforce Democrats. 2018. "If Republicans Were Serious About Investing in Training, They Would Invest in Our Current Workforce Development System." <https://democrats-edworkforce.house.gov/download/-farm-bill-v-wioa-investments-fact-sheet>.

97 OECD. "Active Labour Market Policies: Connecting People with Jobs." <http://www.oecd.org/employment/activation.htm>.

98 The percent of unemployed workers who receive unemployment benefits fell from an average of about 50 percent in the 1950s to about 35 percent in 1990s to under 30 percent since 2010. For a discussion of the impact of reduced benefit length on reciprocity rates, see:

McHugh and Kimball. 2015. "How Low Can We Go?" Economic Policy Institute. <https://www.epi.org/publication/how-low-can-we-go-state-unemployment-insurance-programs-exclude-record-numbers-of-jobless-workers/>.

99 OECD. 2016. "Back to Work: United States." *OECD Publishing*. https://www.oecd-ilibrary.org/employment/back-to-work-united-states_9789264266513-en.

ability to provide support to workers, industries, and regions facing acute disruptions, but funding is limited and grants are administered at the discretion of the Department, rather than being broadly available.

The social contract between employers and workers has also frayed, with long-term declines in the coverage and generosity of critical workplace benefits. In many cases, employers have turned toward outsourcing and contracting as a way to reduce labor costs, but these jobs often lack the benefits, protections, and job security afforded to traditional full-time employees. Coverage and generosity of benefits have declined for full-time workers, as well. For instance, most employers over the past several decades moved away from offering defined benefit pensions and toward defined contribution retirement plans such as 401(k)s,¹⁰⁰ which tend to offer less financial security for workers.¹⁰¹ Contributing to these trends has been the long-term decline in union representation. The result is that many American workers today have less security in their jobs and receive less stability from their jobs than in the past.

Rising Income and Regional Inequalities Highlight Consequences of Limited Supports

The past several decades have seen slow and painful economic adjustment for many workers and communities. The average length of unemployment, while cyclical, has generally increased since 1970.¹⁰² Displaced workers' earnings losses have increased since the mid-1990s.¹⁰³ Inequality has grown, reaching levels not seen since the 1920s.¹⁰⁴ Labor's share of national income has fallen, in part due to automation.¹⁰⁵ And with the growth of educational attainment slowing during this period, the wage premium for an additional year of education grew, returning to the levels of the early 1900s, which preceded the high school movement.¹⁰⁶ Real wages for non-college workers, particularly men, have fallen since 1980.¹⁰⁷

At a regional level, the economic growth of recent decades also has not been broadly shared. For most of the 20th century, prosperity across regions tended to converge. Per capita income in poorer regions grew more quickly than incomes in richer regions, allowing lagging regions to catch up over time. But this trend reversed over the past half century, with more prosperous regions pulling further away.¹⁰⁸ A recent study

100 Minaya. 2019. "Defined-Contribution Plans Surpass Half of Pension Assets, Report Finds." *Wall Street Journal*. <https://www.wsj.com/articles/defined-contribution-plans-surpass-half-of-pension-assets-report-finds-11550006365>.

101 Orlova, Rutledge, and Wu. 2015. "The Transition from Defined Benefit to Defined Contribution Pensions." Boston College. http://crr.bc.edu/wp-content/uploads/2015/06/wp_2015-17.pdf.

102 Bureau of Labor Statistics. "Average (Mean) Duration of Unemployment [UEMPMEAN]." Retrieved from Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/series/UEMPMEAN>.

103 Farber. 2010. "Job Loss and the Decline in Job Security in the United States." In *Labor in the New Economy*. <https://www.nber.org/chapters/c10822.pdf>.
Displaced workers are defined as "persons 20 years of age and over who lost or left jobs because their plant or company closed or moved, there was insufficient work for them to do, or their position or shift was abolished."
Bureau of Labor Statistics. 2018. "Worker Displacement: 2015-17." U.S. Department of Labor. <https://www.bls.gov/news.release/disp.nr0.htm>.

104 Stone et al. 2018. "A Guide to Statistics on Historical Trends in Income Inequality." Center on Budget and Policy Priorities. <https://www.cbpp.org/research/poverty-and-inequality/a-guide-to-statistics-on-historical-trends-in-income-inequality>.

105 A study from the IMF which looked at a variety of industries and occupations since 2001 found that automation of routine tasks—which has the effect of increasing demand for capital over labor—accounted for 44 to 57 percent of the decline in labor's share of national income, depending on the occupation.
Abdih and Danning. 2017. "What Explains the Decline of the U.S. Labor Share of Income?" International Monetary Fund. <https://www.imf.org/en/Publications/WP/Issues/2017/07/24/What-Explains-the-Divide-of-the-U-S-45086>.

106 Goldin and Katz. 2007. "The Race between Education and Technology." National Bureau of Economic Research. <http://www.nber.org/papers/w12984>.

107 Autor. 2019. "Work of the Past, Work of the Future." National Bureau of Economic Research. <https://economics.mit.edu/files/16724?mod=djemCIO>.

108 Nunn, Parsons, and Shambaugh. 2018. "The Geography of Prosperity." Brookings Institution. <https://www.brookings.edu/research/the-geography-of-prosperity/>.

shows that the occupational polarization of jobs and wages outlined in Section I has been felt most acutely in urban areas, which once held large shares of the middle-class jobs that more recently have been heavily impacted by automation and globalization, including blue-collar production and white-collar clerical and administrative support jobs.¹⁰⁹ Importantly, because African American workers have been over-represented in manufacturing employment, particularly in cities, the decline in these jobs expanded racial gaps in employment, wages, and poverty.¹¹⁰

Many communities today are still struggling with the after-effects of disruptions to their industries decades later. For instance, The Hamilton Project recently released its new Vitality Index to compare county-level economic outcomes over time, and found that counties in 1980 with higher shares of manufacturing employment generally scored higher in vitality, but those counties scored the lowest by 2016.¹¹¹ Recent research from the Federal Reserve Bank of San Francisco found that at least half the decline in prime-age labor force participation is due to the loss of manual labor jobs in manufacturing and other industries.¹¹² More workers in disrupted regions, particularly those with lower educational attainment, are falling out of the labor force entirely than did in the past, with more moving into early retirement or onto disability, and fewer relocating to find jobs elsewhere.¹¹³

Slow recoveries and the reduced employment prospects for less-educated workers in recent decades have been linked to serious public health crises. Nearly half of prime-age men not in the labor force take daily pain medication.¹¹⁴ Since the turn of the century, areas with lower growth,¹¹⁵ higher unemployment,¹¹⁶ and greater declines in labor force participation¹¹⁷ suffer from greater rates of opioid addiction and drug mortality. Mortality rates for whites with a high-school degree or less have actually *increased* since 2000 while decreasing for all other groups—a stunning reversal from long-run trends in the developed world. This has been attributed to rising rates of drug overdoses, suicides, and alcohol-related deaths.¹¹⁸

American Workers Today Are Especially Vulnerable to Disruption

Today's workers are especially vulnerable to the potential impacts of automation disruption because of broader societal trends:

- » **Financial Insecurity:** Though personal savings rates have recovered from the historic lows experienced during the credit boom of the early 2000s, Americans are still saving less today than in previous generations, contributing to serious financial insecurities. Since the end of the Great Recession, monthly personal

109 Autor. 2019. "Work of the Past, Work of the Future." National Bureau of Economic Research. <https://economics.mit.edu/files/16724?mod=djemCIO>.

110 Gould. 2018. "The impact of manufacturing employment decline on black and white Americans." Centre for Economic Policy Research. <https://voxeu.org/article/manufacturing-decline-has-hurt-black-americans-more>.

111 Nunn, Parsons, and Shambaugh. 2018. "The Geography of Prosperity." Brookings Institution. <https://www.brookings.edu/research/the-geography-of-prosperity/>.

112 Valletta and Barlow. 2018. "The Prime-Age Workforce and Labor Market Polarization." Federal Reserve Bank of San Francisco. <https://www.frbsf.org/economic-research/publications/economic-letter/2018/september/prime-age-workforce-and-labor-market-polarization/>.

113 Foote, Grosz, and Stevens. 2015. "Locate Your Nearest Exit." National Bureau of Economic Research. <http://www.nber.org/papers/w21618>.

114 Krueger. 2017. "Where have all the workers gone?" Brookings Papers on Economic Activity. <https://www.brookings.edu/bpea-articles/where-have-all-the-workers-gone-an-inquiry-into-the-decline-of-the-u-s-labor-force-participation-rate/>.

115 Ruhm. 2018. "Deaths of Despair or Drug Problems?" National Bureau of Economic Research. <http://www.nber.org/papers/w24188>.

116 Hollingsworth, Ruhm, and Simon. 2017. "Macroeconomic Conditions and Opioid Abuse." National Bureau of Economic Research. <http://www.nber.org/papers/w23192>.

117 Krueger. 2017. "Where have all the workers gone?" Brookings Papers on Economic Activity. <https://www.brookings.edu/bpea-articles/where-have-all-the-workers-gone-an-inquiry-into-the-decline-of-the-u-s-labor-force-participation-rate/>.

118 Case and Deaton. 2017. "Mortality and morbidity in the 21st century." Brookings Papers on Economic Activity. <https://www.brookings.edu/bpea-articles/mortality-and-morbidity-in-the-21st-century/>.

savings rates have averaged about 7 percent; rates in the 1960s, 1970s, and 1980s averaged over 11 percent.¹¹⁹ At the same time, household debt, driven by increasing consumer¹²⁰ and student loan¹²¹ debt, has surpassed its 2008 levels, reaching all-time highs. In a recent report, the Federal Reserve showed that 40 percent of families couldn't afford an unexpected \$400 bill without borrowing.¹²²

» **Ageing Workforce:** For older workers, retraining and transitioning to new occupations following displacement can be especially difficult, often leading to significantly lower earnings upon re-employment relative to younger, shorter-tenured displaced workers.¹²³ Older displaced workers often move into early retirement rather than transition to new occupations late in their careers.¹²⁴ This is particularly concerning given that a quarter of Americans have no retirement savings or pension,¹²⁵ and others are less secure due to the move away from pensions and toward defined contribution retirement plans such as 401(k)s.¹²⁶

» **Declining Geographic Mobility:** Americans are moving less than ever before, with the lowest rate on record in 2017.¹²⁷ Workers with less education are less geographically mobile.¹²⁸ This means today's workers, particularly those in lower-skilled jobs at greater risk of automation, are less likely to move to a different region for work, leaving them at a disadvantage if the geographic distribution of jobs shifts. As mentioned above, this is also concerning in regions facing disruption, where relocation traditionally has been an important way to reduce unemployment and restore growth.¹²⁹

» **Occupational Licensing:** A greater share of jobs today require some form of occupational license, credential, or post-secondary education, making it more difficult to transition into many occupations. In the 1950s, five percent of jobs required an occupational license but today, nearly 25 percent do.¹³⁰ It can be prohibitively expensive and time consuming to acquire such a license. The Institute of Justice surveyed licenses for 102 low-income occupations across the U.S. and found that, on average, they require \$267 in fees and nearly a year of education and experience.¹³¹

119 Bureau of Labor Statistics. "Personal Saving Rate [PSAVERT]." Retrieved from Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/series/PSAVERT>.

120 Dowdy. 2018. "Are Plummeting Savings and Rising Debt Red Flags for Household Finances?" Aspen Institute Financial Security Program. <https://www.aspeninstitute.org/blog-posts/plummeting-savings-rising-debt-red-flags-household-finances/>.

121 Board of Governors of the Federal Reserve System. 2019. "Consumer Credit Outstanding (Levels)." https://www.federalreserve.gov/releases/g19/HIST/cc_hist_memo_levels.html.

122 Board of Governors of the Federal Reserve System. 2018. "Report on the Economic Well-Being of U.S. Households in 2017." <https://www.federalreserve.gov/publications/files/2017-report-economic-well-being-us-households-201805.pdf>.

123 Jacobson, LaLonde, and Sullivan. 2011. "Policies to Reduce High-Tenured Displaced Workers' Earnings Losses Through Retraining." Brookings Institution. http://www.hamiltonproject.org/papers/policies_to_reduce_high-tenured_displaced_workers_earnings_losses_thro.

124 Foote, Grosz, and Stevens. 2015. "Locate Your Nearest Exit." National Bureau of Economic Research. <http://www.nber.org/papers/w21618>.

125 Board of Governors of the Federal Reserve System. 2018. "Report on the Economic Well-Being of U.S. Households in 2017." <https://www.federalreserve.gov/publications/files/2017-report-economic-well-being-us-households-201805.pdf>.

126 Minaya. 2019. "Defined-Contribution Plans Surpass Half of Pension Assets, Report Finds." *Wall Street Journal*. <https://www.wsj.com/articles/defined-contribution-plans-surpass-half-of-pension-assets-report-finds-11550006365>.

127 Census Bureau. 2018. "CPS Historical Migration/Geographic Mobility Tables." U.S. Department of Commerce. <https://www.census.gov/data/tables/time-series/demo/geographic-mobility/historic.html>.

128 Malamud and Wozniak. 2010. "The Impact of College Education on Geographic Mobility." National Bureau of Economic Research. <http://www.nber.org/papers/w16463>.

Wozniak. 2010. "Are College Graduates More Responsive to Distant Labor Market Opportunities?" *The Journal of Human Resources*. <http://jhr.uwpress.org/content/45/4/944>.

129 Foote, Grosz, and Stevens. 2015. "Locate Your Nearest Exit." National Bureau of Economic Research. <http://www.nber.org/papers/w21618>.

130 Kleiner and Krueger. 2013. "Analyzing the Extent and Influence of Occupational Licensing on the Labor Market." *Journal of Labor Economics*. <http://archive.hhh.umn.edu/people/mkleiner/pdf/Final.occ.licensing.JOLE.pdf>.

131 Carpenter et al. 2017. "License to Work: A National Study of Burdens from Occupational Licensing." Institute for Justice. <https://ij.org/report/license-work-2/report/executive-summary/>.

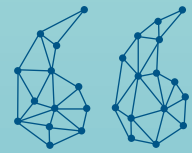
Why the Impact of Automation May Be Different This Time

Automation need not be any more disruptive in the future than it has been in the past to warrant increased policy intervention.¹³² That said, new technologies may well represent a tipping point, leading to deeper, faster, broader, and more disruptive automation in the near future—despite some current economic indicators that might suggest otherwise.

Recently, many researchers have developed methodologies to project the share of jobs and tasks that could be impacted by coming automation. Though methodologies differ, these studies have generally used data on current jobs and the capacity of existing technologies to automate those jobs and tasks. The result has been a wide range of projections about what jobs are at risk, and how many workers could become displaced.

In a 2017 report, the McKinsey Global Institute projected that as many as 16 to 54 million workers—10 percent to 32 percent of the American workforce—may need to retrain for different occupations by as early as 2030. Other projections provide a wide range of outcomes. At the high end, in 2013, Oxford professors Carl Benedikt Frey and Michael Osborne¹³³ estimated that 47 percent of U.S. jobs are at risk of being automated “relatively soon, perhaps over the next decade or two.” In 2017, PriceWaterhouseCoopers projected that 38 percent of jobs in the U.S. are at potential high risk of automation.¹³⁴ In 2018, Bain & Company’s Macro Trends Group projected that automation would eliminate 20 to 25 percent of current jobs by 2030.¹³⁵ In 2016, OECD researchers estimated that about 9 percent of U.S. jobs faced a high automatability.¹³⁶

These studies are not suggesting that all of the jobs with automatable tasks will be eliminated entirely, but rather that some portion of those jobs may be at risk. For example, McKinsey estimates that less than 5 percent of jobs are fully automatable by adapting currently demonstrated technologies, but over 90 percent of jobs are partially automatable.¹³⁷ Additionally, the results of these projections are highly sensitive to their underlying assumptions and methodologies, such as: whether the unit of analysis is at the occupation level or at the task level; whether a job or task that *can* be automated *will* be automated; how quickly employers adopt automating technologies; and how regulatory regimes and public attitudes will affect implementation. The wide range of results suggests there is still some disagreement about the best methodologies and assumptions to use. But these projections should not be cast aside. Rather, researchers



Automation need not be any more disruptive in the future than it has been in the past to warrant increased policy intervention, but action is particularly important because the U.S. economy could soon experience increased automation disruption.

132 Former Council of Economic Advisers chair Jason Furman recently published a paper arguing this point. Furman. 2017. “Should We Be Reassured If Automation in the Future Looks Like Automation in the Past?” Harvard Kennedy School and Peterson Institute for International Economics. <http://www.nber.org/chapters/c14031.pdf>.

133 Frey and Osborne. 2013. “The Future of Employment” University of Oxford. https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.

134 PricewaterhouseCoopers. 2017. “Will robots steal our jobs?” UK Economic Outlook. <https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf>.

135 Harris, Kimson, and Schwedel. 2018. “Labor 2030: The Collision of Demographics, Automation and Inequality.” Bain & Company. <https://www.bain.com/insights/labor-2030-the-collision-of-demographics-automation-and-inequality/>.

136 Arntz, Gregory, and Zierahn. 2016. “The Risk of Automation for Jobs in OECD Countries.” OECD Social, Employment and Migration Working Papers. https://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecd-countries_5j1z9h56dvq7-en.

137 According to McKinsey Global Institute, at least 10 percent of work hours are automatable in 91 percent of jobs. Manyika et al. 2017. “Jobs Lost, Jobs Gained.” McKinsey Global Institute. <https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages>.

and data experts should be doing more to improve on these studies so all stakeholders can better understand and prepare for future contingencies.

These projections have proven controversial, in part due to the sheer magnitude of predicted displacements, particularly coming at a time when unemployment is historically low. But there are several reasons to believe that the economy soon might experience increased automation, and that the impacts might be deeper, faster, broader, and more disruptive than in the recent past.

Deeper: Machine Learning Has Expanded the Types of Tasks that Can Be Automated

In the past, the tasks which have proven most difficult to automate are those which humans cannot fully understand, explain, and codify. For example, driving a car safely requires reacting quickly, accurately, and appropriately in response to unexpected inputs, making the tasks performed by driverless cars highly difficult for humans to explain and code. Even something as simple as recognizing whether an object crossing the street is a pedestrian, a biker, or a dog is extremely difficult to teach a machine, especially with the near-zero error rate that would be necessary for autonomous vehicles to be considered safe. As philosopher Michael Polanyi famously argued, “we know more than we can tell”—this concept has served as a natural limit on automation throughout human history.¹³⁸

But recent advancements in artificial learning technologies, such as artificial neural networks, and machine learning and its subset deep learning, are beginning to enable machines to be trained tasks by recognizing patterns in data without explicit human programming. These technologies power self-driving cars already operating in Pittsburgh, Phoenix, and other cities. AlphaGo, a computer program created by Google which learned to play the board game Go better than humans, taught itself the correct moves without being told how to do so by programmers. Speech recognition and transcription software—once highly error-prone—has surpassed humans in speed and accuracy at an accelerating rate.

These machine learning technologies, which improve every hour as data is collected and fed back into the system, may represent an inflection point as the firewall between codifiable and non-codifiable tasks breaks down. This could precipitate significant disruption. As an example, while the manufacturing industry lost 1.7 million jobs per decade since its peak in 1978, over the next 30 years a single technology—autonomous vehicle technology—could disrupt about half as many jobs per decade.¹³⁹

Faster: Digital Advancements Could Lead to a Higher Pace of Change

Labor market disruptions resulting from advancements in digital technologies have the potential to manifest more quickly than those resulting from advancements in physical technologies. First, new software can be adopted more cheaply and quickly than new

138 Autor. 2014. “Polanyi’s Paradox and the Shape of Employment Growth.” National Bureau of Economic Research. <https://www.nber.org/papers/w20485>.

139 Groshen et al. 2018. “Preparing U.S. Workers and Employers for an Autonomous Vehicle Future.” Securing America’s Future Energy. <https://avworkforce.secureenergy.org/wp-content/uploads/2018/06/Groshen-et-al-Report-June-2018-1.pdf>.

hardware. Software has little if any marginal cost. It increasingly can be downloaded and installed from anywhere almost instantaneously, reducing the lag time between advances in technology and their impact on the economy. For example, Uber has grown rapidly and caused massive disruption to the taxi industry by introducing software that seamlessly automates dispatch, leading an influx of workers to enter and compete in the for-hire driving industry. Uber's rapid growth is due in part to the ease and speed at which software technology can be adopted. Users only need to download a free app from the cloud.

It should be unsurprising that artificial intelligence is penetrating mainstream businesses at a high rate. In a 2018 survey of executives, 61 percent of respondents said they had implemented some form of AI in their business operations, up from 38 percent in 2017.¹⁴⁰ Annual venture capital investment into U.S. startups developing AI has increased more than four-fold since 2013, suggesting that development and adoption will soon accelerate.¹⁴¹

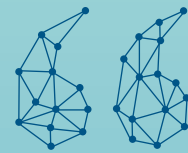
Second, through machine learning and big data analysis, AI technology is constantly updating itself and becoming more effective and accurate over-time. By comparison to other technologies, AI is less reliant on humans (who are relatively slow at coding prescriptive tasks) to make improvements. In this way, the task of improving digital technologies is itself becoming automated, potentially allowing for faster changes in jobs impacted by those technologies.

Recent tax legislation could accelerate business adoption of automation. Passed in 2017, the Tax Cuts and Jobs Act allows businesses to immediately deduct equipment purchases, including automation technologies, rather than expense the cost of the equipment over a period of time. By providing a new tax benefit for investing in automation technologies but no new benefit for investing in workers, the legislation encourages businesses to rely more on technology and less on human labor.¹⁴²

Broader: Digital Technology Has Application in Nearly Every Industry and Occupation

In the past, adoption of new technologies has varied across industries and regions. For instance, advances in robotics technology brought profound changes to the manufacturing sector, but had far less impact on industries that used less manual labor. This pattern allowed workers in disrupted industries to transition to other, more stable industries.

In contrast, digital technologies including artificial intelligence are increasingly incorporated across a broad array of industries and jobs.¹⁴³ Examples already exist of how tasks performed by workers as disparate as truck drivers,¹⁴⁴ retail clerks,¹⁴⁵



Software has little if any marginal cost. It increasingly can be downloaded and installed from anywhere almost instantaneously, reducing the lag time between advances in technology and their impact on the economy.

140 Narrative Science. 2019. "Outlook on Artificial Intelligence in the Enterprise." https://narrativescience.com/wp-content/uploads/2019/02/Research-Report_Outlook-on-AI-for-the-Enterprise.pdf.

141 Shoham et al. 2018. "The AI Index 2018 Annual Report." Human-Centered AI Initiative, Stanford University. <http://cdn.aiindex.org/2018/AI%20Index%202018%20Annual%20Report.pdf>.

142 Tangel and McGroarty. 2018. "Tax Incentive Puts More Robots on Factory Floors." *Wall Street Journal*. <https://www.wsj.com/articles/tax-incentive-puts-more-robots-on-factory-floors-1516962600>.

143 Muro et al. 2017. "Digitalization and the American workforce." Brookings Institution. <https://www.brookings.edu/research/digitalization-and-the-american-workforce/>.

144 Haubursin. 2017. "Automation is coming for truckers. But first, they're being watched." *Vox*. <https://www.vox.com/videos/2017/11/20/16670266/trucking-eld-surveillance>.

145 Fitzpayne, Pollack, and Greenberg. 2017. "Industry at a Glance: The Future of Retail." Aspen Institute Future of Work Initiative. <https://www.aspeninstitute.org/blog-posts/industry-at-a-glance-the-future-of-retail/>.

longshoremen,¹⁴⁶ sports¹⁴⁷ and financial journalists,¹⁴⁸ lawyers,¹⁴⁹ and hedge fund managers¹⁵⁰ may soon be automated. This means that future waves of disruption may impact a wide variety of industries and occupations at the same time, making it more difficult for disrupted workers to find a stable industry or occupation into which to transition.

More Disruptive: Automation's Adverse Labor Market Impacts May Be Intensifying

Over the last few decades, automation has become more disruptive to workers. Recent forms of automation, such as the use of robotics in manufacturing, appear to focus more on replacing labor rather than augmenting it. Acemoglu argues this change is evident in the polarization of the labor market and labor's declining share of national income.¹⁵¹ Similarly, Autor and Salomons find this effect evident in that recent automation has reduced labor's share of value added in the economy.¹⁵²

In addition, automation is increasingly occurring during cyclical downturns, forcing disrupted workers to find new jobs or occupations when opportunities are especially sparse. For instance, the 2014 heavy slump in the oil and gas market led to significant job losses before employment began to slowly rise in 2018, with 50,000 fewer oil and gas jobs today than the pre-crash peak.¹⁵³ But with investments in automation, oil and gas production rebounded to pre-crash levels in 2017 and today there is 20 percent greater output than there was before despite having 25 percent fewer workers in the industry.¹⁵⁴

Businesses appear to be using economic downturns as opportunities to make structural changes in their workforce for two reasons. First, technological investments tend to be cheaper during recessions. And second, profits are depressed, meaning that the opportunity cost of the investment—which diverts money away from profit-creating activities—is lower. Researchers from the University of Pennsylvania and Cornell University found that occupations characterized by routine, easily automated tasks have experienced significant job losses since the mid-1980s, and that 88 percent of those job losses occurred during recessions. In contrast, jobs characterized by nonroutine tasks only declined slightly, and quickly recovered.¹⁵⁵ This is particularly concerning because displaced workers face larger earnings losses when the unemployment rate is higher—making displacements during recessions especially painful.¹⁵⁶

146 O'Reilly. 2017. "Automation of port terminals threatens thousands of lucrative dock worker jobs." *Fox News*. <http://www.foxnews.com/us/2017/03/27/automation-port-terminals-threatens-thousands-lucrative-dock-worker-jobs.html>.

147 Mullin. 2016. "The Associated Press will use automated writing to cover the minor leagues." *The Poynter Institute*. <https://www.poynter.org/news/associated-press-will-use-automated-writing-cover-minor-leagues>.

148 Miller. 2015. "AP's 'robot journalists' are writing their own stories now." *The Verge*. <https://www.theverge.com/2015/1/29/7939067/ap-journalism-automation-robots-financial-reporting>.

149 Dvoskin. 2017. "This Silicon Valley start-up wants to replace lawyers with robots." *Washington Post*. <https://www.washingtonpost.com/news/innovations/wp/2017/09/14/this-silicon-valley-startup-wants-to-replace-lawyers-with-robots/>.

150 *The Economist*. 2017. "Hedge funds embrace machine learning—up to a point." <https://www.economist.com/finance-and-economics/2017/12/09/hedge-funds-embrace-machine-learning-up-to-a-point>.

151 Toulouse Network for Information Technology. 2017. "Daron Acemoglu on: Will robots take our jobs?" https://idei.fr/sites/default/files/IDEI/documents/tnit/newsletter/issue_17.pdf.

152 Autor and Salomons. 2018. "Is automation labor-displacing?" *Brookings Papers on Economic Activity*. <https://www.brookings.edu/bpea-articles/is-automation-labor-displacing-productivity-growth-employment-and-the-labor-share/>.

153 Bureau of Labor Statistics. "All employees, thousands, oil and gas extraction." U.S. Department of Labor. <https://data.bls.gov/timeseries/CES1021100001>.

154 Bureau of Labor Statistics. "Industrial Production: Mining: Oil and gas extraction." Retrieved from Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/series/IPG211S>.

155 Kopytov, Roussanov, and Taschereau-Dumouchel. 2018. "Short-Run Pain, Long-Run Gain?" *National Bureau of Economic Research*. <http://www.nber.org/papers/w24373>.

156 Davis and von Wachter. 2011. "Recessions and the Costs of Job Loss." *Brookings Papers on Economic Activity*. <https://www.brookings.edu/bpea-articles/recessions-and-the-costs-of-job-loss/>.

The gains from recent automation also appear to be more concentrated in the hands of capital owners and high-skill workers. In *The Second Machine Age*, Erik Brynjolfsson and Andrew McAfee note that labor's declining share of national income and rising wage inequality may signal a new "winner-take-all economy" in which an ever-shrinking set of "superstars" are able to capture an increasing share of gains through automation, among other means.

Some Data Suggest Declining Automation Disruption— but Traditional Metrics May Be Obscuring Underlying Trends

It is true that certain traditional economic indicators suggest productivity growth and job disruption, both products of automation, are at relatively low levels compared to historical norms. These data potentially undercut the idea that the present is a period of transformational technological change. For instance, research from the Information Technology and Innovation Foundation indicates that measures of occupational churn are at historic lows.¹⁵⁷ But there are several reasons why these indicators may be underestimating existing and future automation disruption.

First, current rates of innovation, automation, and disruption may be higher than some data suggest. Many technological innovations of recent decades, such as the internet and the smartphone, have had a significant impact on leisure activities, which may not be fully reflected in official economic indicators.¹⁵⁸ In addition, productivity metrics in certain industries are difficult to measure. For example, ongoing Bureau of Labor Statistics research is specifically studying productivity growth metrics in the construction sector. Traditional metrics show productivity in construction has been essentially flat since the 1950s, but these metrics may not accurately account for price changes over time.¹⁵⁹ Finally, as automation disruption increasingly occurs during recessions, it can be harder to distinguish between cyclical and automation job loss.¹⁶⁰

Second, there is a significant lag between the introduction of new technology and its impact on the economy. Adoption and diffusion of new technology takes time. Technology must become widely available, businesses have to find ways to use it and change processes to take advantage of it, and the regulatory and policy environment have to keep pace. Further, new technology does not fully impact the economy until new businesses are created around the technology (rather than existing businesses built around old technology adopting the new technology), and complimentary "co-inventions" are created for it to realize its potential.¹⁶¹ For example, productivity gains of general purpose technologies like electricity and the internal combustion engine were significantly delayed because they first required factory redesigns, interstate highways, new business processes, and changing workforce skills.¹⁶²

157 Atkinson and Wu. 2017. "False Alarmism: Technological Disruption and the U.S. Labor Market." Information Technology and Innovation Foundation. <https://itif.org/publications/2017/05/08/false-alarmism-technological-disruption-and-us-labor-market-1850-2015>.

158 Klein. 2016. "Technology is changing how we live, but it needs to change how we work." Vox. <https://www.vox.com/a/new-economy-future/technology-productivity>.

159 Sveikauskas et al. 2016. "Productivity Growth in Construction." *Journal of Construction Engineering and Management*. <https://ascelibrary.org/doi/10.1061/%28ASCE%29CO.1943-7862.0001138>

160 Kopytov, Roussanov, and Taschereau-Dumouchel. 2018. "Short-Run Pain, Long-Run Gain?" National Bureau of Economic Research. <http://www.nber.org/papers/w24373>.

161 Brynjolfsson, Rock, and Syverson. 2017. "Artificial Intelligence and the Modern Productivity Paradox." National Bureau of Economic Research. <https://www.nber.org/papers/w24001>.

162 For example, economist Paul David notes that similar slowdowns in productivity growth occurred in the U.S. and Britain around the turn of the 20th century, despite major advances in electricity technology poised to usher in a new industrial revolution, with productivity growth relatively sluggish until nearly four decades after the first central power station opened for business. David. 1990. "The Dynamo and the Computer." *The American Economic Review*. <https://www.jstor.org/stable/2006600>.

Conclusion

Technological progress can and should be a cause for hope. The American economy has been mired in very low rates of productivity growth, and long-run economic, job, and wage growth have suffered as a result. We should embrace technology and its potential to boost productivity.

But the nature of this progress is not predetermined. The future can take many paths, and depends on the choices made by government, businesses, and individuals. We must work together to create a future in which progress is paired with opportunity, justice, and broadly shared prosperity.

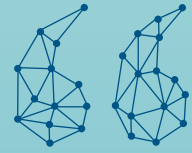
Technological progress and economic justice need not be in tension. Workers are better able to take advantage of the opportunities technology presents if they have access to skills training, if good jobs are available to them, and if they are given supports to transition from shrinking occupations to those that are growing. Similarly, businesses cannot realize the full benefits of new technology without a skilled workforce. And if work no longer provides the security and opportunity it once did, pressures can mount to slow or halt technological innovation.

Unfortunately, public and private investments in worker training have been going in the wrong direction. In part due to the lingering effects of the Great Recession, the economy and social safety net are unprepared to help a large number of workers weather disruption. Current programs for managing workforce transition are limited in scope and not widely available to all who might need assistance. The result is a system that simply is not well designed to help workers find and prepare for new occupations as the economy and labor market evolve.

Part II of this report, *Automation and a Changing Economy: Policies for Shared Prosperity*, outlines a policy agenda for addressing the challenges posed by automation and the inadequacies of our existing supports. The paper identifies four overarching objectives that guide this policy effort:

The first objective—**Encourage Employers to Lead a Human-Centric Approach to Automation**—promotes increased employer engagement and investment in workforce development through a worker training tax credit, expansion of apprenticeships, and new funding for sector and regional workforce partnerships. It encourages employers to adopt a multi-stakeholder approach to automation by promoting new forms of worker voice and ownership and developing proactive strategies to identify and address potential impacts further in advance.

The second objective—**Enable Workers to Access Skills Training, Good Jobs, and New Economic Opportunities**—gives workers the tools to succeed by improving access to effective and affordable skills training and advocating for a culture and system of lifelong learning. It helps ensure that technological change does not lead to greater economic insecurity for low-wage workers by increasing wage subsidies and the minimum wage, and empowering workers to access opportunity by improving labor market flexibility and promoting entrepreneurship.



We must ensure that our economy encourages continued technological innovation while at the same time supporting the value and dignity of work with broadly shared prosperity.

The third objective—**Help People and Communities Recover from Displacements**—strengthens supports for displaced workers through retraining, job search, reemployment services, and Unemployment Insurance to help them transition to new jobs and careers. It assists disrupted communities by supporting local economic development and improving regional competitiveness through sector-based development strategies and investment in digital infrastructure.

The fourth objective—**Understand the Impact of Automation on the Workforce**—arms workers, businesses, training and education providers, and policymakers with better information on automation trends by collecting data on technological advancements, adoption rates, and workforce impacts.

We shouldn't stifle innovation because it may be disruptive. We should embrace it, and craft effective, responsive policies to address the challenges. We must ensure that our economy encourages continued technological innovation while at the same time supporting the value and dignity of work with broadly shared prosperity.

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