MIT work OF THE FUTURE

# The Work of the Future:

## Building Better Jobs in an Age of Intelligent Machines

2020

## MIT Work of the Future Task Force

**DAVID AUTOR, CO-CHAIR**
Ford Professor of Economics, Margaret MacVicar Fellow, and Associate Department Head
Labor Studies Program Co-Director, National Bureau of Economic Research

**DAVID MINDELL, CO-CHAIR**
Professor of Aeronautics and Astronautics
Dibner Professor of the History of Engineering and Manufacturing
Founder and CEO, Humatics Corporation

**ELISABETH REYNOLDS, EXECUTIVE DIRECTOR**
Principal Research Scientist
Executive, Director, MIT Industrial Performance Center
Lecturer, Department of Urban Studies and Planning

# Table of Contents

## CHAPTER 1

# Introduction

Three years ago, robots, artificial intelligence (AI), and self-driving cars seemed to be coming fast. A widely cited study projected nearly half of all jobs in industrialized countries could soon be performed by robots or AI. A *New Yorker* cover published in late 2017 showed robots striding to work on a sidewalk where a disheveled human panhandler begged for coins. During the 2019 Super Bowl, six TV commercials featured robots or AI-enabled assistants. One beer advertisement showed robots gleefully surpassing humans in running, bicycling, and golfing, but ended with a robot gazing wistfully through a window at people socializing in a bar. Humans would soon be outcompeted in every arena except social drinking, this ad seemed to say.

---

In this context, MIT President L. Rafael Reif commissioned the MIT Task Force on the Work of the Future in the spring of 2018. He tasked us with understanding the relationships between emerging technologies and work, to help shape public discourse around realistic expectations of technology, and to explore strategies to enable a future of shared prosperity. The Task Force is co-chaired by this report's authors: Professors David Autor and David Mindell and executive director Dr. Elisabeth Reynolds. Its members include more than 20 faculty members drawn from 12 departments at MIT, as well as over 20 graduate students.

In the two-and-a-half years since the Task Force set to work, autonomous vehicles, robotics, and AI have advanced remarkably. But the world has not been turned on its head by automation, nor has the labor market. Despite massive private investment, technology deadlines have been pushed back, part of a normal evolution as breathless promises turn into pilot trials, business plans, and early deployments — the diligent, if prosaic, work of making real technologies work in real settings to meet the demands of hard-nosed customers and managers.

Yet, if our research did not confirm the dystopian vision of robots ushering workers off of factory floors or artificial intelligence rendering superfluous human expertise and judgment, it did uncover something equally pernicious: Amidst a technological ecosystem delivering rising productivity, and an economy generating plenty of jobs (at least until the COVID-19 crisis), we found a labor market in which the fruits are so unequally distributed, so skewed towards the top, that the majority of workers have tasted only a tiny morsel of a vast harvest.

Four decades ago, for most U.S. workers, the trajectory of productivity growth diverged from the trajectory of wage growth. This decoupling had baleful economic and social consequences: low-paid, insecure jobs held by non-college workers; low participation rates in the labor force; weak upward mobility across generations; and festering earnings and employment disparities among races that have not substantially improved in decades. While new technologies have contributed to these poor results, these outcomes were not an inevitable consequence of technological change, nor of globalization, nor of market forces. Similar pressures from digitalization and globalization affected most industrialized countries, and yet their labor markets fared better.

History and economics show no intrinsic conflict among technological change, full employment, and rising earnings. The dynamic interplay among task automation, innovation, and new work creation, while always disruptive, is a primary wellspring of rising productivity. Innovation improves the quantity, quality, and variety of work that a worker can accomplish in a given time. This rising productivity, in turn, enables improving living standards and the flourishing of human endeavors. Indeed, in what should be a virtuous cycle, rising productivity provides society with the resources to invest in those whose livelihoods are disrupted by the changing structure of work.

Where innovation fails to drive opportunity, however, it generates a palpable fear of the future: the suspicion that technological progress will make the country wealthier while threatening livelihoods of many. This fear exacts a high price: political and regional divisions, distrust of institutions, and mistrust of innovation itself.

The last four decades of economic history give credence to that fear. The central challenge ahead, indeed the work of the future, is to advance labor market opportunity to meet, complement, and shape technological innovations. This drive will require innovating in our labor market institutions by modernizing the laws, policies, norms, organizations, and enterprises that set the "rules of the game."

As this report documents, the labor market impacts of technologies like AI and robotics are taking years to unfold. But we have no time to spare in preparing for them. If those technologies deploy into the labor institutions of today, which were designed for the last century, we will see similar effects to recent decades: downward pressure on wages, skills, and benefits, and an increasingly bifurcated labor market. This report, and the MIT Work of the Future Task Force, suggest a better alternative: building a future for work that harvests the dividends of rapidly advancing automation and ever-more powerful computers to deliver opportunity and economic security for workers. To channel the rising productivity stemming from technological innovations into broadly shared gains, we must foster institutional innovations that complement technological change.

We are living in a period of significant disruption, but not of the kind envisioned in 2018. The final phases of researching and writing this document occurred during the 2020 months of COVID-19. Our technologies have been instrumental in enabling us to adapt via telepresence, online services, remote schooling, and telemedicine. While they don't look anything like robots, these remote work tools too are forms of automation, displacing vulnerable workers from low-pay service jobs in industries like food service, cleaning, and hospitality.

We face a labor market crisis stemming from the COVID-19 pandemic. Millions are unemployed. But technological advances had little to do with this crisis. Long before this disruption, our research on the work of the future made it clear how many in our country are failing to thrive in a labor market that generates plenty of jobs but little economic security. The effects of the pandemic have made it even more viscerally and publicly clear: Despite their official designation as "essential," most low-paid workers cannot effectively do their jobs through computing platforms. Most must be physically present to earn their livings. Some see robots taking over those roles (though few have yet). Others see the indispensable role of human flexibility as people have been essential to transforming supply chains. Still others see COVID-19 as an automation-forcing event. However it plays out, we will be living with the effects of

> History and economics show no intrinsic conflict among technological change, full employment, and rising earnings.

COVID-19 on technology and work for a long time, though those effects will look different from what anyone had anticipated in 2018.

Other forces have also roiled the 2018 visions of the future, including the rupture between the world's two largest economies and a surge of political turmoil and economic populism. These pressures are reshaping alliances, breaking apart and reorganizing global business relationships, and even altering patterns in human migration. The United States and China had friction before, but nothing like the fracture that is now occurring. What began as a trade war has morphed into a technology war.

This clash is filtering out through the economy and threatens to hinder innovation, which increasingly emerges from countries around the world, often by researchers who are collaborating across borders and time zones. How can we make sure that technological advances, whenever they come, yield prosperity that is widely shared? How can the U.S. and its workers continue to play a leading role in inventing and shaping the technologies and reaping the benefits?

Following two years of study, data collection, and analysis, the Task Force draws the following conclusions:

1. **Technological change is simultaneously replacing existing work and creating new work. It is not eliminating work altogether.**

No compelling historical or contemporary evidence suggests that technological advances are driving us toward a jobless future. On the contrary, we anticipate that in the next two decades, industrialized countries will have more job openings than workers to fill them, and that robotics and automation will play an increasingly crucial role in closing these gaps. Nevertheless, the impact of robotics and automation on workers will not be benign. These technologies, in concert with economic incentives, policy choices, and institutional forces, will alter the set of jobs available and the skills they demand.

This process is both challenging and indispensable. Inventing new ways of accomplishing existing work, new business models, and entirely new industries drives rising productivity and new jobs. Such innovations bring new occupations to life, generate demands for new forms of expertise, and create opportunities for rewarding work. Most of today's jobs hadn't even been invented in 1940. The United States needs not less, but more technological innovation to meet humanity's most pressing problems, including climate change, disease, poverty, malnutrition, and inadequate education. Meeting these challenges through investment and innovation will create opportunity and improve well-being.

2. **Momentous impacts of technological change are unfolding gradually.**

Spectacular advances in computing and communications, robotics, AI, and manufacturing processes are reshaping industries as diverse as insurance, retail, healthcare, manufacturing, and logistics and transportation. But we observe substantial time lags, often on the scale of decades, from the birth of an invention to its broad commercialization, assimilation into business processes, widespread adoption, and impacts on the workforce. We find examples of this incremental pace of change in the adoption of novel industrial robots in small and medium-sized firms, and in the still-imminent large-scale deployments of autonomous vehicles. Indeed, the most profound labor market effects of new technology that we found were less due to robotics and AI than to the continuing diffusion of decades-old (though much improved) technologies of the internet, mobile and cloud computing, and mobile phones. This time scale of change provides the opportunity to craft policies, develop skills, and foment investments to constructively shape the trajectory of change toward the greatest social and economic benefit.

3. **Rising labor productivity has not translated into broad increases in incomes because labor market institutions and policies have fallen into disrepair.**

Peer nations from Sweden to Germany to Canada have faced the same economic, technological, and global forces as the United States, and have enjoyed equally strong economic growth, but have delivered better results for their workers. What sets the United States apart are U.S.-specific institutional changes and policy choices that failed to blunt, and in some cases magnified, the consequences of these pressures on the U.S. labor market.

The U.S. has allowed traditional channels of worker voice to atrophy without fostering new institutions or buttressing existing ones. It has permitted the federal minimum wage to recede to near-irrelevance, lowering the floor under the labor market for low-paid workers. It has embraced a policy-driven expansion of free trade with the developing world, Mexico and China in particular, yet failed to direct the gains towards redressing the employment losses and retraining needs of workers.

No evidence suggests that this strategy has paid off for the United States. U.S. leadership in growth and innovation is longstanding: It led the world throughout the 20th century, and led even more definitively in the several decades immediately after World War II. Conversely, the labor market maladies documented here are recent. Nothing suggests that these failures inevitably follow from innovation or constitute costs worth paying to gain the other economic benefits that they ostensibly deliver. We can do better.

4. **Improving the quality of jobs requires innovation in labor market institutions.**

In the absence of deliberate policy, good jobs are undersupplied by markets and yet have broad social and political benefits, especially in a democracy. Work is a crucial human good. "Not simply a source of income," Task Force Research Advisory Board member Josh Cohen writes in a MIT Work of the Future research brief, "work is a way that we can learn, exercise our powers of perception, imagination, and judgement, collaborate socially, and make constructive social contributions." Even when work is solely a means of acquiring an income, it should offer a sense of purpose and not require submission to demeaning or arbitrary authority, unhealthy or unsafe conditions, or physical or mental degradation.

The U.S. must innovate to rebalance the desire of employers for low-cost, minimal commitment, and maximal flexibility, with the necessity that workers receive fair treatment, reasonable compensation, and a measure of economic security. The U.S. must craft and enforce fair labor standards, ensure effective collective bargaining, set a well-calibrated federal minimum wage, extend the scope and flexibility of its unemployment insurance system, and modernize its dysfunctional system of employer-based health insurance.

> To channel the rising productivity stemming from technological innovations into broadly shared gains, we must foster institutional innovations that complement technological change.

5. **Fostering opportunity and economic mobility necessitates cultivating and refreshing worker skills.**

Enabling workers to remain productive in a continuously evolving workplace requires empowering them with excellent skills programs at all stages of life: in primary and secondary schools, in vocational and college programs, and in ongoing adult training programs. The distinctive U.S. system for worker training has many shortcomings, but it also has unique virtues, for example, offering numerous points of entry for workers who may want to reshape their career paths or need to find new work after a layoff. The U.S. must invest in existing educational and training institutions and innovate to create new training modes to make ongoing skills development accessible, engaging, and cost-effective.

6. **Investing in innovation will drive new job creation, speed growth, and meet rising competitive challenges.**

Investments in innovation grow the economic pie, which is crucial to meeting challenges posed by a globalized and fiercely technologically competitive world economy. Throughout our studies, we found technologies that were direct results of U.S. federal investment in research and development over the past century and longer: the internet, advanced semiconductors, artificial intelligence, robotics, and autonomous vehicles, to name but a few. These new goods and services generate new industries and occupations that demand new skills and offer new earnings opportunities. The U.S. has a stellar record of supporting innovations that inventors, entrepreneurs, and creative capital deploy to support and create new businesses. We must foster and grow the U.S. innovation system to ensure that when workers are displaced by technological change, they can move to new jobs in new industries. Simultaneously, we can shape the direction of innovation through public investment and policy to maximize these benefits.

Adopting new technology creates winners and losers and will continue to do so. Involvement of all stakeholders — including workers, businesses, investors, educational and social organizations, and government — can minimize the damage done to individuals and communities and help ensure that the jobs of the future offer benefits that are shared by all. We explore this inclusive approach by examining the institutional frameworks around work, including how education and training programs can be made more effective and inclusive, as well as new ways of empowering workers who may never have the protections afforded by traditional union structures.

This report begins by documenting and diagnosing the challenges facing the U.S. labor market. Next, we survey the technological frontier to draw lessons about the pace and direction of change and its likely impacts on employment, skill demands, and opportunity. Finally, we synthesize insights from work and technology to consider how our policies and institutions should innovate to leverage technological and economic opportunities while surmounting the substantial challenges that lie ahead.

CHAPTER 2

# Labor Markets and Growth

We envision a labor market that, in concert with rapidly advancing automation and computation, offers dignity, opportunity and economic security for workers. How can we make that labor market a reality? Research in multiple fields, from economics and engineering to history and political science, tells us how we got here and offers some glimpses of possible futures. This chapter draws lessons from that work and synthesizes them to point towards ways forward.

## 2.1 Two Faces of Technological Change: Task Automation and New Work Creation

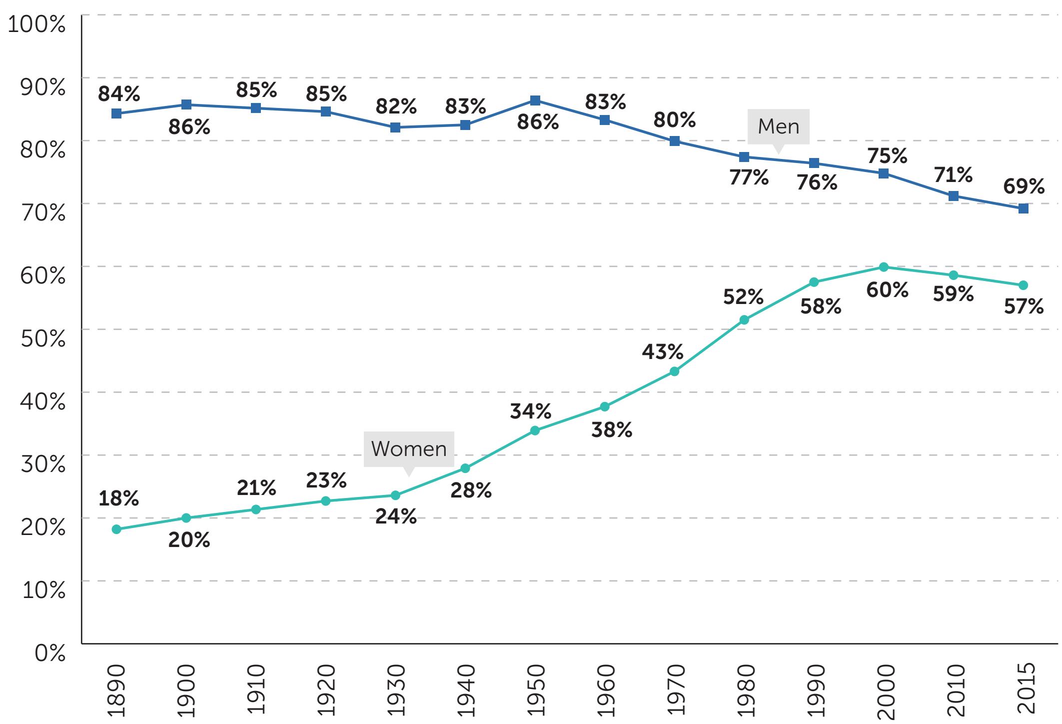
Technological change enables people to accomplish previously infeasible tasks or to perform conventional tasks with greater efficiency. Such changes have helped elevate humanity from the continual threats of darkness, hunger, illness, physical dangers, and backbreaking labor over multiple centuries.[1] Such technological progress is desirable, indeed essential, for addressing humanity's most pressing problems, including climate change, disease, poverty, malnutrition, and lack of education.

But technological advances do not necessarily benefit everyone, let alone all workers. The majority of adults in industrialized countries are currently able to escape poverty by working in paid employment. But this state of affairs is exceptional and should not be taken for granted.[2] Does technological change, and automation in particular, threaten this favorable arrangement?

The threat could take two forms. First, automation could ultimately reduce the number of jobs in which humans are more productive than machines, spurring mass unemployment.[3] Second, automation could reshape job skill demands such that a minority of workers with highly specialized skills earn outsized rewards while the majority of citizens lose ground.

**Figure 1. The Fraction of Adults in Paid Employment Has Risen for Most of the Past 125 Years**

**EMPLOYMENT TO POPULATION RATIO OF U.S. ADULTS BY SEX, 1890–2015**




*Source: Blau, Francine D, and Anne E Winkler. The Economics of Women, Men, and Work. 8th ed. New York: Oxford Press, 2018, Table 5.1*

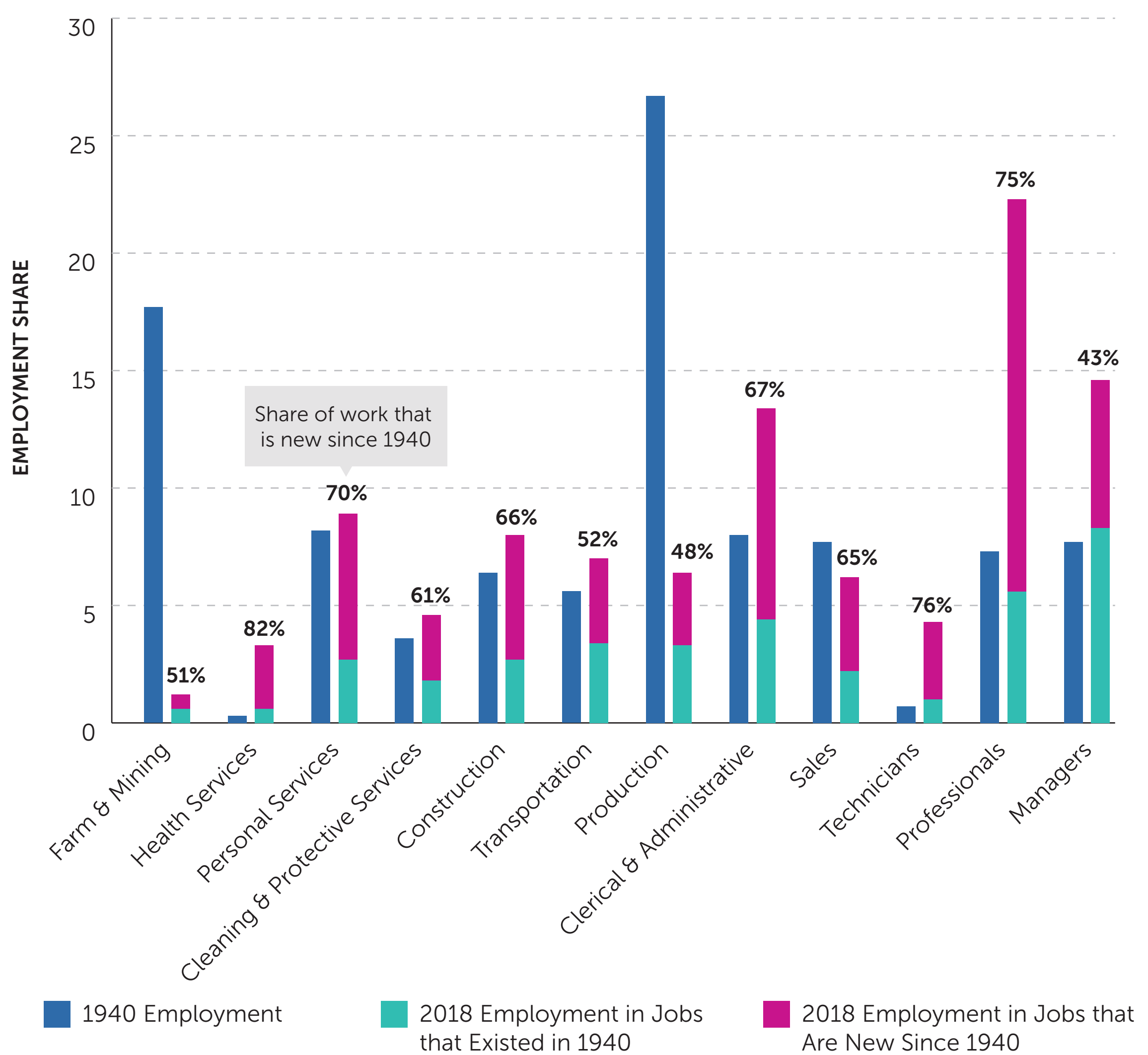
The prospect of mass unemployment runs contrary to the evidence. Even as technological advances have made life longer, more comfortable, and more interesting, it has generally led to net job creation rather than net job destruction. How do we know this to be true? Figure 1 shows that the fraction of U.S. adults working in paid employment rose steeply throughout the 20th century.[4] If automation (or its predecessor, mechanization) tends to render human labor redundant, then paid employment would not have risen persistently over the most technologically innovative century in human history. Indeed, in the economic research on automation and employment, no rigorous evidence suggests that automation has caused aggregate employment to fall over a sustained time period.[5] Moreover, even as concern about technological unemployment has risen in recent years, the industrialized world has seen sustained rapid employment growth.

If automation "saves labor," why does it not reduce total employment? While this question lacks a definitive answer, it is certain that even as technological advances displace human labor from some tasks, they spur three other forces that generate new work. First, automation makes workers more productive in the tasks that are not automated: roofers wield pneumatic nail guns to hang shingles; doctors deploy portfolios of tests to make diagnoses; architects rapidly render designs; teachers deliver lessons through telepresence; filmmakers use computer graphics to simulate unworldly action sequences; and long-haul truck drivers upload their route parameters to cloud-based dispatching platforms to ensure that they never ride with an empty load. In each of these instances, automation of a subset of tasks augments the productivity of workers accomplishing larger objectives by vastly increasing their efficiency.

Second, automation drives productivity increases that raise total income in the economy. Much of this income is then spent on additional goods and services — larger houses, safer vehicles, better meals and entertainment, more frequent and distant travel, further education, and more comprehensive healthcare. All of this consumption demands workers and hence raises employment.

Finally, and perhaps most profoundly, even as automation eliminates human labor from certain tasks, technological change leads to new kinds of work. New goods and services, new industries and occupations demand new skills and offer new earnings opportunities. A century ago, there was no computer industry, no solar energy jobs, no television networks, and no air travel sector. Automobiles, electrification, and home telephones were only becoming commonplace. In the past century, new industries, products, and services have generated vast numbers of new jobs, often demanding higher skill levels and paying higher wages than those that preceded them. These innovations transformed the economy.

**Figure 2. More Than 60% of Jobs Done in 2018 Had Not Yet Been "Invented" in 1940**




*Notes: Comparing the Distribution of Employment in 1940 and 1918 Across Major Occupations; Distinguishing Job Categories Added Between 1940 and 2018 from Job Categories Present in 1940.*
*Source: Autor, Salomons, and Seegmiller, 2020.*

Consider the set of jobs active in 1940 as compared to those active today, as shown in Figure 2. In 2018, 63% of jobs in new occupational titles had not yet been "invented" as of 1940.[6] Many of these new jobs are directly enabled by technology, including jobs in information technology, solar and wind power, engineering, design, installation, and repair of new products, and new medical specialties (see Table 1).

But not all new work is in "high tech" jobs. Some is found in in-person service jobs, such as mental-health counselors, chat room hosts, sommeliers, home health aides, and fitness coaches. These roles partly reflect new demands stemming from rising incomes (an indirect effect of rising productivity) and the novel needs of individuals in an industrialized society. Meanwhile, traditional sectors, such as agriculture and production, have created less work, and new occupations have stopped emerging.

Jobs recede in some sectors, such as agriculture, as technology advances. In others, like manufacturing, globalization reduces domestic demand. Sometimes consumer tastes shift. Simultaneously, new work emerges in innovative industries, such as computing, renewable energy, and healthcare. Rising incomes also create new consumption demands, such as for new fitness clubs.

Many new jobs have their roots in earlier decades of investment. In the second half of the 20th century, the U.S. built a research and development infrastructure that enabled the nation to innovate more rapidly and effectively than other advanced economies.[7] As a prime example, computer and internet revolutions of the 1980s and 1990s, as well as the current progress in AI and robotics, stem directly from long-term investments by agencies like DARPA (the Defense Advanced Research Projects Agency). Not only did these investments speed innovation, they provided the training ground for generations of experts and built clusters of employment in high-tech industries that persist for decades.

### Table 1. Examples of New Occupations Added to the U.S. Census Between 1920 and 2018

| YEAR | EXAMPLE TITLES ADDED | |
|---|---|---|
| 1940 | Automatic welding machine operator | Gambling dealer |
| 1950 | Airplane designer | Beautician |
| 1960 | Textile chemist | Pageants director |
| 1970 | Engineer computer application | Mental-health counselor |
| 1980 | Controller, remotely piloted vehicle | Hypnotherapist |
| 1990 | Certified medical technician | Conference planner |
| 2000 | Artificial intelligence specialist | Chat room host/monitor |
| 2010 | Wind turbine technician | Sommelier |
| 2018 | Pediatric vascular surgeon | Drama therapist |

*Source: Autor, Salomons, and Seegmiller, 2020*

> No economic law dictates that the creation of new work must equal or exceed the elimination of old work. Still, history shows that they tend to evolve together.

The trajectory of work creation mirrored the direction of innovation throughout the 20th and 21st centuries. The flowering of new occupations and industries shifted from manufacturing and heavy industry in the first decades of the 20th century to high-tech process-intensive sectors during the post–World War II decades (e.g., photography, metallurgy, material chemistry). In the later decades of the 20th century, the emergence of new occupations shifted again to instruments, information, and electronics, coinciding with the information technology revolution.[8] Innovation spurs job creation, and that innovation is frequently catalyzed, funded, and shaped by public investment.

However, these processes do not benefit everyone. Changes in the structure of work inevitably generate riches for some and hardships for others. Merely to keep pace with shifting product and skill demands, workers, firms, and governments must make costly investments. Recent decades have witnessed sharp declines in sectors, such as steel, mining, and textile production, which have ushered in concentrated and persistent job loss in communities specializing in these activities.[9] Even if some of these transitions were necessary, such as the progression from coal to cleaner energy, the net benefits do not erase the hardship borne by those who found themselves on the wrong side of the labor demand curve.

No economic law dictates that the creation of new work must equal or exceed the elimination of old work. Still, history shows that they tend to evolve together.[10] Indeed, as detailed in Chapter 3, in each instance where the Task Force focused its expertise on specific technologies, we found technological change — while visible and auguring vast potential — moving less rapidly, and displacing fewer jobs, than portrayed in popular accounts. New technologies themselves are often astounding, but it can take decades from the birth of an invention to its commercialization, assimilation into business processes, standardization, widespread adoption, and broader impacts on the workforce. This evolutionary pace of change opens opportunities to craft policies, develop skills, and foment investments to shape the trajectory of change to create broader social and economic benefits.

As noted in the previous chapter, history and economics show no intrinsic conflict among technological change, full employment, and rising earnings. The dynamic interplay among task automation, innovation, and new work creation, while always disruptive, is a primary wellspring of rising productivity.

This brings us to a central concern: whether rising productivity generates broadly improving living standards or instead enriches a relatively small subset of the population depends on the societal institutions that channel productivity into incomes. These institutions interact with the labor market, which itself accounts for the majority of the economy.[11] In this crucial arena, the United States has performed poorly along multiple dimensions.

Over the last four decades, wage growth for the majority of U.S. workers has diverged from overall productivity growth. Alongside weak wage growth for rank-and-file workers, this divergence has entailed multiple labor market maladies with enormous social consequences: low-paid, insecure noncollege jobs; low participation in the labor force; historically high levels of earnings inequality; and festering earnings and employment disparities among races that have not substantially improved in decades.

No single cause accounts for these multiple maladies, but three factors appear most important. First, the advancing digitalization of work has made highly educated workers more productive and made less-educated workers easier to replace with machinery. Second, the acceleration of trade and globalization, spurred by surging U.S. imports from China and rapid outsourcing of U.S. production work, caused a rapid decline of manufacturing employment. Finally, institutions that once enabled rank-and-file workers to bargain for wage growth to match productivity growth have eroded. This erosion is seen in plummeting labor union membership and falling real federal minimum wage levels that are now approaching historic lows.

These unfavorable outcomes were not an inevitable consequence of technology, globalization, or market forces. No other wealthy industrialized country has seen an equally large rise in inequality or equally severe wage stagnation among rank-and-file workers as has the U.S.

Boosted by rising education and skill levels, advancing workplace technologies, growing global integration, and numerous accompanying factors, labor productivity in the United States has risen steeply. And yet, these productivity gains have not translated into broadly based increases in incomes because the supporting societal institutions and labor market policies that perform that function have fallen into disrepair. The U.S. must reinvigorate and modernize those institutions and policies to restore the synergy between rising productivity and improvements in work.

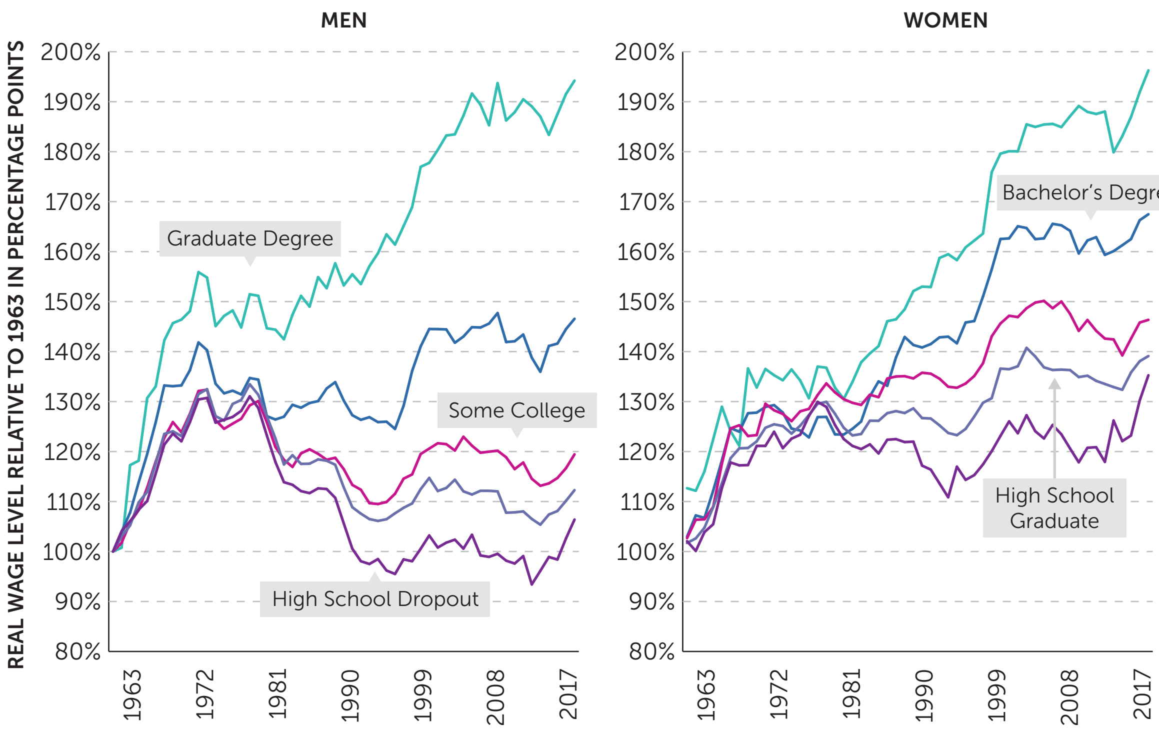
The remainder of this chapter delves into the basis for these conclusions.

## 2.2 Rising Inequality and the Great Divergence

Starting in the 1960s and continuing through the early 1980s, earnings grew for U.S. workers of both sexes, regardless of education (see Figure 3). In fact, the U.S. economy delivered stellar, broadly shared growth in the preceding two decades as well, from the end of World War II through 1963. The growth in earnings was both rapid and evenly distributed.

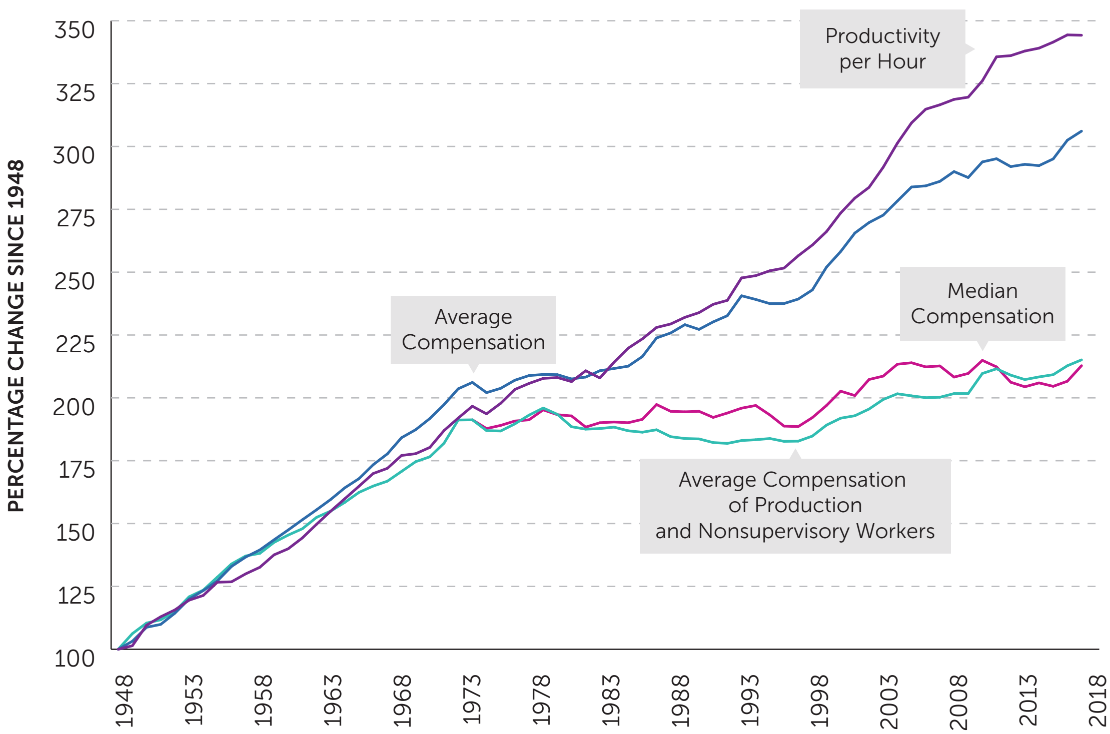
**Figure 3. Real Wages Have Risen for College Graduates and Fallen for Workers with High School Degree or Less Since 1980**

**CUMULATIVE CHANGE IN REAL WEEKLY EARNINGS OF WORKING-AGE ADULTS AGES 18–64, 1963–2017**




*Source: Autor, David H. "Work of the Past, Work of the Future." AEA Papers and Proceedings 109 (May 2019): 1–32.*

Figure 4. Productivity and Compensation Growth in the United States, 1948–2016




*Source: Summers and Stansbury (2018, Figures 1 and 2). Note: Data from BLS, BEA, and Economic Policy Institute. Labor productivity is total economy real output per hour. Average compensation is total economy real compensation per hour, deflated by CPI-U-RS. Compensation is median economy real compensation per hour and mean real compensation for production and nonsupervisory workers, both deflated by CPI-U-RS. The chart depicts the percent change in each series from its value in 1948 for all series exception median compensation. The median compensation series starts in 1973 and is normalized to equal the average compensation of production and non-supervisory workers in that year.*

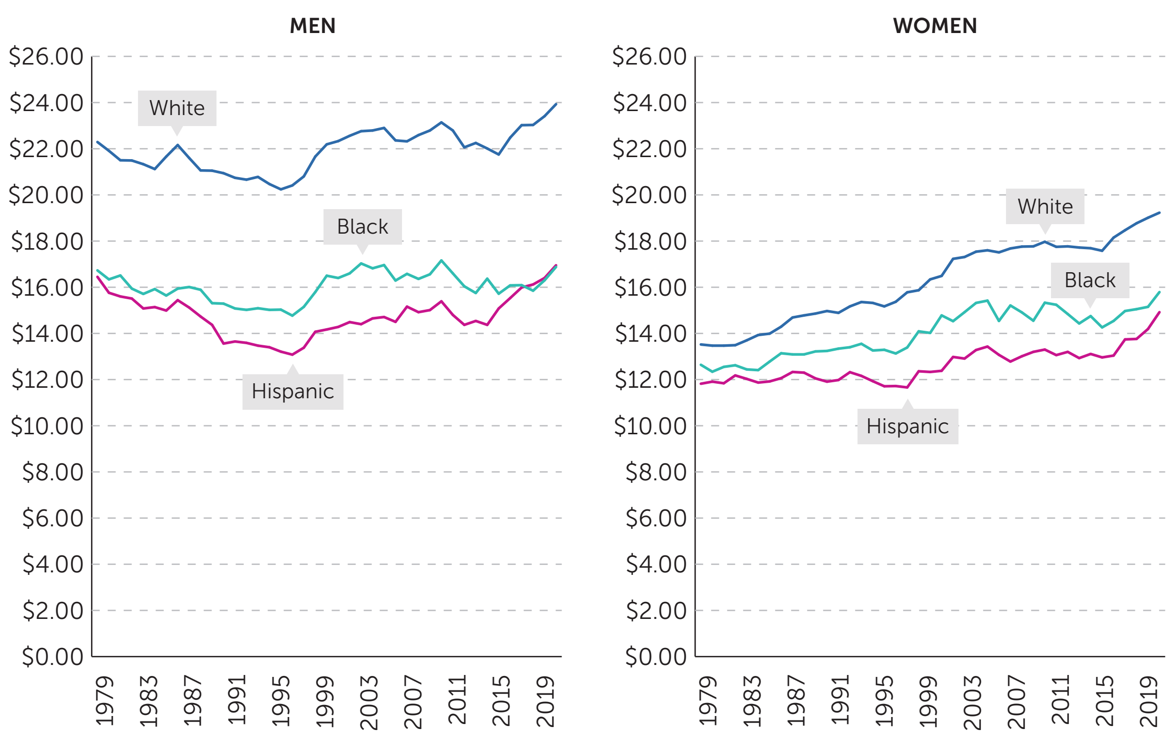
Today's concerns originate in what happened after 1980. As compared to the earlier period, earnings growth in the past 40 years has been slow, sporadic, and unequal. Between 1948 and 1978, U.S. total output per hour of work rose by 108%, as shown in Figure 4, an annual growth rate of 2.4%. During the same period, average compensation of production and non-supervisory workers (a stand-in for the median since median wages are not available for this period) rose in near lock-step, increasing by 95%. By contrast, in the subsequent four decades, between 1978 and 2016, aggregate productivity rose by a further 66% (an annual growth rate of 1.3%), while production and nonsupervisory compensation rose by a mere 10% and median compensation rose by 9%. This growing gulf between rising productivity and stagnating median wages is often referred to as "the great divergence."

Within this "great divergence" lurk further disparities of race and gender. In this period, white men and white women notched the bulk of the modest median wage growth (see Figure 5). Specifically, the median hourly wages of white men rose by 7% while those among Black and Hispanic men rose by only 1% and 3%, respectively. And among women, median hourly wages rose by 42% among white women, relative to only 25% and 26% among Black and Hispanic women, respectively.

Reported changes in "real" wage levels should be viewed as approximate; it is not possible to capture all changes in living standards across decades using a single cost of living index. Indeed, the true purchasing power of the median worker has likely risen faster than these numbers suggest, which also means that productivity likely rose faster than depicted here and that real wages stagnated by less. But these caveats do not alter the key points made by Figures 4 and 5: Median earnings stagnated relative to productivity growth over the last four decades; earnings of women rose faster than earnings of men; and earnings of whites rose faster than those of Blacks or Hispanics.

Could the decoupling between average productivity growth and median wage growth simply mean that the median worker is not getting much more productive while the productivity of high-wage, high-education workers is surging ahead?[12] This idea is challenging to test since economic data measures average productivity of industries and economies, not productivity of individual workers. However, other countries have also experienced rising educational wage differentials and a "decoupling" between productivity growth and median earnings growth. This pattern suggests that technological factors that countries have in common — as opposed to institutional factors that they do not — are likely part of the explanation. But the U.S. is an extreme case. Among 24 countries for which data is available, the OECD reports that the U.S. had the third-largest decoupling between productivity growth (1.8%) and median wage growth (0.5%) between 1995 and 2013, a gap of 1.3%, exceeded by only Poland and Korea.[13] By comparison, the gap between productivity growth and median wage growth was less than half as large (0.7%) in Canada, the Netherlands, Australia, and Japan; and only one-sixth as large (0.2%) in Germany, Austria, and Norway.[14]

**Figure 5. Modest Median Wage Increases in the U.S. Since 1979 Were Concentrated Among White Men and Women**




*Source: Economic Policy Institute, State of Working America Data Library, "Median/Average Hourly Wages," 2019. https://www.epi.org/data/#?subject=wage-avg*

Amidst this general stagnation, not all workers fared poorly. In fact, Figure 4 shows that average worker compensation roughly kept pace with productivity over the last four decades (at least until the early 2000s), even while median compensation did not. The relative strength of average compensation is largely the result of sharp increases in pay for those with high education. Real earnings of males with college and post-college degrees rose by 25% to 50% between 1980 and 2017, as shown in Figure 3.

By contrast, real weekly wage earnings among men without a four-year college degree peaked around 1980 and fell over the next several decades. While there was some wage rebound during the high-pressure labor markets of the late 1990s and the few years prior to the COVID-19 pandemic, average weekly earnings of males with some college, high school, or less than high school education were 10% to 20% lower in 2017 than in 1980.

Earnings growth among women was stronger than among men but just as unequal. Among women with college or post-college education, real earnings rose steeply, by 40 to 60 percentage points, between 1980 and 2017. Among women with less than a four-year degree, however, wages rose by no more than 10 percentage points.

The rising earnings gap between workers with and without four-year college degrees drives a large fraction of the growth of earnings inequality. This gap has grown in almost every industrialized country, though as in many domains, the U.S. presents an extreme case.[15] Conventional supply and demand forces help to explain what is going on. Throughout much of the 20th century, successive waves of innovation— electrification, mass production, motorized transportation, telecommunications—intensified the demand for formal education, technical expertise, and cognitive ability upward. Boosted by the War II and Korean War GI bills, these demands were met by a surge in new college graduates.[16] In the 1980s and 1990s, the virtuous coincidence between rising college demand and expanding college supply broke down: College enrollment among young U.S. adults flatlined and even fell in the case of U.S. men, and the college wage premium surged. That premium has exceeded its previous high-water mark, set in 1915, in every year of the 21st century.[17]

This history underscores that to boost individual and aggregate productivity, the U.S. must continually invest to raise education and skill levels, as it has done for more than a century. But this history does not explain why the earnings of the median U.S. worker decoupled from productivity growth four decades ago, even while the education level of that median worker was rising rapidly.[18]

One additional factor that contributes to the rising gap between productivity and wage growth in the U.S. after the year 2000 is the falling share of national income paid to labor. That is, a rising share of national income is paid to capital (i.e., equipment, buildings, rentals, purchased services) and to profits over the last two decades. The cause of labor's falling share of national income is heavily debated. Potential explanations include automation, globalization, changes in market structure that favor superstar firms, and a failure of competition policy.[19] Still, researchers agree that the U.S. has experienced perhaps the largest fall in labor's share of national income of any industrialized country.[20] The decoupling between productivity growth and median wage growth starts at least two decades earlier, however, indicating that the falling labor share is not its primary cause.

This decoupling becomes an even more acute issue when productivity growth decelerates, as has occurred in the United States and many industrialized countries since approximately 2005. The research brief by Task Force member Erik Brynjolfsson along with Seth Benzell and Daniel Rock documents that despite the seeming ubiquity of powerful new technologies with enormous industrial potential, the rate of U.S. productivity growth in recent years has been disappointingly low.[21] U.S. productivity growth averaged 2.8% annually between 1995 and 2005, but it has been less than half as rapid since that time.[22]

## 2.3 Employment Polarization and Diverging Job Quality

One factor that both reflects and contributes to these rising earnings disparities is the polarization of job growth into traditionally high-wage and traditionally low-wage occupations at the expense of the middle tier. At the high end of the labor market, a growing cadre of high-education, high-wage occupations offer strong career prospects, rising lifetime earnings, and significant employment security. At the other end, low-education, low-wage occupations provide little economic security and limited career earnings growth. Traditional middle-tier jobs in production, operative, clerical and administrative support, and sales occupations are in decline (see Figure 6).

The causes of labor market polarization are well understood. The movement of labor from agriculture to industry to services over the 20th century has slowly eroded demand for physical labor and raised the centrality of cognitive labor in practically every walk of life. The past four decades of computerization, in particular, have extended the reach of this process by displacing workers from performing routine, codifiable cognitive tasks (e.g., bookkeeping, clerical work, and repetitive production tasks) that are now readily scripted with computer software and performed by inexpensive digital machines. This ongoing process of machine substitution for routine human labor tends to increase the productivity of educated workers whose jobs rely on information, calculation, problem-solving, and communication — workers in medicine, marketing, design, and research, for example. It simultaneously displaces the middle-skill workers who in many cases provided these information-gathering, organizational, and calculation tasks. These include sales workers, office workers, administrative support workers, and assembly line production positions.[23]

Ironically, digitalization has had the smallest impact on the tasks of workers in low-paid manual and service jobs, such as food service workers, cleaners, janitors, landscapers, security guards, home health aides, vehicle drivers, and numerous entertainment and recreation workers.[24] Performing these jobs demands physical dexterity, visual recognition, face-to-face communications, and situational adaptability, which remain largely out of reach of current hardware and software but are readily accomplished by adults with modest levels of education. As middle-skill occupations have declined, manual and service occupations have become an increasingly central job category for those with high school or lower education.

This polarization likely will not come to a halt any time soon. The U.S. Bureau of Labor Statistics (BLS) forecasts that the U.S. will add approximately 6 million jobs in net between 2019 and 2029.[25] Of those 6 million, 4.8 million are projected to emerge in just 30 occupations (see Table 2). Two-thirds of those jobs are projected to occur in occupations that pay below the median wage.

Consistent with ongoing employment polarization, the three occupations projected to add the most jobs are tied to in-person services: home health and personal care aides (1.2 million); fast-food and counter workers (0.46 million); and restaurant cooks (0.23 million). The three occupations that are projected to shed the most jobs in net are: cashiers; secretaries, and administrative assistants; and miscellaneous assemblers and fabricators.[26] The primary duties of all three jobs include performing codifiable information-processing and repetitive assembly tasks that are susceptible to automation.[27]

We stress, however, that while ongoing occupational polarization is eroding employment in middle-skill production, operative, technical, and administrative positions, the U.S. should not stop investing in these types of jobs. Employers will continue to need to hire people for these occupations as workers retire or transition to other sectors. Meanwhile, the rapid expansion of the healthcare sector will add many middle-skill jobs in non-traditional occupations.[28] Jobs such as respiratory therapist, dental hygienist, and clinical laboratory technician offer middle-income salaries to workers with an associate's degree in the relevant field.[29] These fields are strong candidates for targeted training investments.

Employment polarization is not a problem on its own if wages and benefits found in low-paid U.S. occupations enable workers to rise above poverty and attain a reasonable expectation of economic security. But they do not. By almost every measure of job quality — pay, working environment, prior notice of job termination, and access to paid vacation, sick time, and family leave — less-educated and low-paid U.S. workers fare worse than comparable workers in other wealthy industrialized nations.[30] Figure 7 provides one such benchmark, comparing purchasing-power adjusted gross (pre-tax) hourly pay of low-skill workers in 22 OECD countries in 2015.[31]

Low-skill U.S. workers earn only 79% as much as low-skill UK workers, only 74% as much as low-skill Canadian workers, and only 57% as much as low-skill Germans. While no single metric makes for a complete comparison, numerous analyses support the qualitative picture painted by Figure 7.[32]

**Figure 6. Employment Growth Has Polarized Between High- and Low-Paid Occupations**

**CHANGES IN OCCUPATIONAL EMPLOYMENT SHARES AMONG WORKING-AGE ADULTS, 1980–2015**

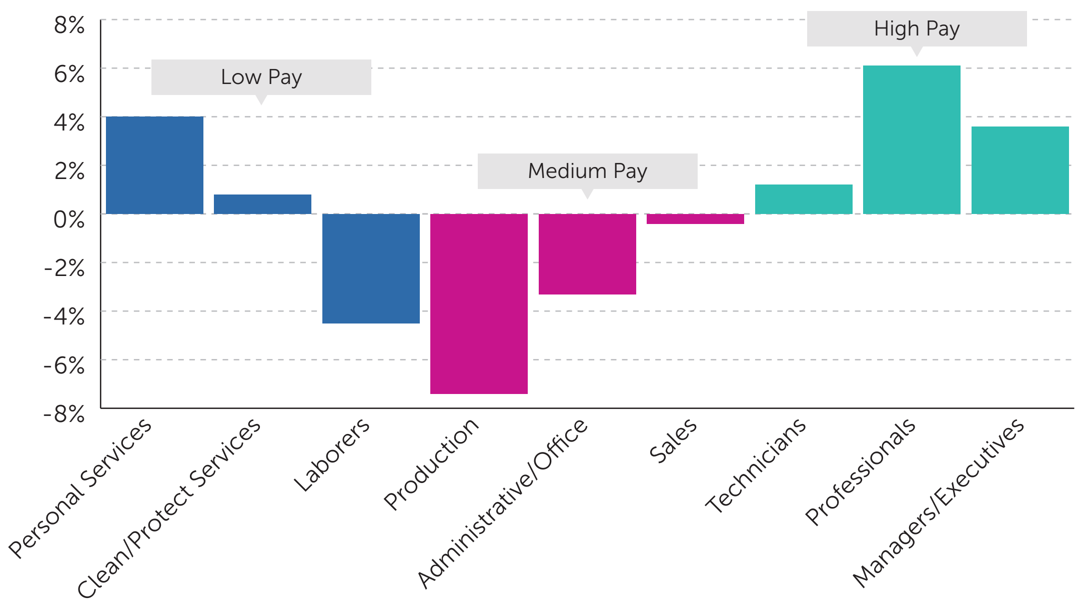
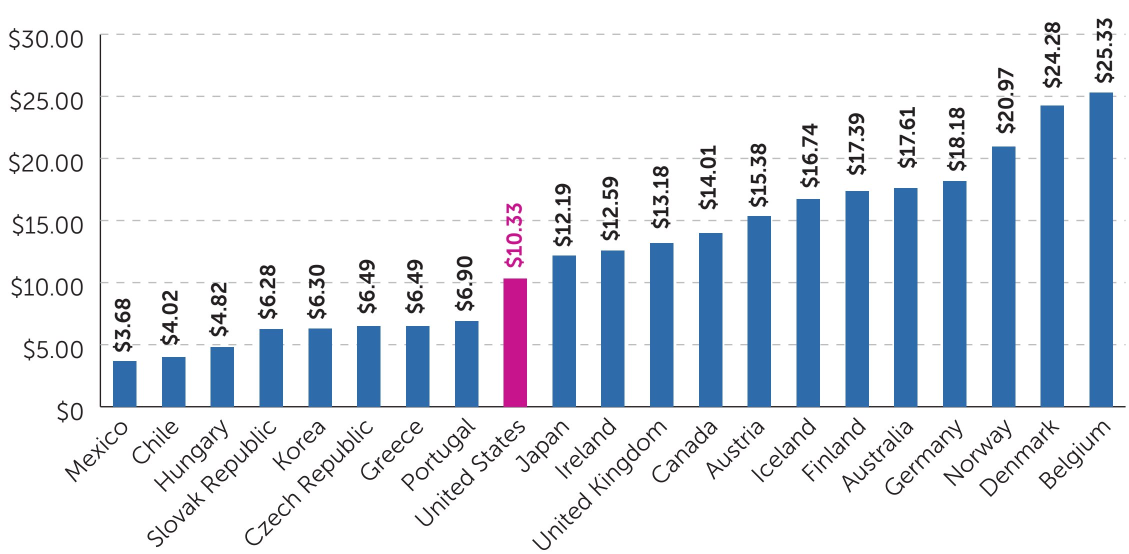



*Figure is constructed using U.S. Census of Population data for 1980, 1990, and 2000, and pooled American Community Survey (ACS) data for years 2014 through 2016, sourced from IPUMS (Ruggles et al., 2018). Sample includes working-age adults ages 16–64 excluding those in the military. Occupational classifications are harmonized across decades using the classification scheme developed by Dorn (2009).*

**Figure 7. Low-Skill Workers in the U.S. Receive Lower Pay Than in Other Industrialized Countries**

**PPP-ADJUSTED GROSS HOURLY EARNINGS OF LOW-SKILL WORKERS IN THE U.S. AND OTHER OECD NATIONS**




*Source: https://stats.oecd.org/Index.aspx?QueryId=82334*

A recent *New York Times* article by Nicholas Kristof memorably illustrates the poor standing of low-wage U.S. workers relative to their counterparts in other industrialized countries.[33] Kristof points out that the starting pay for a grill worker at a McDonald's restaurant in Denmark is about $22 an hour. This figure, which includes pay supplements, would shock any fast-food worker in Indiana, California, or anywhere else in the U.S., including in expensive cities where the so-called "Fight for 15" movement for a higher minimum wage remains an uphill struggle. Yet, these pay differentials actually understate the true gap in compensation. The McDonald's worker in Denmark receives six weeks of paid vacation a year, life insurance, and a pension. Such benefits are unheard of for starting grill cooks at McDonald's restaurants in the United States.[34]

## 2.4 The Geography of Divergence: The Faltering Urban Escalator of Opportunity

Inequality in the United States also has a geographic dimension. Over the past three decades, the United States has seen steeply rising income levels and bustling prosperity in cities such as New York, San Francisco, and Los Angeles. Job opportunities and higher wages attract highly educated workers to such knowledge centers. Indeed, in contrast to predictions about the "death of distance" due to the internet and telecommunications technology, urban areas have become more, not less, attractive, leading to increasing divergence in the economic fortunes of urban vs. rural and younger vs. older areas. Some mid-size cities such as Kansas City, Columbus, Charlotte, and Nashville have also benefited from the knowledge economy while leveraging their relative affordability.

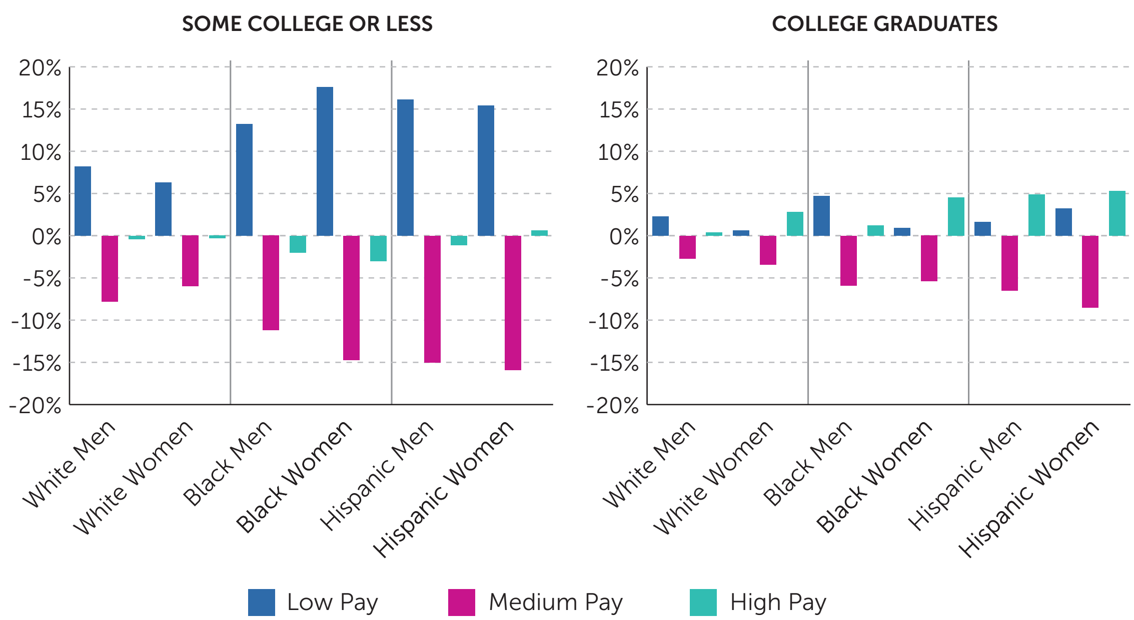
Elsewhere, in many once-thriving metropolitan areas in states from Mississippi to Michigan, the situation is more distressing. These regions face economic stagnation, declining employment of adults in their prime working years, and high rates of receipt of federal disability benefits.

Non-college educated workers used to be able to earn more by moving to cities, but no longer. The economic escalator that U.S. cities once offered to workers of all backgrounds has slowed. Even in the wealthiest U.S. cities, the workforce is increasingly bifurcated. On the one hand, high-wage professionals enjoy the amenities that thriving urban areas can offer. On the other hand, an underclass of less-educated service workers gets by with diminishing purchasing power while attending to the care, comfort, and convenience of the more affluent.

These trends have been particularly harmful to the job prospects of minority workers, who are overrepresented in U.S. cities.[35] Among non-college educated whites, employment in mid-paying occupations fell by 6 to 8 percentage points in urban relative to non-urban areas, as shown in Figure 8. Blacks and Hispanics experienced declines twice as large: 12 to 16 percentage points. In all cases, these falls in mid-pay employment were matched by a rise in low-pay employment. Data show no upward occupational mobility among non-college urban workers. Moreover, although occupational polarization is less pronounced among college-educated urban workers, it is again more than twice as large among Black and Hispanic than white college graduates.[36]

Figure 8. Urban Occupational Polarization Has Been Much Greater Among Minority Workers

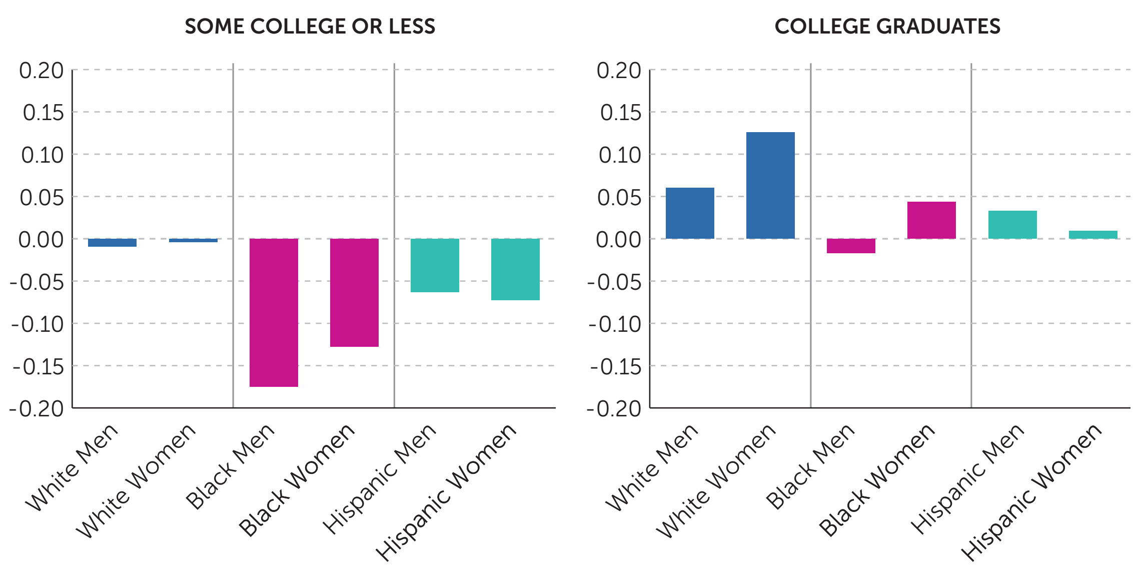
**CHANGES IN OCCUPATIONAL EMPLOYMENT SHARES IN URBAN VS. NON-URBAN LABOR MARKETS BY EDUCATION, GENDER, AND RACE/ETHNICITY, 1980–2015**




*Source: David Autor, "The Faltering Escalator of Urban Opportunity", MIT Work of the Future Research Brief (July 2020).*

Figure 9. The Urban Wage Premium Has Fallen Much More Among Minority Workers

**DIFFERENTIAL URBAN WAGE POLARIZATION AMONG MINORITIES IN URBAN LABOR MARKETS: PERCENTAGE CHANGES IN REAL WAGE LEVELS (NOT ADJUSTING FOR LOCAL COST OF LIVING) IN URBAN VS. NON-URBAN LABOR MARKETS BY EDUCATION, GENDER, AND RACE/ETHNICITY, 1980–2015**




*Source: David Autor, "The Faltering Escalator of Urban Opportunity", MIT Work of the Future Research Brief (July 2020).*

As jobs in urban areas have polarized, the non-college urban wage premium has fallen, and the decline has been greatest among Black and Hispanic workers (see Figure 9). The urban differential dropped by 5 to 7 percentage points among non-college Hispanics and by 12 to 16 percentage points among non-college Blacks.[37] Conversely, there was almost no decline among non-college whites. And even among college-educated workers, where the urban wage premium generally rose, minorities fared less well. Gains were larger for whites of both sexes than for Blacks and Hispanics of either sex. And, consistent with the adverse occupational shifts plotted above, urban Black college-educated men saw their wages fall relative to their non-urban counterparts — a distressing result that deserves deeper study than we can offer here.

## 2.5 Rising Income Concentration

As median wages have stagnated and incomes of highly educated workers have risen, ever-larger shares of national income have flowed to the very top earners. Between 1979 and 2018, the share of all pre-tax national income flowing to the top 10% of adults rose from 35% to 47% — meaning that 10% of individual adults received almost half of all national income. Simultaneously, the share of national income accruing to the top one percent of adults rose from 11% to 19%, meaning that one percent of adults received a fifth of all income. As this occurred, the share of total income flowing to the bottom fifty percent of adults declined from 20% to 14%.[38]

The rise of top incomes has multiple causes, including technology-fueled "superstar" effects that enable top workers and firms in numerous sectors to command outsized market share (e.g. Google, Facebook, ExxonMobil, Disney, BlackRock); the ratcheting down of top tax rates that effectively penalized paying extremely high salaries to top executives; and changing norms about what constitutes reasonable pay levels for executives, managers, and line workers.[39]

The U.S. is again an outlier in both the level of income concentration and the degree of its increase. Among industrialized Anglophone, Western European, and Northern European nations, none approaches the U.S. in either the share of income accruing to the top one percent or the increase in this share over the past four decades.[40] While tax and transfer policies could in theory offset rising pre-tax income concentration, the U.S. does less to offset inequality through taxation than do most European countries (though interestingly, not less than Canada or Sweden).[41] The net result is that the U.S. has higher after-tax inequality, and has seen a steeper rise, than other industrialized countries.

## 2.6 Is the U.S. Getting a Positive Return on Its Inequality?

Could the United States have done better for rank-and-file workers over the last four decades? To some readers, the answer is self-evidently yes. But those who view the U.S. economy through a laissez-faire lens may disagree: From this vantage point, the extreme inequality of market outcomes in the U.S. is a necessary condition — and perhaps a worthy price to pay — for the dynamism, economic mobility, and outsized economic growth that the U.S. economy delivers. By this reasoning, the U.S. could not do better without sacrificing other desirable outcomes.

Is this reasoning correct? Studies of different countries that examine whether inequality helps or hurts economic growth are inconclusive.[42] Still, the data supports a more straightforward conclusion for the U.S.: The nation is getting a low "return" on its inequality.

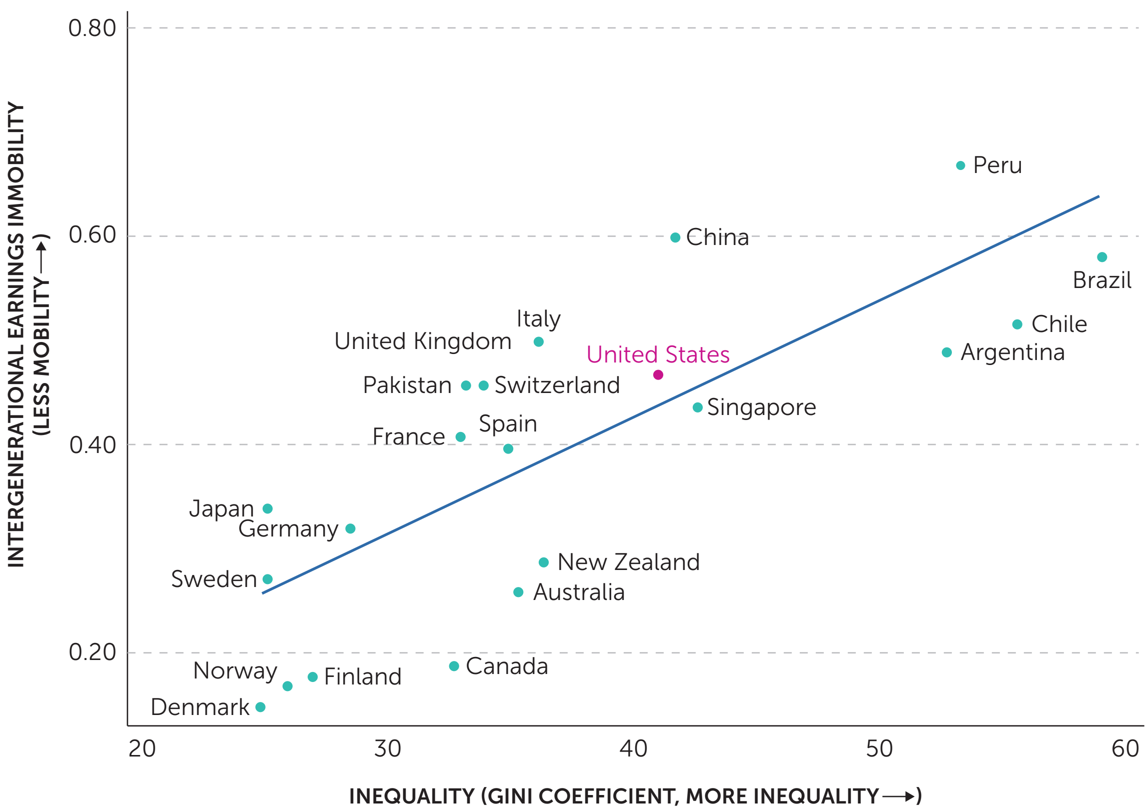
The unfavorable returns on inequality in the U.S. manifests in multiple ways. Consider first the share of the working-age population that is employed. A common economic presumption is that countries that do not tolerate high levels of inequality will instead have low employment rates because workers with low productivity will be "priced out" of the labor market — that is, made unemployable. By this reasoning, given that it has almost no wage floors, the U.S. should enjoy something closer to full employment than peer nations. The data does not bear out this prediction, as Figure 10 documents. The U.S. employment rates of both men and women are decidedly middle of the pack and have fallen sharply relative to peer countries over the last two decades.

**Figure 10. Comparing Employment to Population Rates of Working Age Men and Women Between the U.S. and OECD, 1970 – 2019**


*Source: OECD.stat. Employment to population rates, adults ages 25 – 64.*

Consider a second metric of economic performance: upward mobility between generations. Among industrialized countries, the U.S. stands out for its extremes of rich and poor. Indeed, to locate another large country with greater inequality, one must expand the set to include less-developed nations such as China or Brazil. If high U.S. inequality and accompanying economic dynamism provided U.S. children with better odds of ascending the economic ladder over their lifetimes, the U.S. ought to score high on inequality and low on immobility. Figure 11 shows that the reverse is true. The U.S. has one of the lowest rates of intergenerational mobility among wealthy democratic countries, considerably below that of France, Germany, Sweden, Australia, or Canada. As highlighted by Chetty et al.,[43] the likelihood that a U.S. child born to parents in the bottom fifth of the income distribution will reach the top fifth in adulthood is actually about twice as high in Canada (13.5%).[44] Upward mobility is not a dividend that the U.S. receives on its outsized inequality.

**Figure 11. Across Countries, More Earnings Inequality Is Associated with Lower Intergenerational Economic Mobility**




*Source: Miles Corak (2013), "Inequality from Generation to Generation: The United States in Comparison," in Robert Rycroft (editor), The Economics of Inequality, Poverty, and Discrimination in the 21st Century, ABC-CLIO https://milescorak.com/2012/01/12/here-is-the-source-for-the-great-gatsby-curve-in-the-alan-krueger-speech-at-the-center-for-american-progress/*

> Although the U.S. Labor market has delivered little to rank-and-file workers in recent decades, one should not lose sight of the strengths of the U.S. innovative ecosystem.

While robust intergenerational mobility does not necessarily imply a strong labor market or vice versa, these two outcomes are surprisingly closely connected. Research has shown that the decline in absolute mobility in the U.S. across cohorts is almost perfectly predicted by the growth in the real median income levels of young adults across generations. [45] When median incomes were rising strongly across generations, as was the case in the decades immediately after World War II, absolute income mobility rates were high. When cross-generational growth in median wages flatlined, absolute economic mobility fell in tandem.

A second place to look for an outsized "return" on U.S. inequality is faster economic growth. In general, poorer countries grow faster than rich countries — with important exceptions — as they ride the coattails of key innovations emanating from the rich world (e.g., electrification, telecommunications, medicine). Since rich countries have no coattails to ride, they tend to grow more slowly. This catch-up phenomenon explains the L-shaped relationship seen in Figure 12 between the initial GDP level of countries in 1960 and their subsequent GDP growth between 1960 and 2011. The United States was by far the richest country in 1960, and it experienced the slowest overall growth rate between 1960 and 2011, compared to all other European, Asian, and North American countries. Countries that were far poorer in 1960 grew on average substantially faster. If, contrary to this logic, one had anticipated that by dint of its economic dynamism, the United States would grow faster than other industrialized countries, nothing in this figure suggests that it delivered on that promise.

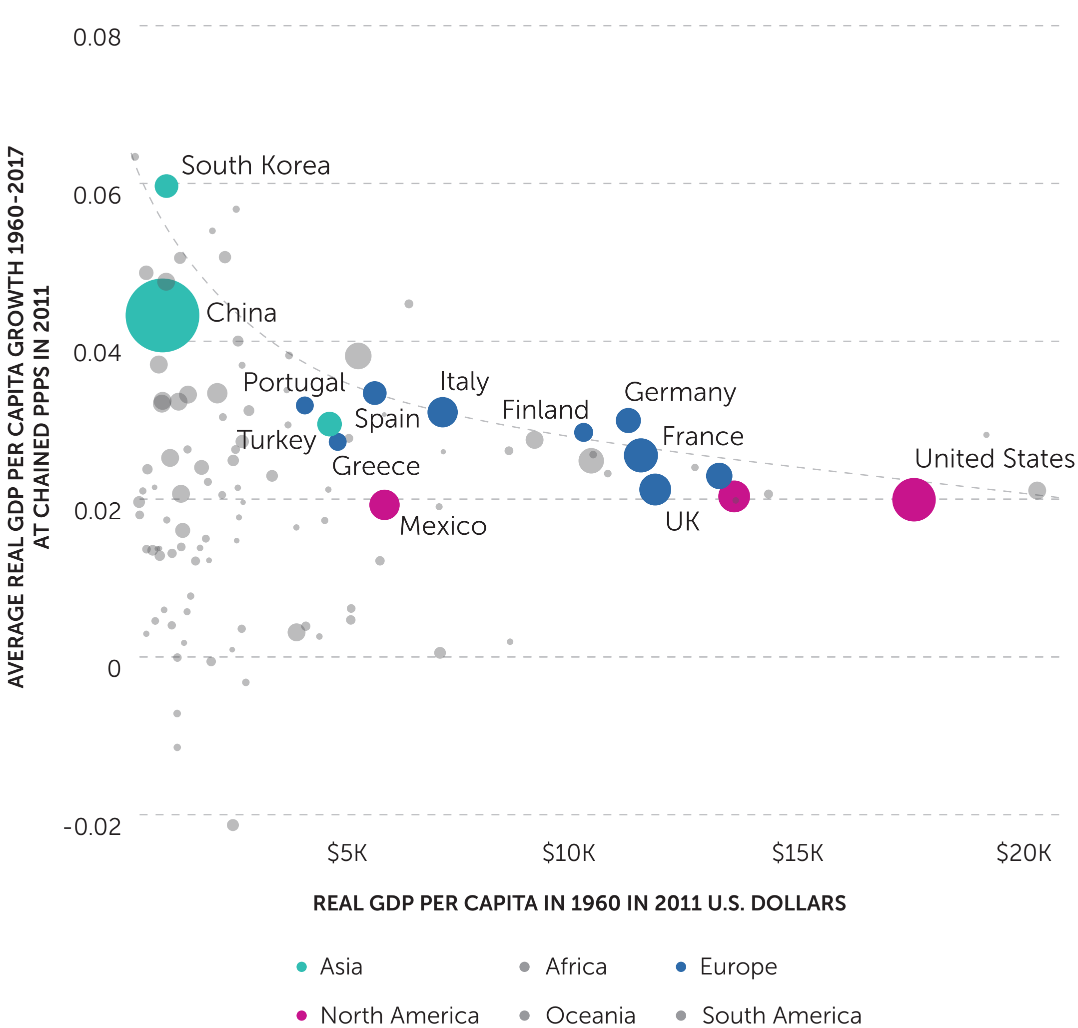
There have been periods in recent history where the U.S. has grown faster than its European peers, for example, during the so-called "dot-com" boom of the mid-1990s. [46] But judged by the most recent half-century of economic data, the U.S. does not stand out from its peers. Moreover, productivity has slowed markedly across industrialized countries since the mid-2000s for reasons that remain poorly understood.[47] Unfortunately, the U.S. is also not an outlier on this dimension: Its productivity growth has decelerated in parallel with other advanced countries.

Although the U.S. labor market has delivered little to rank-and-file workers in recent decades, one should not lose sight of the strengths of the U.S. innovation ecosystem. The U.S. remains by almost any measure the most innovative economy in the world. It is plausible that the U.S. business culture of entrepreneurship and risk-taking correlates to the extremes of inequality seen at the top of the U.S. income distribution.[48] This culture of innovation has benefited the U.S. historically and continues to benefit the country today. At the same time, the significant economic disadvantages and insecurity faced by a substantial share of the U.S. working population almost surely hinders opportunity and mobility. It thwarts the investments that individuals, families, and communities would otherwise make in the education, health, and safety of themselves and their children.

Would the U.S. have to forfeit its culture of innovation to ensure that the gains of economic growth redound to the pay, working conditions, and economic security of rank-and-file workers? No evidence suggests that the U.S. faces such a tradeoff.[49] U.S. leadership in innovation is longstanding: It led the world throughout the 20th century, and led even more definitively in the several decades immediately after World War II. Conversely, the labor market maladies documented above — poor job quality, anemic wage growth, and a decoupling between productivity growth and wage growth — are recent. Nothing suggests that these failures inevitably follow from innovation or constitute costs worth paying to gain the other economic benefits that they ostensibly deliver.

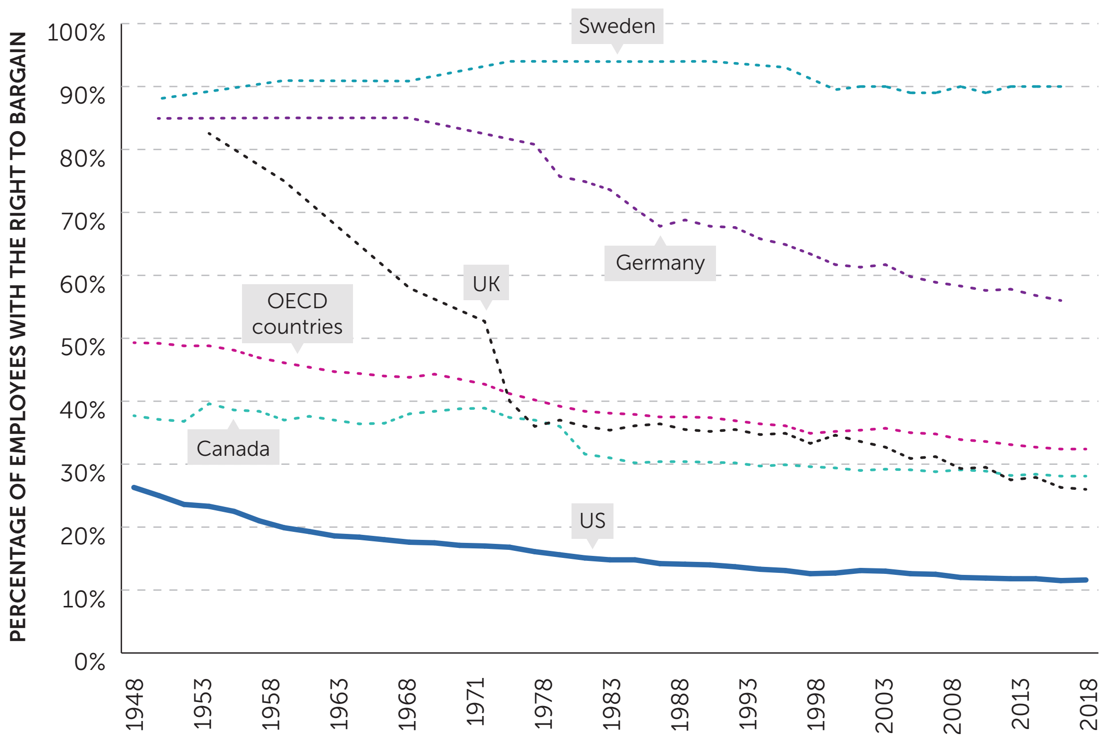
**Figure 12. Countries That Were Wealthier in 1960 Grew Less Rapidly Over the Next Four Decades**

**AVERAGE GDP GROWTH RATE 1960–2011 VS. GDP PER CAPITA IN 1960**




*Sources: Feenstra et al. (2015); Penn World Tables 9.1, Population (Gapminder, HYDE (2016) & UN (2019))*

Figure 13. Share of Workers Covered by Collective Bargaining in OECD Countries, 1979–2017



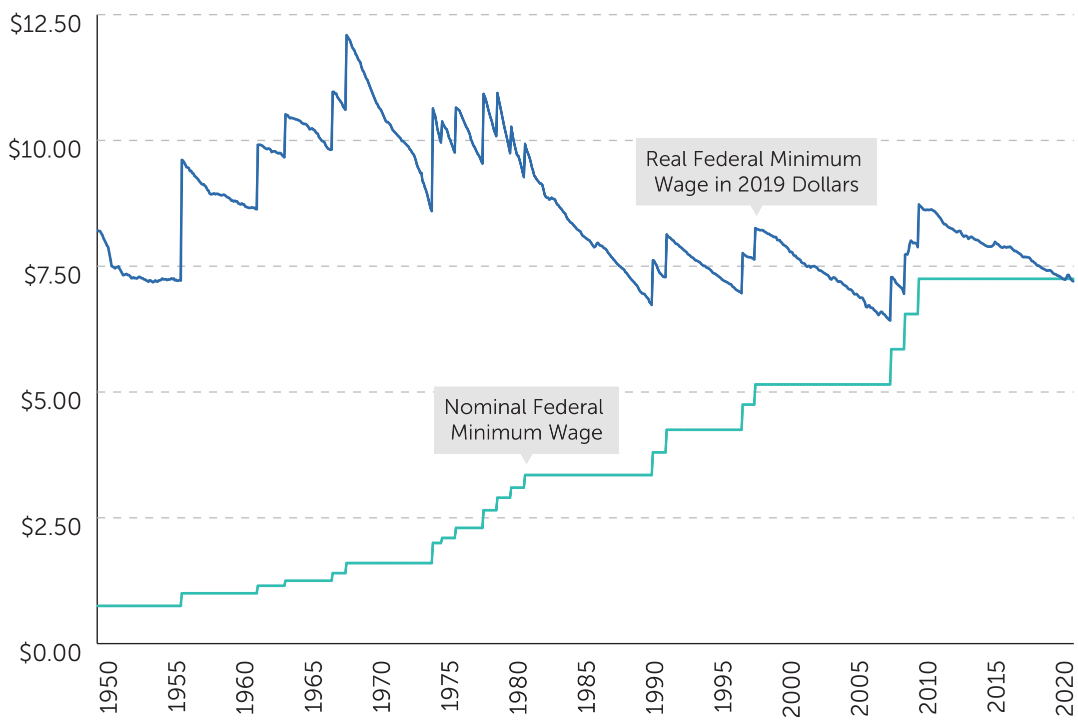

*Source: OECD.Stat: Collective bargaining coverage. ICTWSS database version 6.0 (June 2019).*

## 2.7 Why Did U.S. Workers Fare So Poorly Despite Rising Productivity?

Why has the United States failed, over the past four decades, to translate rising productivity into improved job opportunities and higher earnings for the majority of workers? Three forces contributed: technological change, globalization pressures, and institutional changes.

Technological change has been a central driver of the rising wage premium paid to formal skills and expertise. By enabling a digitalization of work, computers and the internet have made highly educated workers more productive and made less-educated workers easier to replace with machinery. This should not come as a surprise, as information technology has significant genealogy in managerial techniques designed to wrest control away from workers and toward abstract processes. Digitalization has also likely contributed to — though does not solely explain — the rising concentration of top incomes. By allowing innovative ideas to scale rapidly (e.g., in software, in finance, in entertainment, in unique business models such as Amazon or Facebook), digitalization has enabled entrepreneurs to amass vast fortunes. Just as importantly, the multiplier effect of a networked world has created outsized rewards for top talent in many sectors, such as medicine, law, design, finance, and entertainment.[50]

**Figure 14. The U.S. Federal Minimum Hourly Wage, 1979–2020**




*Notes: Federal minimum wage for non-farm workers.*
*Source: U.S. Bureau of Labor Statistics and fred.stlouis.org. Real minimum calculated using Consumer Price Index, Urban Consumers: All Items in U.S. City Average, Dec 2019 = 100.*

International trade has also played an important role. China's admission to the World Trade Organization in 2001 spurred the loss of at least 1 million U.S. manufacturing jobs during the first decade of the 2000s, and that number is larger still if one includes the impacts outside of manufacturing. In the U.S., these job losses were highly concentrated in local labor markets, many in the South Atlantic and South Central regions of the U.S. In these trade-exposed labor markets, the China trade shock generated sustained adverse impacts on employment rates, household incomes, and other measures of population distress. It further contributed to political polarization that is currently playing out at all levels of U.S. politics.[51] Thus, although China's emergence as a global economic power was driven by domestic developments within China, the speed and magnitude of the China trade shock on U.S. labor markets was, unlike the impacts of digitalization, a direct outgrowth of U.S. policy.[52]

Similar pressures from digitalization and globalization affected most industrialized countries. What sets the United States apart? U.S.-specific institutional changes and policy choices failed to blunt — and in some cases magnified — the consequences of these pressures on the U.S. labor market:[53]

1. First, the capacity of rank-and-file workers to bargain for wage growth to match productivity growth was hobbled by a steep, sustained fall in union representation. Between 1979 and 2017, the fraction of U.S. workers covered by collective bargaining agreements fell from 26% to 12%. And this fall was even steeper in the private sector: from 21% of workers in 1979 to 6% in 2019 (Figure 13).[54] Although union representation has generally trended downward in all industrialized

countries, no other peer country aside from the UK — which also witnessed an outsized rise in inequality — has seen such a large proportional drop in union coverage nor reached such a low level. This fall in turn has numerous causes: a shift of employment away from the traditionally union-heavy manufacturing sector; rising employer resistance to union-organizing efforts, enabled in part by weakening enforcement of collective bargaining protections by the U.S. National Labor Relations Board; growing international competition throughout the post–World War II era that placed U.S. workers in closer competition with their foreign counterparts; and a nearly nine-decades old collective bargaining framework, the 1935 Wagner Act, that made it difficult for U.S. unions and other worker representatives to adapt to a rapidly changing, increasingly service-based economy.

2. The second source that magnified pressures on the labor market in the U.S. is a minimum wage that has not kept pace with inflation. In the face of strong ideological and business resistance, successive U.S. Congresses have allowed the real value of the federal minimum wage to atrophy — with only brief respites during the Clinton and Obama administrations. As of 2020, the real value of the federal minimum wage was essentially at the same level as in 1950, seven decades earlier, and was approximately 35% below its real value in 1979 (Figure 14). The best available evidence indicates that well-calibrated minimum wages exert modest to undetectable adverse effects on employment, reduce household poverty, and are particularly effective at bolstering the earnings of minority workers who are overrepresented at the lower tail of the U.S. wage distribution.[55] The erosion of the U.S. federal minimum wage, itself a deliberate policy decision, has magnified U.S. earnings inequality, retarded the earnings growth of low-paid U.S. workers, and likely further weakened the hand of labor unions in negotiating on behalf of their members.

3. Third, U.S. labor policies are leftovers from an earlier era. Congress failed to modernize U.S. labor and social policies to extend conventional protections, like those afforded to direct-hire employees, to the growing ranks of contract, temporary, and gig workers. It also failed to increase the availability and flexibility of unemployment insurance benefits for those not in full-time employment. Finally, it did not ensure that a foundational level of portable health insurance, medical, family, and parental leave is available to all workers. This policy vacuum has fostered a 'fissuring' of the workforce where, in the words of Task Force member Chris Walley, "employees find themselves increasingly outsourced, sub-contracted, working part-time or on demand, and with less leverage and fewer worker protections."[56]

4. A fourth source of pressure on the U.S. labor market has been an expansion of free trade without guard rails. Under both Republican and Democratic administrations, the United States has embraced a policy-driven expansion of free trade with the developing world — Mexico and China in particular — without enacting complementary trade adjustment policies to buffer the earnings and employment losses and provide for the full range of retraining needs of workers and communities facing sudden policy-induced changes in competitive conditions. While we venerate the core economic insight that trade expansion lowers consumer prices, opens new markets for producers, and fosters the creation of new products and services, the value of these collective benefits provides an even stronger case for assisting workers and communities that are badly hurt by trade policy. The failure of the U.S. to provide such assistance has yielded greater economic, social, and political damage than any plausible cost of the policies that the U.S. might have enacted.

In light of the great divergence in the labor market, and the role of technology, particularly information technology, in exacerbating that divergence, concerns about new technologies such as AI, robotics, autonomous vehicles, and advanced manufacturing take on a new salience. Will these technologies ease or intensify problems in today's labor market? Or, as people have asked the Task Force, "Will a robot take my job?"

## CHAPTER 3

# Technology & Innovation

Will a rapid wave of human-like AI put us all out of work? Will the recent growth in low-wage work in the service economy be hobbled by algorithms and dexterous robotics? Will robots soon be packing our boxes and caring for the elderly?

---

We don't know precisely. The future will contain a mix of technologies and a mix of approaches across firms large and small. We do know that new technologies will evolve within a nation of empowered high-skill work, increasing inequality, eroded worker voice, and racial disparities. Just as policies shape trade and labor institutions, they also shape technology. They shape the rate and manner in which firms develop and adopt technologies, as do organizational cultures, economic incentives, and management practices.

Anxieties about "robots" also express broader cultural unease.[57] Even before COVID-19, middle- and working-class Americans, especially those without post-secondary education or specialized skills, had ample cause for worry, given the unrelenting march toward increasingly precarious forms of labor. The U.S. has a poor record of tending to the needs of workers and communities left behind by technological change. The reasons for these economic transformations remain opaque to the public, making it tempting to focus on iconic "robot" machines that conform to familiar narratives as embodiments of broader, subtler changes.

One reason the 2018 wave of concern about technology and work seemed so salient is that AI threatens to displace work requiring judgment and expertise in the way earlier waves of automation and computerization displaced repetitive physical and cognitive work. Several reports point to highly specialized office work — including, for example, insurance adjusters, paralegals, and accountants — as categories subject to automation and worker displacement. The Task Force brief by Thomas W. Malone, Task Force member Daniela Rus, and Robert Laubacher reviews this situation and considers what may lie ahead.

We also know that the future is not etched into machines and algorithms by laws of mathematics or physics: Myriad moments in the process of technological change enable, indeed require, human choices to shape the outcome. Engineers encode social relationships and preferred futures into the machines they build. And economic incentives, R&D programs, and organizational choices are at least as powerful as engineering visions in shaping the evolution of new technologies. Autonomous vehicle technology, for example, drew on decades of federal support from DARPA and other agencies, legacies that still inflect the technology. Similarly witness the seismic shift to the use of telepresence tools by companies, schools, and governments during the COVID-19 pandemic as a public health crisis inflects development and adoption. Decisions made by R&D program managers, directors in boardrooms, planners in offices, and managers on shop floors also determine how jobs evolve as new tools emerge and become widely available.

This chapter synthesizes research from the Task Force that explores the status of key technologies and assesses their implications for jobs: AI in business processes in insurance and healthcare, autonomous vehicles, robotics in manufacturing and distribution, and additive manufacturing. Some of these technologies, such as autonomous vehicles, are far from widespread use so it remains speculative to forecast how jobs will be reshaped, other than to forecast general timelines and gradual transformation in a decade or more. In other cases, we have a clearer sense, because forms of the technology are already being adopted, such as the robots that now increasingly roam through warehouses. Others are harder to visualize because they involve the use of software to read documents and claims, scan medical prescriptions, or follow transactions to flag potential fraud. All draw on long periods of federally supported basic research to cultivate their genesis and infancy, and to train their practitioners for industry.

Three key themes emerge from this research. First, AI and robotic applications take time to develop and deploy, especially into safety- and production-critical applications. While they are coming, they are not as close as some would fear, offering some glimpses of potential futures and time for preparation. Flexibility in dynamic environments remains a key human attribute still largely out of reach for machines. This gradualism offers an opportunity to consider how to deploy new technologies for the greatest social and economic benefit. That said, if these technologies deploy into an economy run according to our existing inadequate labor institutions, they can easily make current trends worse: technological change where benefits narrowly accrue to employers and the most highly educated workers, leaving rank-and-file workers with little benefit.

Second, technologies offer mixes of job replacement and augmentation, and those mixes are shaped by a variety of factors. In one case below, legal auditors find that AI helps them in their work, freeing their time for other tasks, simultaneously requiring a firm to hire more auditors, and improving efficiency. In other cases, warehouse workers are augmented by mobile robots, focusing the human jobs into dexterous tasks that robots cannot do today.

Finally, organizations have a great deal of influence over how technologies are adopted and deployed, and hence policies that affect organizations can shape technology. Integration and adaptation are costly and time-consuming tasks in the deployment of any technology to support a particular business. Innovations in these phases of the technology curve can be technical, such as easier programming and standardized interfaces, or organizational, such as engaging frontline workers in the deployment of technology. In both cases, they crucially link technological change to higher productivity and a labor market that can provide opportunity, mobility, and a measure of economic security to the majority of workers.

## 3.1 AI Today, and the General Intelligence of Work

Most of the AI deployed today, while novel and impressive, still falls under a category of what Task Force member, AI pioneer, and Director of MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) Daniela Rus calls "specialized AI." That is, these systems can solve a limited number of specific problems. They look at vast amounts of data, extract patterns, and make predictions to guide future actions. "Narrow AI solutions exist for a wide range of specific problems," write Rus and MIT Sloan School Professor Thomas Malone, "and can do a lot to improve efficiency and productivity within the work world."[58] The systems we will explore below in insurance and healthcare all belong to this class of narrow AI, though they vary in different classes of machine learning, computer vision, natural language processing, or others. Moreover, by their reliance

> The ability to adapt to entirely novel situations remains an enormous challenge for AI and robotics, a key reason for companies' continued reliance on human workers for a variety of tasks.

on largely human-generated data, they excel at producing behaviors that mimic human data on well-known tasks (potentially including human biases). The ability to adapt to entirely novel situations is still an enormous challenge for AI and robotics, a key reason for companies' continued reliance on human workers for a variety of tasks.

From a work perspective, these technologies tend to be task oriented, that is they execute limited sets of tasks, more than the full set of activities comprising an occupation. Still, all occupations have some exposure. For example, reading X-ray images is a key part of radiologists' jobs, but one of dozens of tasks they perform. The AI in this case can allow the doctor to spend more time on other tasks, such as conducting physical examinations or developing customized treatment plans.

Artificial general intelligence (AGI), the idea of a truly artificial human-like brain, remains a topic of deep research interest but a goal that experts agree is far in the future. A current point of debate around AGI highlights its relevance for work. MIT professor emeritus, robotics pioneer, and Task Force Research Advisory Board member Professor Rodney Brooks, argues that the traditional "Turning test" for artificial intelligence should be updated. The old standard was a computer behind a wall, with which a human could hold a textual conversation and find indistinguishable from another person. This goal was achieved long ago with simple chatbots which few argue represent AGI.

In a world of robotics, as the digital world increasingly mixes with the physical world, Brooks argues for a new standard for artificial general intelligence: the ability to do complex work tasks that require other types of interactions with the world. One example would be the work of a home health aide. These tasks include physical aid of a fragile human, observations of their behavior, and communications with family and doctors. Brooks's idea, whether embodied in this particular job, that of a warehouse worker, or other kinds of work, captures the sense that today's intelligence challenges are problems of physical dexterity, social interaction, and judgment as much as they are of symbolic processing. As we shall see below, these dimensions remain out of reach for current AI, which has significant implications for work. Pushing Brooks's idea further, the future of AI is the future of work.

## 3.2 The Robots You Don't See: AI in Insurance

To explore the current state and future potential of AI in service occupations, MIT researchers did deep dives in insurance and healthcare. They found firms experimenting with new software and AI technologies to redesign workflows, revise task allocation, and improve job design, for both higher- and lower-educated workers, with the aim of boosting productivity. The pace of adoption appears uneven across industries as well as firm sizes. In the insurance industry as well as healthcare, automation is occurring at the task level more so than at the job level, and we are still in the early days of implementation.

Task Force executive director Dr. Elisabeth Reynolds led a team of researchers to look closely at a major insurance company's efforts to adopt automated systems.[59] The insurance industry has a long history of leading in information technologies. This company had already experimented with robotic process automation (RPA), which is software that automates rules-based actions performed on a computer, often as an overlay to legacy software systems. The company concluded that RPA hadn't delivered the expected results: Most workers accomplish heterogeneous tasks, and the software is insufficiently flexible to automate all of them. Even people ostensibly doing the same job had different methods or routines for accomplishing them.

So the company reassessed its approach, looking for ways to automate certain functions. These included installing chatbots to handle the simplest questions to their internal help desk and customer service centers, while then training the workers to engage with customers at more meaningful levels.

> “It’s not about the technology,” but rather about the ability of the firm to crystalize its problems in a way that they are solvable by even today’s technology. “We lack the maturity [as an industry] in coming up with what’s possible.”

Overall, automation raised the productivity of the current workforce while reducing the number of workers needed to accomplish the job (though the dynamic may evolve if automation allows the firm to reduce prices or offer better products). Another challenge the company found was to ensure that such automation of tasks didn’t lock them into old routines and legacy technologies, which could hobble future efforts at innovation.

The dominant force for this firm was digitalization, advanced applications of information technology, and cloud computing, not necessarily AI-type algorithms. “Our business is technology,” one company leader said. “There isn’t a separation now.” The firm adopted the new management techniques of agile methods and agile software developed over 20 years by the software industry. Agile methods include small, highly cooperative teams that rapidly execute multiple design iterations (as opposed to larger teams that follow more linear workflows). As a consequence, the firm moved from heavy reliance on two software vendors (IBM and Microsoft) to dozens of smaller, cloud-based platforms. These changes in software development and use have had the deepest impacts on how the firm does business.

By contrast, AI applications have not yet lived up to their promise. Deployment of machine learning (ML) based chatbots for customer service and RPA to increase efficiencies in back-office work represent some of the earliest applications of automation technologies. While the latter is not fundamentally new (the initial development was started after the 1990s), its scope and reach into different sectors and companies that have sizable traditional back-office operations have made it a building block of firms’ AI strategies. “Consulting firms did a huge disservice to firms like ours by telling them they could save billions with these new AI functions,” one company leader said. “We’ve used some of this, but it hasn’t been dramatically impactful.” The company’s processes were simply not sufficiently homogeneous or standardized to be amenable to today’s AI.

“We’re at the infancy of what AI and ML can bring to the insurance industry,” another leader observed. “We’re tinkering...just scratching the surface of how AI and ML are capable of disrupting the industry.” Moreover, the challenges are business and organizational. “It’s not about the technology,” but rather about the ability of the firm to crystalize its problems in a way that they are solvable by even today’s technology. “We lack the maturity [as an industry] in coming up with what’s possible.”

Consider one example where the firm successfully implemented an AI-based system: creating efficiency in evaluating legal bills. As an insurance company, this firm hires thousands of law firms over a broad area of states and jurisdictions, and the company must audit the legal bills to be sure the charges comply with the company’s policies. It buys more than a billion dollars’ worth of legal services annually and employs a couple of dozen auditors — college-educated attorneys and financial specialists who read through the bills to verify the claims.

Applying AI to this problem required convening three separate groups of experts: data scientists who understood the electronic billing formats, coders who wrote algorithms, and auditors who initially resisted the idea. It took months of learning, coordination, and development to build ML models to calibrate algorithms to detect anomalies in bills. After a few cycles of trial, including presentation to and support from the CEO, the model achieved 85% accuracy.

When the models were applied to the end of the auditing process, the results persuaded the auditors that the algorithms could pick up anomalies that the humans had missed. Soon the system was yielding millions of dollars in annual savings, freeing the auditors to move on to more complex work. This AI system has had a substantial impact, though it proceeded like a traditional IT project, requiring the right mix of experts, innovative teamwork, executive support, and upfront investment before showing benefits.

Reynolds and her team found that AI-based software systems did not result in laying off entire teams of people, but they did slow down hiring in relevant departments, as in the earlier example. While both layoffs and hiring slowdowns ultimately mean fewer employees in the affected departments, they have qualitatively different effects on workers.

This company still relies on the traditional role of the insurance agent. Here, AI and RPA have largely been complementary. Insurance, like other retail products, is now sold through an omni-channel approach: direct to consumer (online), direct response center (online plus human on the phone or just the latter), and in-person. This situation is likely to change as the next generation of customers becomes more comfortable engaging the company without human assistance.

Ten years ago, the firm expected to see in-person agent jobs fade away and more direct-to-consumer activity. But despite pick-up in the latter, the number of in-person agents has held relatively steady. Customers still want human interactions before they purchase insurance. While used by only a fraction of customers, self-service options lets agents spend more time selling insurance to those who want in-person interactions, increasing their sales and commissions and allowing for more customized insurance packages. At the same time, new digital technologies like e-signatures are making certain tasks more efficient by obviating the need for stacks of documents to be signed. Machine learning algorithms provide more insight into existing or potential customers through the collection, aggregation and analysis of third-party data. This data enables predictions that a customer might be calling about an upcoming bill; they can suggest calling the family to offer to add a new driver to the auto policy because their child has just turned 16. While agents have had to become more technologically savvy with the use of apps and tablets, the new training required is modest and acquired on the job.

## 3.3 Invisible Robots in Healthcare

Heavy investment in new tools and technologies in healthcare is yielding rapid change. The Task Force's John Van Reenen and the MIT Sloan School of Management's Joseph Doyle, working with PhD candidate Ari Bronsoler, took a close look at how this technology, including electronic medical records, has impacted the sector.[60]

Healthcare is a potential bright spot for workers in low- and middle-pay jobs. Healthcare employment is growing rapidly, which appears likely to continue as the population ages and new treatments emerge. It is also a sector that offers good jobs, with reasonable wage and non-wage benefits, at least for those working directly for healthcare systems. By contrast, home healthcare workers are poorly paid with few benefits.[61]

The sector is also considered to be recession-proof, though ironically, the COVID-19 crisis caused a steep fall in healthcare employment: as people chose to avoid elective medical procedures and doctors' offices during the pandemic.[62]

Bronsoler, Doyle, and Van Reenen conclude that the rise of new technologies in healthcare has the potential to slow the growth of new jobs, but not to reduce the overall number of jobs. At the same time, new technology is clearly impacting the mix of workers you might see in a hospital. Workers who specialize in use of computer applications outpaced nurses in both employment and wage growth in recent years (Figure 15).

Still, for all of the new healthcare technology and investment in IT, the sector has, surprisingly, shown relatively little productivity growth. Lessons from other industries suggest that the management of new technologies is an important driver of productivity gains.[63] This poses particular challenges for an industry renowned for being highly fragmented, with clinical workers used to a high degree of autonomy when it comes to making choices about patients. "Despite the presence of so much technology in healthcare," one senior healthcare technology leader interviewed during the course of this research acknowledged, "it's hard to bring it together and use it to its full effect."

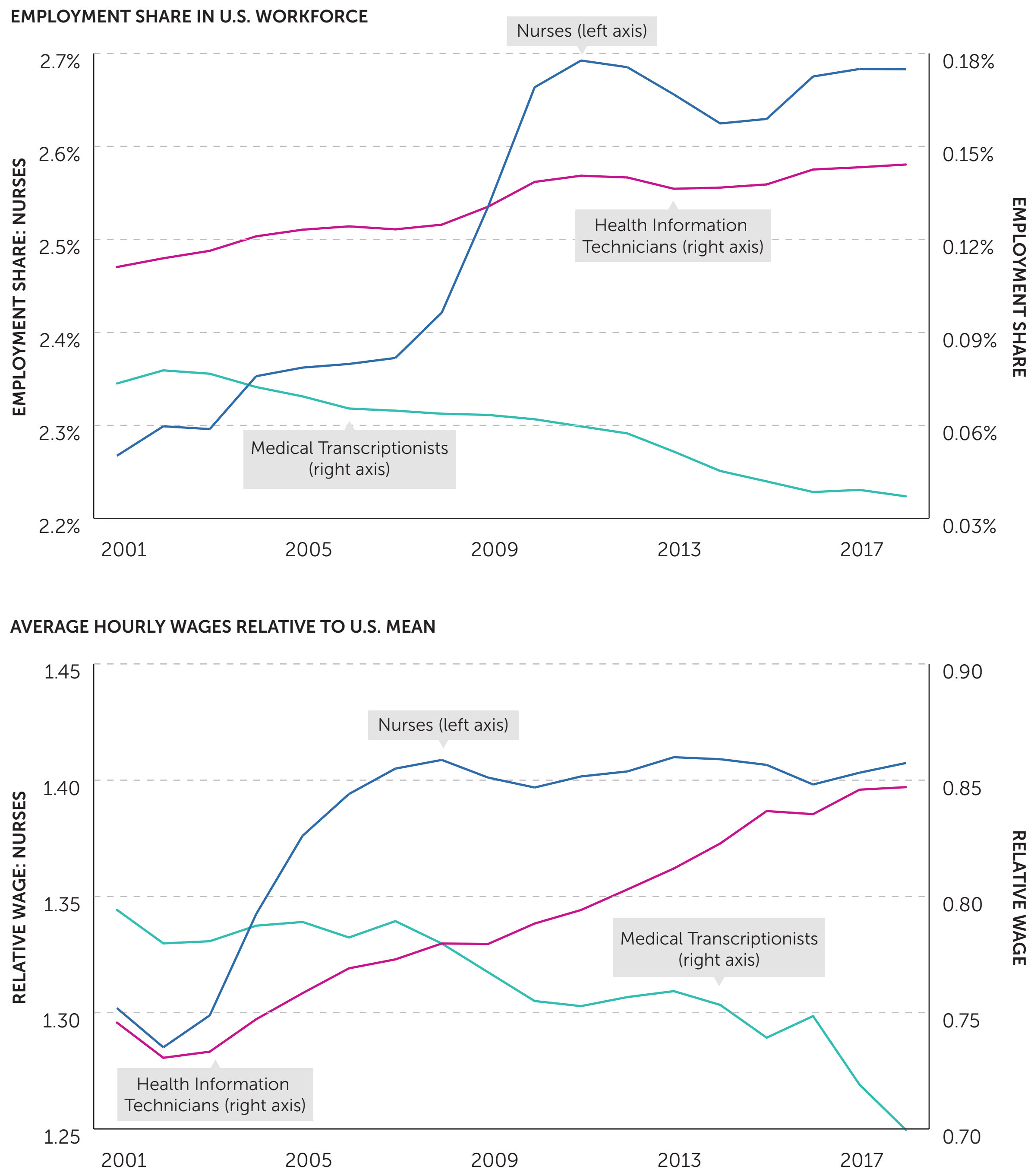
New Electronic Health Record (EHR) technology such as EPIC is the most significant IT investment in healthcare in decades, with $30 billion dedicated to its implementation since 2010. The rapid adoption of EHR was spurred by the 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the Affordable Care Act, which aims to increase the use of electronic health records. EHRs serve as a platform for decision support, combining patient-level data with best practices and clinical guidelines, as well as data analytics that can lead to larger long-term gains in quality and efficiency. Yet, for all the benefits and potential it brings to improving healthcare productivity, limitations remain, including a lack of robust competition in the EHR market, which can slow adoption and innovation. “EPIC was designed for the healthcare of the past and built on the healthcare of the past,” said one senior healthcare IT expert, “not for the healthcare at the digital frontier.”

As in other industries, new technologies in healthcare tend to complement the work of highly educated and highly specialized workers, and to substitute for workers with less specialized expertise. On the clinical side, artificial intelligence and machine learning technologies are driving significant change through the use of medical imaging to read X-rays, natural language processing (NLP) to read clinical documentation, and data science to process massive amounts of data to generate inferences and predictions on patient diagnoses. These technologies tend to provide greater insights for clinicians as well as increased efficiency. New scanning technologies for nurses, for example, where nurses scan every piece of information about a patient’s details, including medications, rather than manually typing in information, lead to improved safety and efficiency. Likewise, new communications technologies, such as secure messaging rather than pager technology, allow nurses to reach other team members (doctors, residents, other nurses) in a timely manner about treatment protocols and ensure consistency, accuracy, and timeliness of treatment. In both of these cases, the technology is complementing a subset of tasks while replacing others. Amidst these many technological changes, the wages of nurses as compared to average U.S. workers have remained relatively constant over the past 15 years (while rising for health IT workers–see Figure 15).

New technologies hold the potential for large cost savings in healthcare. In a well-known RAND study, Hillestad et al. estimated that adoption of digital technologies could save between $142 billion and $371 billion over a 15-year period. [64] So far, the actual results of the impact of the HITECH Act have been disappointing. A subsequent RAND study by Kellerman found that the predicted savings had not materialized due, in part, to a lack of information sharing across providers and a lack of acceptance by the workforce in an environment where incentives run counter to the goal of reducing healthcare costs.[65]

When it comes to the impact of new technologies on cost savings, the much greater focus for healthcare systems is in non-clinical work. This includes back-office and clerical work such as finance, administration, compliance, billing, health information, and supply chain management. In interviews at a large healthcare system, senior technology leaders outlined their goal to reduce their labor dependency with automation. One senior executive estimated that 50%–60% of human resource work could be replaced by RPA. The challenge, however, is a familiar one — how to align processes such that they can be easily automated. There is little uniformity on how tasks are performed: “There are 13 different ways of doing things because there are 13 different departments,” the executive confirmed. “The challenge is the ability to change the culture within an organization to do things in a particular way.”

**Figure 15. Employment and Earnings of Nurses, Medical Transcriptionists, and Health Information Technicians, 2001–2018**




*Notes: Upper panel reports the employment of nurses, medical transcriptionists, and health care information technicians as a share of the total U.S. workforce. Lower panel reports the average hourly wages of nurses, medical transcriptionists, and health care information technicians relative to the mean hourly wage in the U.S. economy. Figures are based on Occupational Employment Statistics data provided by the U.S. Bureau of Labor Statistics. https://www.bls.gov/oes/tables.htm.*

In the case of one large healthcare system, RPA has been introduced to replace multiple tasks from the classic scanning of medical records, to verifying clinicians' licenses and rapidly communicating details about drug recalls across a hospital. However, one senior leader emphasized that automation has not led to one-for-one replacement of a worker: "No worker has been fully replaced by automation." In most cases, the tasks that have been automated represent a modest subset of the tasks in which the worker is engaged. Typically, workers have been redeployed or have found different jobs within the system, in part because the healthcare system as a whole has been growing in recent years. As suggested earlier, the primary impact on jobs has been the elimination of open positions (retirements have also played a role in the transition), which in the long run implies a decline in employment in those positions.

Not all transitions have been painless, however. Employees with non-transferable skills, such as those engaged in medical transcription, have been hit hard as their relative employment and wages have fallen steadily since the early 2000s. According to HR leaders, workers in these positions have been challenging to redeploy within the organization, and many have been let go since the introduction of EHRs. Some recent studies conclude that every position in healthcare based on paperwork will eventually become obsolete, although there may be much work remaining in the non-paperwork versions of those activities.[66]

The introduction of healthcare IT tends to be associated with an increase in costs, as Bronsoler, Doyle, and Van Reenen discuss, but it has had a positive impact on patient outcomes. One can anticipate with reasonable (but far from complete) confidence that the former will tend to decrease while the latter will continue to grow. Healthcare IT will likely be adopted at an increasing rate. The impact on the workforce, as with other industries, appears likely to be a steady increase in the need for technical skills, whether working on the frontlines or in the back office.

## 3.4 A Driverless Future?

Few sectors better illustrate the promises and fears of robotics than autonomous cars and trucks. Autonomous vehicles (AVs) are essentially high-speed industrial robots on wheels, powered by cutting-edge technologies of perception, machine learning, decision-making, intelligence ethics, regulation, and user interfaces. Their cultural and symbolic resonance has brought AVs into the forefront of excited press coverage about new technology, and have sparked large investments of capital, making a potentially "driverless" future a focal point for hopes and fears of a new era of automation.

The ability to transport goods and people across the landscape under computer control embodies a dream of 21st technology, and also the potential for massive social change and displacement. In a driverless future, accidents and fatalities could drop significantly. The time that people waste stuck in traffic could be recovered for work or leisure. Urban landscapes might change, requiring less parking and improving safety and efficiency for all. New models for the distribution of goods and services promise a world where people and objects move effortlessly through the physical world, much as bits move effortlessly through the internet.

As recently as a decade ago, it was common to dismiss the notion of driverless cars coming to roads in any form for many decades. Federally supported university research in robotics and autonomy had evolved for two generations and had just begun to yield advances in military robotics. Yet today, virtually every car maker in the world, plus many startups, startups, have engaged to redefine mobility. The implications for job disruption are massive. Auto manufacturing itself accounts for just over 5% of all private sector jobs, according to one estimate. Millions more work as drivers and in the web of companies that service and maintain these vehicles.

Task Force members John J. Leonard and David A. Mindell, with graduate student Erik L. Stayton, have both participated in the development of these technologies and studied their implications. Their research suggests that the grand visions of automation in mobility will not be fully realized in the space of a few years.[67] The variability and complexity of real-world driving conditions require the ability to adapt to unexpected situations that current technologies have not yet mastered. The recent tragedies and scandals surrounding the death of 346 people in two Boeing 737 MAX crashes stemming from flawed software, as well as accidents involving self-driving car testing programs on public roads, have increased public and regulatory scrutiny, adding caution about how quickly these technologies will be widely dispersed. The software in driverless cars remains more complex and less deterministic than that in airliners; we still lack technology and techniques to certify it as safe. Some even argue that solving for generalized autonomous driving is tantamount to solving for artificial general intelligence.

Analysis of the best available data suggests that the reshaping of mobility around autonomy will take more than a decade and will proceed in phases, beginning with systems limited to specific geographies. More automated systems will eventually spread as technological barriers are overcome, but current fears about a rapid elimination of driving jobs are overstated.

Autonomous vehicles, whether cars, trucks, or buses, combine the industrial heritage of Detroit and the millennial optimism and disruption of Silicon Valley, as well as a DARPA-inspired military vision of unmanned weapons. Truck drivers, bus drivers, taxi drivers, auto mechanics, and insurance adjusters are but a few of the workers expected to be displaced or complemented. This transformation will come in conjunction with a shift toward full electric technology, which would also eliminate some jobs while creating others.[68] Electric cars require fewer parts than conventional cars, for instance, and the shift to electric vehicles will reduce work supplying motors, transmissions, fuel injection systems, pollution control systems, etc. This change too will create new demands, such as for large-scale battery production (that said, the power-hungry sensors and computing of AVs will at least partially also offset the efficiency gains of electric cars). AVs may well emerge as part of an evolving mobility ecosystem, as a variety of forces including connected cars, new mobility business models, and innovations in urban transit converge to reshape how we move people and goods from place to place.

As with other new technologies, introducing new modalities into a region's evolving mobility ecosystem will just perpetuate existing inequalities as they relate to access and opportunity if institutions that support workers don't evolve as well.[69]

A rapid emergence of automated vehicles would be highly disruptive for workers since the U.S. has more than 3 million commercial vehicle drivers. These drivers are often people with less education as well as immigrants with language barriers. Leonard, Mindell, and Stayton conclude that a slower adoption timeline will ease the impact on workers, enabling current drivers to retire and younger workers to get trained to fill newly created roles, such as monitoring mobile fleets. Again, realistic adoption timelines provide opportunities for shaping technology, adoption, and policy. A 2018 report by Task Force Research Advisory Board member Susan Helper and colleagues discusses a range of plausible scenarios.[70]

Meanwhile, car and truck makers already make vehicles that augment rather than replace drivers. These products serve as high-powered cruise control and warning systems, and

## Transportation Jobs in a Driverless World

The narrative on autonomous vehicles (AV) suggests the replacement of human drivers by artificial intelligence-based software systems, itself created by a few PhD computer scientists in a lab. This is, however, a simplistic reading of the technological transition currently underway as MIT researchers discovered through their work in Detroit. It is true that AV development organizations tend to have a higher share of workers with advanced degrees compared to the traditional auto industry. Even so, implementation of automated vehicle systems requires efforts at all levels, from automation supervision by safety drivers to remote managing and dispatching to customer service and maintenance roles on the ground.

Take for instance a current job description for "site supervisor" at a major AV developer. The job responsibilities entail overseeing a team of safety drivers focused in particular on customer satisfaction and reporting feedback on mechanical and vehicle-related issues. The job offers a middle-range salary with benefits, does not require a two- or four-year degree, but requires at least one year of leadership experience and communication skills. Similarly, despite the highly sophisticated machine learning and computer vision algorithms, AV systems rely on technicians routinely calibrating and cleaning various sensors both on the vehicle and in the built environment. The job description for "field autonomy technician" to maintain AV systems provides a middle-range salary, does not require a four-year degree, and generally only requires background knowledge of vehicle repair and electronics. Some responsibilities are necessary for implementation — including inventorying and budgeting repair parts and hands-on physical work — but not engineering.

The scaling up of AV systems, when it happens, will create many more such jobs, and others to ensure safety and reliability. An AV future will require explicit strategies to enable workers displaced from traditional driving roles to transition to secure employment.

frequently appear on vehicles sold today. At some level, replacement-type driverless cars will be competing with augmentation-type computer assisted-human drivers. In aviation, this competition went on for decades before unmanned aircraft found their niches, while human-piloted aircraft became highly augmented by automation. When they did arrive, unmanned aircraft such as the U.S. Air Force's "Predator" and "Reaper" vehicles required many more people to operate than traditional aircraft, and offered completely novel capabilities such as persistent, 24-hour surveillance.[71]

Based on the current state of knowledge, we estimate a slow shift toward systems that require no driver, even in trucking, one of the easier use cases, with limited use by 2030. Overall shifts in other modes, including passenger cars, are likely to be no faster.

Even when it's achieved, a future of automated vehicles will not be jobless. New business models, potentially entirely new industrial sectors, will be spurred by the technology. New roles and specialties will appear in expert, technical fields of engineering of automated vehicle systems and vehicle information technologies. Automation supervision or safety-driver roles will be critical for levels of automation that will come before fully automated driving. Remote management, or dispatcher, roles will bring drivers into control rooms and require new skills of interacting with automation. New customer service, field support technicians, and maintenance roles will also appear. Perhaps most important, creative use of the technology will enable new businesses and services that are difficult to imagine today. When passenger cars displaced equestrian travel and the myriad occupations that supported it in the 1920s, the roadside motel and fast-food industries rose up to serve the "motoring public." How will changes in mobility, for example, enable and shape changes in distribution and consumption?

## 3.5 Warehousing and Distribution

Technologies often have their greatest impact, and create the most jobs, when they enable new business models and transform industries, more than automating tasks previously done by people. The rise of e-commerce, whereby the internet has enabled entirely new ways of shopping and ordering for consumers and for business, epitomizes such a transformation, and especially its impact on the movement and distribution of goods ("logistics").

E-commerce can be seen as a kind of automation of retail shopping, with corresponding employment effects in the retail sector. Whereas a customer used to have to visit a store to select, purchase, and carry home a product, now the consumer can use a web page to enter an order directly into a semi-automated supply chain, with the delivery accomplished by a mix of people and machines.

Major technologies often take four decades from invention to full adoption. The greatest impact of technology on logistics and warehousing is perhaps only part-way through this 40-year cycle, with information technology and networking still transforming the system.

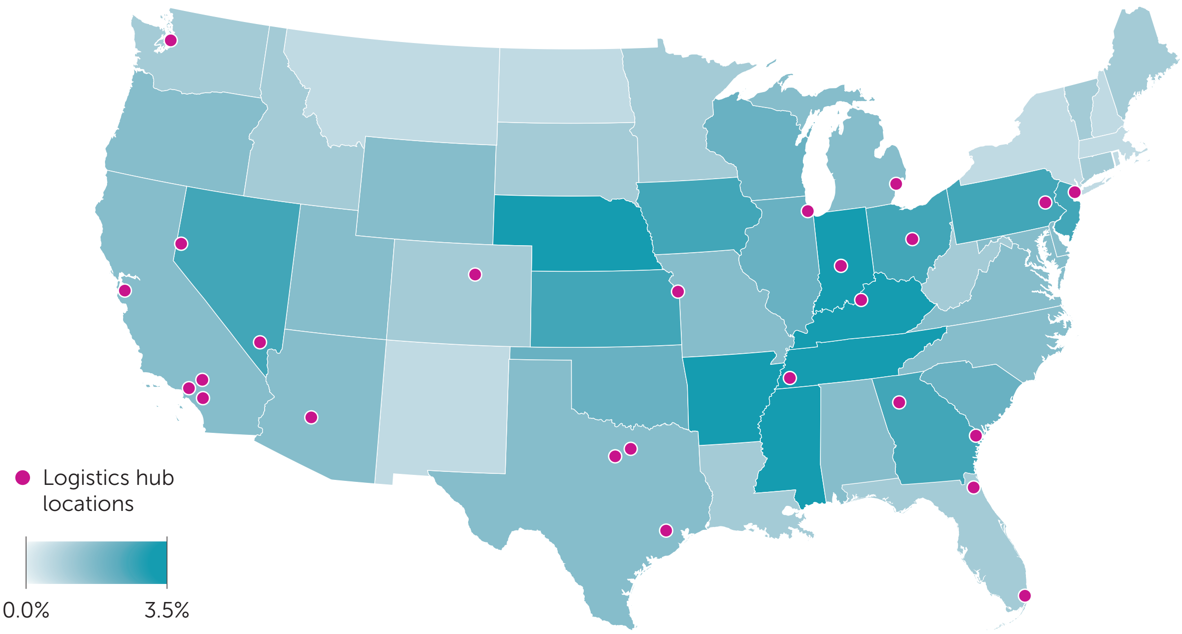
As with mobility, news reports on distribution might lead one to believe that jobs are about to start drying up. Indeed, a Google search for "warehouse automation" produces 73 million hits, many of them promotions for new systems, suggesting a rapidly changing landscape. The landscape is unquestionably rich with exciting new technology and investment.[72]

But Task Force member Frank Levy, working with Wellesley College student Arshia Mehta, found a gradual process of adoption underway. They queried automation suppliers, distribution center managers, and leaders in established companies and startups. One-third of respondents to a recent published survey reported using automated guided vehicles but less than one-fifth reported using automated packaging solutions, collaborative robotics or automated picking.[73]

Compared to other industries, logistics is geographically dispersed, and present in more rural areas (see Figure 16). We define logistics as a sum of three industries: warehousing and storage, freight trucking, and freight trucking arrangements (i.e., brokers and third-party logistics providers or 3PLs), accounting for just over 3 million jobs (before the COVID-19 pandemic). This amounts to about 2% of jobs in the economy (about one-fourth the fraction in manufacturing).

E-commerce has driven two fundamental changes in logistics. First, the industry has historically been set up for the delivery of goods in bulk sizes to local retailers for sale. E-commerce has changed the endpoint for the bulk of those deliveries from warehouses and distribution centers to individual residences.

**Figure 16. Warehousing, Storage, and Freight Trucking Employment as a Percentage of Total Employment**




*Source: Authors' calculations.*

Second, e-commerce has radically reduced the size of orders that logistics centers must now handle, right down to individual items. The warehouse industry was traditionally built around the bulk movement of goods. Trucks would line up at rows of doors to disgorge products that would get reshuffled and dispatched again in large quantities to stores, restaurants, or other warehouses for further processing. But with e-commerce, warehouses now are just as likely to handle huge numbers of individual or small-batch items: a single toy ordered by a customer in California, for example, or a half-dozen bottles of hand sanitizer ordered by a doctor's office in Connecticut.

Levy and Mehta argue that if we think of logistics employment as a tug of war between job gains from e-commerce and job losses from automation, job gains are winning decisively at present. Since 2000, the trucking industry added 130,000 jobs (to 1.75 million). The warehousing and storage industries more than doubled to 1.1 million during that same period (about 30% of these are low-wage manual laborers). More of these gains were in rural than in urban areas.

By some measures, productivity has not improved despite this vast expansion. Industry statistics find that productivity rose more than 20% from 2000–2014 but actually declined thereafter, leaving it less productive in 2019 than in 2000. A plausible explanation for this reversal is that the challenge of logistics has increased in the e-commerce era.[74] Today, distribution and fulfillment centers face the problem of unloading, unwrapping, storing, accurately selecting ("picking"), and packing products, from small jewelry to 50-pound bags of pet food and large sports equipment.

Warehouses have been slow to adopt automation; their rapid output increases from 2014–2019 have been achieved by adding labor in less automated facilities. Many of these tasks — in particular, picking and packing individual items

## Data-Enabled Trucking

Thirty years ago, an employee in a truck brokerage connected firms to truckers using a Rolodex, a telephone, personal relationships, and a fax machine. The connection process began when a firm called a broker with the details of a shipping job including what they wanted to pay (subject to negotiation). In making the connection, the size of the broker's Rolodex was key. A large set of contacts meant the broker might be able to offer a trucker a sequence of shipments with little time when the truck was driving empty.

Third-party logistics firms (aka 3PLs) operated in a similar way with one important addition: the need to plan an efficient route in which a trucker delivered shipments from several firms to several different destinations. By the end of the 1980s, 3PLs were using computerized spreadsheets (e.g., Lotus 1-2-3) to help in trial-and-error route design.

Because brokers and 3PLs deal in information, the evolution of digital tools has sharply increased what employees can do and how they do it. For the traditional broker, a connection no longer begins with a phone call from a firm with a shipping job. Instead, many firms now post jobs directly on large, digital job boards. A broker surveys one or more boards to find jobs for which he or she thinks they have a potential driver. Being able to view many jobs at once increases the chances of constructing a trip with limited time spent driving empty.

Some startups are expanding the self-service aspect of the digital job board by encouraging drivers to use proprietary mobile phone applications to access their job board directly. In a few cases, a startup can use machine learning to identify the kinds of jobs a trucker prefers and alert the trucker when such jobs appear. While humans are still needed to deal with problems that might arise — for example, a scheduled shipment that isn't ready to be picked up — these startups are trying to automate broker jobs much as direct purchase of airline tickets has automated travel agent jobs.

At the same time, digitalization allows brokers and 3PLs to automate highly routine tasks that were previously performed by lower-level employees. In some cases where a 3PL has a steady relationship with a firm, it can offer a self-service ordering portal where a firm can specify all aspects of a shipment — the type and shape of containers, the precise location of pick-up and drop-off, the presence of any hazardous materials, and so on. Previously, this information might have been collected in a back-and-forth exchange with a person. Similarly, shipping documents that used to be hand collected from the web (e.g., a signed proof of delivery) are now scraped off the web automatically.

As a result, the employment mix, particularly in 3PLs, has shifted away from hourly personnel to salaried personnel with training in software design, data analysis, and related fields.

("each picks") — are still performed by people. The simple challenge of removing plastic wrapping from a pallet of goods remains beyond today's commercially available robots.

"In warehousing," Levy and Mehta write, "robotic arms that can identify, grasp, and manipulate streams of diverse items are still in their infancy." Great effort and investment is going into automated gripping systems, but it will take an estimated three to five years to develop the technologies that would endanger the numerous jobs in picking and packing.[75] This timeframe, however, does not account for the extended time for broad diffusion, as retrofitting older warehouses and fulfillment centers with state-of-the-art technology is a disruptive and risky investment (some industry leaders we spoke to see the timeline for automated picking pushed out further still). Today, human-like physical dexterity, including its wondrous flexibility, remains out of reach for robotic systems.

As elsewhere, major impacts on labor and efficiency are coming from maturing applications of decades-old information technology. What gains in efficiency there have been in trucking have come from the "arrangements" sector, where digital tools improve processes like brokering, loading, and scheduling. "Significant technology," write Levy and Mehta, "is not always the newest technology."

Similarly, the technologies transforming most warehouses are not robots at all, but information technology, often known as "Warehouse Management Systems." These software systems record and track products from loading dock to loading dock and connect to other systems that track the supply chain.

Many fewer warehouses use robotic systems. A 2019 survey conducted by the Modern Materials Handling Institute confirms that while 80% of survey respondents use warehouse management systems and 86% use barcode scanners, only 26% use even the mature technology of Radio Frequency Identification (RFID) tags. With respect to automated goods movement, 63% use conveyor and sortation systems, but only 22% use automated storage and retrieval systems, and 15% use autonomous mobile robots.

Robotics and automation, especially when combined with IT innovations, are rapidly evolving and taking novel forms. Automated storage and retrieval systems (ASRS) resemble automated warehouses in a box, though they remain expensive and suitable for only the largest, high-throughput applications. In Amazon's Kiva robot system, armies of mobile robots carry shelves of randomly mixed items to human pickers, forming a kind of distributed ASRS. Elsewhere in "Pick to light" systems, computer-controlled lights guide human pickers to select items. Robotic carts (such as those made by 6 River Systems, recently acquired by Shopify) accompany human pickers through aisles and help them rapidly pick orders. Various forms of automated forklifts and tuggers are finding niche applications and will surely grow in robustness and flexibility.

"What I would really like is software that keeps track of every person and every robot on the floor and tells each of them what it should do next," one manager told Levy and Mehta. Such systems exist today. But they are complex and extremely difficult to develop and deploy, especially in a rapidly changing industry that is simply struggling to keep up with demand. They also raise concerns about surveillance. One can imagine an evolution toward a world where an entire fulfillment or distribution center, or even an entire supply chain, becomes a collaborative robotic system comprising people, robots, and infrastructure, all quickly reconfigurable with software. How can such systems develop to value human autonomy and flexibility, without simply treating workers like software-directed automata?

As in manufacturing, higher levels of automation are most viable for large firms. Smaller firms often pursue automation investment incrementally; leased robots are finding some success as a business model because they enable smaller firms to apply robots without capital expense in a rapidly changing industry. The largest warehouse firms gain a potentially large cost advantage because they have the resources to afford the risk and expense required to implement advanced automation.

Outside of the warehouse, the logistics industry stands to benefit from the advancing capabilities of autonomous vehicles described above. As in other AV arenas, the path remains long and the direction uncertain. We described above the AV potential in long-haul trucking. But even if the driverless truck problem were perfectly solved today, the time constant for change would be half a generation. The typical Class 8 truck (over 33,000 pounds) stays on the road an average of 14 years before it is junked, (though they might be retired sooner were sufficiently better technology to come along). Automated platooning, with a single human driver leading several follower unmanned vehicles, is likely coming sooner, though the labor impacts are more incremental. As with other types of robots, autonomous trucks are likely to benefit larger, better-capitalized fleets like J.B. Hunt, and corporate fleets like UPS and Walmart.

Much of the employment growth in e-commerce trucking has been in the last few miles of local delivery. Techie publications abound with images of mini delivery robots plying urban streets or delivery drones serving up much-needed medicines to rural areas. The possibilities are indeed compelling and the technologies exciting (potentially more so in the COVID era). Current demonstrations of these delivery robots are often monitored by human operators with back up radio control. The promise is that these operators, like the safety drivers in autonomous cars and trucks, will be removed at some point in the future, or will supervise large fleets of vehicles. But the complexity of the environment, including navigating curbs, pets, and non-cooperative (i.e., ordinary) pedestrians, suggests that for some time it will be hard to achieve autonomous operation outside of constrained and well-defined areas.

Levy and Mehta conclude that fully autonomous trucks are not likely to displace significant numbers of truck drivers for at least a decade. During that time, warehouses will likely be dominated by low-wage jobs, some of which are at risk from increasing automation in picking and packing. Automation and robotics will create jobs for technicians, software developers, data scientists, and similarly skilled positions, but they will likely eliminate a larger number of picker and packer jobs in warehousing and driver jobs in trucking. "The occupational structure of freight transportation arrangements [brokers and 3PLs]," they note, "already favors skilled positions, and continued automation of routine clerical tasks will further tilt the balance." As elsewhere, the development of new technologies will favor large firms, and middle- and higher-skill workers.

## 3.6 Lights Out Factories? Or Lights Dimmed?

The current state of the art in manufacturing parallels that in AVs — promising technologies abound, but the crucial work of making them robust and reliable poses myriad challenges.

As part of the Task Force's research, MIT robotics professor Julie Shah and her students studied the deployment of industrial robots in Germany, one arm of "Industry 4.0" efforts underway across Europe. Industry 4.0, which began as a strategic initiative in Germany in 2011, bills itself as the "fourth industrial revolution." Its goal is to knit together machines and processes in factories so they can be monitored and controlled through advanced digital tools. Shah and her team assessed which technologies have been developed by researchers and adopted by industry, the challenges they faced, the future paths that companies deemed important, and the research challenges that remain for robotics to be widely adopted by industry. They found sizable gaps between technology's potential, even when demonstrated in research settings, and its actual use on shop floors today.[76]

Shah and her team looked at "top-down" approaches to automation — where the tasks are adapted to the technology — and "bottom-up" where workers start with tasks to be done and adapt technology accordingly. Generally, bottom-up approaches appear more successful, as the solutions are closer to the people and the tasks in need of improvement. One company set up Robotic Experience Centers on the factory floor, where engineers, working closely with line workers, could generate new ideas, prototype solutions, and make changes to production lines. Companies preferred "programming the task, and not the robot" — that is, solving a larger job to be done, and empowering people to guide the deployment of robots to raise productivity and address "pain points." As other Task Force studies have shown, worker voice remains an important component of success with today's automation.

Challenges remain in integrating robotics into manufacturing lines. Industrial robots have been at work at large scale for decades, but most remain dangerous to people around them. Innovation in safety systems allows robotic systems to work more closely with people. Collaborative robot arms are one approach to this problem — they carry lighter payloads, run at slower speeds, and have other characteristics that make them acceptable to work outside of cages. Their low cost also offers lower barriers to experimentation and deployment. However, to ensure safety, collaborative robots function at slower speeds and with less mechanical force than caged robots, which reduces their output and range of capabilities.

But even as robots are coming down in cost, the human labor of integrating them into existing lines remains expensive. Efforts are underway to ease the transitions with better interfaces and easier programming, though the work remains hampered by a lack of standards and the high levels of human skill required to do the integrations. In fact, the adoption of the industrial "internet of things" (IoT) — low-cost ubiquitous sensor networks — has been slow, mostly due to data and security concerns and unclear value. Digital twins, advanced simulation, and augmented and virtual reality systems all remain promising colors in future automation palettes, but broad adoption requires overcoming similar challenges.

Technological bottlenecks also remain: in vision, perception and sensing, and robustness and reliability. "Deep learning-based approaches," for example, "haven't delivered well on their promise within industrial environments." Such techniques require vast amounts of data, which is hard to come by in factories; they tend to be brittle and difficult to adapt to new situations, and sensitive to their original data sources as well as variations in the environment.

Autonomous guided vehicles (AGVs) have had impact in industry in materials handling (as in warehousing, discussed above). These mobile robots carry everything from small totes to large vehicles around a production environment. Future visions include production lines where the line itself is never fixed and merely consists of products on AGVs carried past various self-organizing workstations — which are themselves made up of AGVs and robotic arms. But this vision has yet to materialize, held back among other things by the inability of AGVs to navigate with the millimeter precision required for production operations.

Better interfaces that enable easier programming push the applications of robotic systems closer to production lines, increasing flexibility and reducing costs. But because robotic systems remain difficult and expensive to program, Shah's team found that they largely remain technological islands on factory floors, not part of integrated digital oceans powered by AI. The researchers concluded that these technologies — even in Germany, where they are deeply rooted — "have yet to permeate the industrial landscape."

> Today's gripping systems are evolving rapidly toward enabling robotic hands to grasp an ever-greater variety of products and parts. The search remains for a general-purpose gripper that could pick any product in any orientation.

Shah also found a bottleneck identified in other Task Force studies: inadequate robotic dexterity. Until recently, robots used traditional forms of two-fingered pincers or single-purpose tools which can pick up objects but risk damaging soft or inconsistent materials. More recently, purpose-built automated grippers directed by machine vision can do remarkably delicate and precise work, for example, picking up glazed donuts on an automated bakery line without cracking the shiny coating. But such a gripper might work only on doughnuts. It can't pick up a clump of asparagus or a car tire.

Today's gripping systems are evolving rapidly toward enabling robotic hands to grasp an ever-greater variety of products and parts. The search remains for a general-purpose gripper that could pick any product in any orientation. Deep learning and other AI techniques have helped here (and they are making an impact in the logistics industry). Still despite investment and confident predictions, most AI techniques remain too brittle, complex, or slow for manufacturing operations. As noted earlier, some think that the generalized robotic dexterity problem may, like driving, equate to the search for artificial general intelligence. Major players in manufacturing and distribution have told us they believe that this problem is a decade or more away from resolution.

These findings largely resonate with the research of a team of MIT researchers led by Task Force Research Advisory Board member Susan Helper. Helper and colleagues interviewed many U.S.-based large firms, primarily automotive companies and their Tier 1 (major) suppliers. They chose automotive because about 40% of all robots in the United States (and globally) are found in this industry.[77] While firms in this sector are striving to move toward a more data-intensive and analytic form of manufacturing, company production systems remain siloed within firms as well as between firms and their suppliers.

Nevertheless, significant changes are afoot. Firms are experimenting with technologies and production systems that will flexibly adapt, whether they are making traditional vehicles or those that incorporate more electric or autonomous capabilities. Given the uncertainty regarding these markets, firms are emphasizing flexibility. Like Shah's findings in Germany, Helper's team found that workers are still central to firms' production processes. However, firms have different practices in how they use technologies that affect which technologies are substitutes for, or complements to, worker skills, and which may be the subject of organizational tension. In one case, a firm's data scientists developed an algorithm to determine when cooling fans should be replaced; technicians were expected to follow the algorithm and to eschew discretion. In other cases, firms have been adding or deepening problem-solving tasks for their shop floor workers. One company introduced a machine vision system that at first led to a dramatic spike in reported defects. Because of their experience and training in statistical process control, workers were able to quickly point out that many of the defects were false positives. Together with engineers, they determined how to relocate the vision system for better results.

> Rethinking production systems to combine IT with operations technology (OT) and generate vast amounts of real-time data creates challenges that are as much cognitive, social, and organizational as they are technical.

Rethinking production systems to combine IT with operations technology (OT) and generate vast amounts of real-time data creates challenges that are as much cognitive, social, and organizational as they are technical. Decisions about how the data is used, interpreted, and shared all shape how workers fit into the factories of the future and whether jobs are deskilled or upskilled.

## 3.7 "Surprised to Find Very Few Robots Anywhere": Small and Medium-Sized Firms

Shah's research team focused on robot makers and relatively cutting-edge firms in Germany, while Helper's team focused on large, U.S.-based automotive-related companies that had used robotics in manufacturing for many years. Task Force member Suzanne Berger led a team studying manufacturing in the U.S. with a particular focus on small and mid-sized manufacturing firms. Berger, who led MIT's Production in the Innovation Economy study in 2013, drew on several decades of research in the U.S., China, Japan, and the E.U.

Some U.S. firms are well on the road to using advanced automation, including America's automotive factories and Amazon warehouses. But Berger's researchers found a sharp divide between the automation in some large companies and in smaller mid-sized companies.[78]

The team visited plants owned by 44 U.S. companies, 10 of which were large multi-nationals and 34 of which were small and medium-sized enterprises (SMEs) in Ohio, Massachusetts, and Arizona. SMEs are companies with fewer than 500 workers; they represent 98% of all manufacturing establishments in the U.S. and employ 43% of the nation's manufacturing workers. More than half of the companies that the team studied had previously participated in the 2013 study, enabling some analysis of change over time.

Productivity growth in manufacturing has been slow over the past decades in comparison with that in other advanced industrial countries. It has been even slower in manufacturing SMEs. If we want to accelerate growth, shift to "greener" production, or raise wages, the work of Berger's team underscores that we need to understand why, when, and how SMEs acquire new technologies and train their workers for new skills. The researchers asked each company about new technology adoption in the past five years, how they found the skills to operate the equipment, and what became of workers who used to do the job in cases where the new technology was so radically different that it required a new operators to perform the task.

"We had read the literature predicting a massive wave of robots replacing workers over a 5- to 10-year horizon," the team reported, "so we were surprised to find very few robots anywhere." The largest adopter of robots they found was an Ohio company they had first visited in 2010, which had subsequently been acquired by a Japanese company. It now had more than a hundred robots, while its workforce had more than doubled. In all the other Ohio SMEs they studied, the team found only a single robot purchased in the previous five years. In Massachusetts: one. In Arizona: three.

Equally telling were the reasons that managers at these SMEs gave to explain the robot scarcity. Several said they wished they could purchase robots, but that the typical size of the orders they received rarely justified the purchase. SMEs are mostly high-mix/low-volume producers. Robots are still too inflexible to be switched at a reasonable cost from one task to another. As Shah reported, the price of a robot is only about one-quarter of the total cost. The rest is the cost of programming and integration into a work cell or process.

All of the firms had, however, purchased new equipment or software over the same previous five years, including CNC machines, new welding technology, laser- and water-jet cutters, servo-press metal stamping machines, and sensors. They also purchased computer-aided-design (CAD), data analytics, and even blockchain software. They were capturing data on production processes, though, like managers interviewed in large companies, the SMEs said they did not know what to do with most of the data they collected.

Smaller firms tend to automate incrementally, adding a machine here or there, rather than installing whole new systems that are more expensive to buy and integrate. This approach minimizes disruptions for workers while generally increasing factory productivity.[79]

Often, technology acquisition means modifying existing machines with new hardware and software rather than purchasing new ones. This approach leads to a kind of layering of technology: bringing in new alongside older equipment, some dating back to the 1940s. This may be one reason why acquiring new technology in SMEs has not typically led to layoffs. Older workers without the skills to work on the new equipment continue to work on the older machines while younger workers, who are excited about the newest technologies, may be unwilling to invest time in older equipment. The companies that the researchers visited both in 2013 and in 2019 had increased their number of workers over that time period, and no firms reported layoffs due to new technology.

Even for some of the larger firms interviewed, automation today is as much about quality as it is about reducing the number of workers. A Boston-based plant manager put the goal as not “lights out” but “lights dimmed” — moving away from people manipulating objects on assembly lines toward people on the shop floor analyzing production statistics on screens — though we note that the number of workers in that particular plant has declined by 50% in the past two decades.

New orders and new production demands from customers drive technology acquisition in SMEs. And new technology drives the search for new skills and training. When researchers asked managers what they were looking for in new hires, the most frequent response was “someone who will show up on time and stay.” Many managers were deeply skeptical about the value of formal workplace education in community colleges and other programs for jobs they wish to fill. It’s only when advanced technology enters the shop that their search for skills begins. The “perfect hire” would be someone who had previously done the same job, but such a person is rarely available, at least at the wages the manager is willing to pay. So, managers usually turn to younger or more enterprising workers they already employ and ask them if they can figure out how to use the new software or hardware. The workers often turn to online videos. As one worker who learned online how to master a new set of CAD/CAM software in order to work on a new CNC machine said: “Technology takes a step, then workers take a step forward, too. People grow with the software.”

For all these reasons, a promising route both to productivity growth and to better jobs starts with aiding the adoption of advanced manufacturing technology in the SMEs. At present, the largest national programs that work with SMEs are the Manufacturing Extension Partnership (MEP), whose major focus has been on improving “lean” manufacturing practices, and the Manufacturing USA institutes, which support and diffuse applied R&D, working primarily with large manufacturing companies. New policy levers can advance technology and skills in SMEs.

---

Despite the 20th-century rise in uniformity and mass production, manufacturing today remains a highly dynamic environment. Model changes, evolving technology, shifts in supply chains, even upheavals such as Brexit and COVID-19 all mean that 21st-century manufacturing operates within an environment of constant change, even for stable, highly standardized products. A rubber gasket that fits into a chassis one day may not fit the same way the next day when its supplier changes. Robotics and automation still do best when most variables are fixed and operations are highly standardized, while human workers remain key to adapting to changing conditions. New AI and ML-based approaches to robotics, new sensors and actuators, and new software are making these machines more flexible, but it remains early in a long evolution.

## 3.8 Additive Manufacturing

3D printer technology is advancing rapidly and could be the most disruptive manufacturing technology on the horizon. Using a single machine to craft a complex finished part has the potential to replace vast numbers of production jobs. Aerospace engineers now use 3D printers to make inspection tooling and auto plants, and other manufacturers make prototypes and fixtures on the machines. The machines are spreading, but their use remains limited, and concentrated in large firms with well-funded internal technology budgets.

3D printing has generated a great deal of excitement in the past decade for its potential impacts on manufacturing and supply chains. While not traditionally considered part of robotics, 3D printers can be thought of as desktop robots that mix hardware, materials, and software to create objects in entirely new ways. These machines have found traction as consumer products for "Makers," and have occasioned strong industrial interest as well. The ability to produce prototypes, parts, or even entirely new products at the place and time of use has far-reaching implications. The supply chain could become digital until the point of purchase or deployment. Production can be distributed into digital warehouses that produce parts on demand. Already, companies like Mercedes-Benz use this technology to print spare parts for legacy vehicles.

"Additive manufacturing" (AM) is the more formal, general term for the colloquial "3D printing." Additive distinguishes the approach from "subtractive manufacturing" such as machining, where material is subtracted by a cutting tool from raw stock such as a block of steel. In AM, material is laid down in small increments by a computer-controlled placement head. While familiar consumer desktop 3D printers can do this with colored plastic and small parts, today's AM machines range from the nanoscale to large structural or metal components, in materials ranging from high-precision polymers to aerospace-grade titanium.

The power of AM not only lies in the moment of fabrication itself, but also reaches far upstream into design and downstream into the supply chain. Where subtractive manufacturing must obey rules of cutting tools, AM upends the traditional tradeoffs of cost and complexity, providing designers greater freedom in realizing complex shapes. It also opens the door to AI-enabled "generative design" techniques, where AI designs prototypes that AM builds and engineers test, that can optimize parts for cost, weight, or strength in entirely new ways. Experts expect AM to complement more than replace subtractive manufacturing, and also to have profound effects on how products are designed, manufactured, and brought to market.

"Realizing mass customization at scale," writes Task Force member John Hart, a leading expert in AM, "would be unthinkable were it not for the rapidity of converting digital information into a physical form through the use of AM." Hart studied the spread of AM and concluded that it will eventually allow companies to shift effortlessly to supply changing needs.[80] AM can also open the way for new businesses that couldn't exist without the tool. Align Technology's Invisalign® product, for example, makes custom orthodontic retainers based on scans of an individual patient's mouth.

Configurable production assets, including AM systems, may enable firms to respond quickly in periods of uncertainty to pivot their production activities if needed. During the COVID-19 pandemic, for example, additive manufacturing firms were quick to leverage existing production infrastructure and pre-qualified medical-grade materials for the production of nasopharyngeal swabs. These swabs are vital for virus testing and were in drastically short supply early in the crisis. The project, initiated by faculty at Harvard and MIT, in collaboration with companies Desktop Metal, Formlabs, Carbon, and others, resulted in the production of millions of swabs per week within a few weeks of initiation.

Still, large-scale adoption of AM, and its attendant potential impact on jobs, is slowed by high (though falling) costs and a lack of common standards, which may take years to develop. AM-based systems still do not have the high speed or low cost required for large-scale production that have developed over more than a century in subtractive manufacturing. Material properties of built-up parts can lack the predictability that subtractive techniques already deliver for critical components. Standards for AM design, testing, and materials are lacking. And, ironically in light of our discussion of job loss, the growth of the industry is currently limited by the need for specialized professionals trained in AM techniques. These limitations will all be addressed over time, from innovations in high-rate AM production equipment to new training pipelines.

> Artificial intelligence, machine learning, robotics, and additive manufacturing are indeed poised to transform the economy. But those transformations will be the culmination of thousands of innovations from managers, organizations, and business models.

So, as in other areas, we see the opportunity to apply smart training strategies to ease factory workers into emerging roles. Manufacturers will likely need smaller teams of workers, but those remaining will need specialized training to operate the new machines.

In Hart's study, the owner of one small Ohio plant predicted that he could transition entirely to the new technology in about a decade, and that it would result in many fewer jobs if his production volume stayed constant. But he also believed that he would grow so productive compared to his competitors that his own workforce would likely grow. Whether this means more industry jobs in net, or simply more jobs at this firm but fewer at its competitors, depends on how customer demand responds to improving quality and lower costs.[81]

## 3.9 Momentous Impacts, Unfolding Gradually

As the major technological advances of earlier eras, such as interchangeable parts, electrification, and internet connectivity took years to diffuse, so today's advanced technologies will take time to roll out throughout the economy. The most profound effects are still playing out from the internet, mobile and cloud computing, and other innovations dating back to the 1990s and earlier. Artificial intelligence, machine learning, robotics, and additive manufacturing are indeed poised to transform the economy. But those transformations will be the culminations of thousands of innovations from managers, organizations, and business models.

It is hopeful and not a skeptical view to empirically chart where today's promising technologies lie along their developmental curves. Those curves, long and uncertain, nonetheless offer glimpses of different futures scattered across the industrial landscape, glimpses that enable us to prepare for what comes next, in as much as we can discern it today.

It is the job of engineers, entrepreneurs, venture capitalists, and journalists to envision their preferred futures, persuade others to join them, and set about making those futures happen. But it is the job of thousands of plant managers, line operators, operations leaders, and others to manufacture products, deliver goods, offer services, and produce the throughput that keeps the economy running. Those responsible for this daily output are inevitably skeptical of new technologies, most of which do not work very well when they're new. Adoption at scale is the product of tens of thousands of small adoption decisions, each time someone with line responsibility sees potential ways to do their job better.

CHAPTER 4

# Institutional Innovation to Support Workers

Innovative technology has been changing the nature of work across industries and occupations. Indeed, as the previous chapter shows, the U.S. has not lacked for innovation over the last four decades. The fruits of these innovations, however, have been so unequally shared that a substantial number of workers have seen little to no earnings gains relative to overall productivity growth.

We observed above that inventing ways of accomplishing existing work, new business models, and entirely new industries drives rising productivity and new jobs. But innovation in technology alone will not generate broadly shared gains absent complementary innovation and reforms in U.S. education and training systems, labor policies, corporate governance, and worker representation. Buttressing existing systems or restoring them to their former glory will not reform a labor market that has changed radically over the course of decades. To channel rising productivity into broadly shared gains, institutional innovation must complement technological change. These “institutions” refer to the norms, rules, and social arrangements that create the “rules of the game” in labor markets. Critical institutions include education and training organizations, social insurance systems, labor laws and regulations, and labor unions, as well as the R&D infrastructure that encourages and shapes innovation.

Every society develops and supports its workforce through a web of institutions that reflect the social contract. In European countries, for example, that web is often tightly knit. Employers collaborate with one another as well as with government and education to train workers both in the classroom and with work-based learning. Union representatives sit on the boards of some companies; strong protections for labor are written into law.

The U.S. model, in contrast, is decentralized. Americans have often viewed the European model as rigid and costly. State and federal agencies do little to coordinate workforce development efforts. Worker protections are limited, by the standards of industrialized countries, and lightly enforced. Companies compete fiercely for skilled labor rather than banding together to develop it. These institutional features have virtues, for example, facilitating competition and creative destruction. But the U.S. could learn lessons from Europe and from Canada.

The U.S. can build a more stable, supportive, and innovative ecosystem with its existing institutions. That it will likely retain much of its fragmented system does not prevent reforming and strengthening current institutions to better serve the majority of workers.

Any proposal to strengthen labor market institutions raises the legitimate concern that these institutions will impose costly constraints and mandates that hobble enterprise performance. Badly designed institutions can sap productivity, inhibit innovation, and harm the public. Still, if institutions are well chosen, their costs are worth paying.

Moreover, not all institutional reforms impose costs: some reduce them. Denmark has one of the world's most flexible labor markets. Employers can hire and fire at will with minimal costs for dismissing workers. Litigation surrounding dismissals is uncommon. But supporting these regulations is a generous social safety net and active labor market policies that provide training, job search assistance, and strong return-to-work incentives for job losers.[82] By insuring workers against income loss and skills obsolescence, public sector institutions lift economic burdens from employers, allowing them to act with maximal flexibility.

To take a contrasting example, the United States healthcare system has been famously labeled as "uniquely inefficient"[83] due to its extraordinarily high costs and cumbersome administration. Unlike in every other advanced country, the direct costs of healthcare in the U.S. are substantially shouldered by employers who purchase health insurance for their workers. This adds a large fixed cost to every full-time hire, generates a sizable wedge between what firms spend on workers and what workers receive in their paychecks, and discourages hiring. Disentangling U.S. health insurance provision from employment would be an institutional innovation that would reduce these labor market distortions.

This chapter highlights four institutional dimensions to the work of the future: (1) investing in education and training, including adopting innovative new approaches to skills development throughout a worker's life; (2) improving job quality, particularly for those in traditionally low-paid jobs, through strengthening labor market institutions and worker voice; (3) expanding and shaping innovation, including rebalancing the tax system to bring taxation of wages and capital investment closer to parity; and (4) strengthening the critical role employers and managers play in fostering higher productivity, which, in turn, allows for higher wages.

## 4.1 Education and Training: Improving Access to Good Jobs

Our policy focus is on education and training for adults, particularly those whose work is more vulnerable to automation. These workers typically (though not exclusively) include those in lower-wage jobs, those whose education pathways include alternatives to four-year degrees, and those who are displaced mid-career. Creating opportunities for these workers requires both investing in existing educational and training institutions and innovating to create new training mechanisms to make ongoing skills development accessible, engaging, and cost-effective.

Primary, secondary, and college and university systems are, of course, crucial. We focus on the skills training system for adults, however, because it is directly targeted toward assisting workers in a changing labor market. This system includes employers, community colleges, unions, and public training programs. It also includes innovative new venues — both online and offline — that prepare workers for the job market. Within these categories, the quality of training varies widely, with correspondingly varying outcomes for workers. The system's heterogeneity and complexity has obvious downsides, but it also offers U.S. workers multiple entry points to training and education throughout adulthood. This flexibility is rare in more centralized European systems.

Task Force member Paul Osterman studied how U.S. adults acquire skills, including employer-provided training, by conducting a national survey to assess what training employers provide and what training workers undertake on their own.[84] The survey found that about half of adults said they received training from their employers in the past year, while about 20% took part in some form of training on their own, a relatively high percentage of which (about three-quarters) was online. Workers at the lower end of the wage and skill distribution received less training. The survey also found substantial racial and ethnic disparities in access to employer-provided training. These disparities remain even after controlling for a full range of personal characteristics, employer characteristics, and job skills requirements.[85]

Employers hesitate to make large, up-front investments in their workers' general portable skills since workers may take those skills to another employer to earn a higher wage. Publicly funded training programs seek to fill this gap. A survey by the U.S. Government Accountability Office in 2019 identified 43 distinct federal job training programs.[86] On the state level, programs range from employment offices — which help match job-seekers to jobs in the community where they are located — to programs aimed at teaching workers specific skills and placing them in related industries. Too often, such programs are short term, of variable quality, and guided neither by employer needs nor current knowledge of skill demands.

### 4.1.1 Community Colleges

The linchpin of America's training ecosystem is its roughly 1,100 community colleges. As the nation's leading provider of training, community colleges enroll close to 7 million students in credit courses annually, of whom 46% are over age 22 and 64% are part-time. A majority of these older students are in vocational programs. In addition, another 5 million people take non-credit courses. Although non-credit courses are poorly tracked, most are vocational and populated by adults who attend part-time. Community college students in credit courses are disproportionally minority, low-income, and first-generation college students.

Economic research has shown that degrees and certificates obtained from community colleges often lead to higher employment and earnings.[87] But to deliver on their potential, community colleges need to assist a larger share of students to complete their studies and attain degrees. Fewer than 40% of students who enroll in these schools complete a certificate or degree from any institution within six years.

## Creating Effective Community College Programs

When MIT researchers visited Florida's Indian River State College in January 2020, they found strong regional partnerships and a commitment to diversity, equity, and inclusion. Forward-thinking leadership was helping the college to keep up with the strong growth trends and increasingly diverse demographics in its region, while balancing the different needs of both urban and rural counties its service area.

With colleagues at the Community College Research Center, researchers identified 4 factors that contributed to creating an effective program:

1. Strong regional partnerships among economic development leaders, workforce development boards, industry, and the college. Three of these include:
    - Florida Power & Light supports the electronic engineering and nuclear technology programs, which train technicians and upskill engineers in a lab with equipment provided by the utility.
    - Disney and other media companies support students' digital media portfolio development through internships and exhibitions.
    - Cleveland Clinic, a hospital system, worked with the college to create two new certificate programs in medical informatics and medical coding and a longer-term program in anesthesia technology to help upskill nurses at the clinic.
2. A collaborative approach to leadership and planning. This collaboration includes faculty, staff, and community members in assessing progress. Ad hoc teams tackle big issues like future demographic and technological change.
3. Policies are data-driven. College deans regularly review detailed data at the school and program level, regarding the progress of specific demographic groups. College leaders break down student achievement data by characteristics, such as race and ethnicity, enrollment status, first time in college, and first-generation college student.
4. State-of-the-art facilities. Due to active fundraising with community benefactors, the college is able to maintain state-of-the-art learning facilities and equipment. Modern facilities, in turn, allow the college to form more effective partnerships with the local community to support student learning, skills development and employability.

Partnerships that leverage the expertise of community colleges and the private sector are emerging to teach needed technology-oriented skills. Google has partnered with 25 community colleges to offer "IT Support Professional Certificates," and Amazon is working with a community college in Virginia to teach students cloud computing as part of the school's information systems technology curriculum.[88] Another example is IBM's P-TECH program, launched in 2011, which links high schools, local industries, and community colleges and enables students to earn both their high school diploma and a two-year associate's degree in STEM-related fields such as cybersecurity. The program targets students from underserved backgrounds.

### 4.1.2 Intermediaries and Sectoral Programs

One approach that appears to enhance outcomes for students enrolled in community colleges (as well as those not in school) are so-called intermediary programs. These work directly with employers to identify skills training that will prepare students for existing jobs.

The components of the most effective intermediaries are:

- Close relationships with employers (the so-called "dual customer" model)
- Support services and counseling for clients
- Substantial investments in training

In order to achieve the close relationship with employers, intermediary staff develop expertise about industry and employer needs. Osterman highlights Project QUEST in San Antonio, for instance, which works with local firms to identify future job openings and then recruits low-wage workers to train them for those positions. Participants engage in remedial education, weekly group meetings that encourage motivation and support life skills development. They receive financial assistance to cover transportation and other needs. A rigorous evaluation of the QUEST program based on a randomized controlled trial found that participants earned significantly more than equivalent control group members who were not randomly selected into the program. By year nine, this gap was over $5,000 per year in additional earnings for graduates of the program. These impacts are not unique to QUEST, and other rigorous evaluations of other best-practice intermediaries also find positive results.

### 4.1.3 School-based Vocational Training and Apprenticeships

High schools and immediate post-secondary education may also play an important role in providing immediately marketable job skills.[89] High school career and technical education (CTE) may be integrated into comprehensive high schools or in dedicated vocational high school facilities. New models for CTE programs have proliferated in recent years.[90] Their core characteristic is to better integrate work experience with the traditional classroom. Examples include the Pathways to Prosperity Network and the IBM P-TECH schools (mentioned above). Another strategy is to work within existing schools and update the traditional apprenticeship model by linking high school classes with work experience. Workers benefit from apprenticeships by receiving a skills-based education that prepares them for good-paying jobs, while employers benefit by recruiting and retaining a skilled workforce.[91] Examples include CareerWise Colorado, the Georgia Youth Apprenticeship Program, and the Toyota FAME model.

## South Carolina's Apprenticeship Strategy

Rather than compete with neighboring states to attract firms using financial incentives, South Carolina has focused on strengthening its workforce training strategy. The state now has what is considered one of the nation's most successful apprenticeship programs, at the technical college level and now with a youth apprenticeship in Charleston starting in high school. Founded in 2007, the state's program, Apprenticeship Carolina, has grown to over 30,000 registered apprenticeships across every county and with the participation of all the state's 16 two-year technical colleges. This initiative allows the state to help employers fill out U.S. Department of Labor apprenticeship credentialing paperwork free of charge, and to formalize a variety of local programs. The program has been embraced by both small and large companies including South Carolina's numerous German-based firms.

In Charleston, the high school apprenticeship program was initiated in 2014 by six smaller employers seeking skilled workers. It comprises a collaboration among employers, the area's technical college, and the Chamber of Commerce. The state provides a $1,000 tax credit to participating companies and the Chamber of Commerce and a state program pay the technical college tuition. Employers cover the wages of student apprentices, who work part-time and during the summer while taking math and science courses at their own high school and technical coursework at the technical college. Firms choose their own apprenticeship hires, who range from 16 to 18 years of age, and students earn about a year's worth of credit toward a two-year associate's degree. Participating employers have spent $5 million since the beginning of the program, with most of the cost borne by small employers — although the city's largest employers, including Boeing and Bosch, have since joined. As of 2018, the program had 94 students currently enrolled, and 232 former apprentices had been hired by hosting firms. [94]

These models draw some of their inspiration from European apprenticeship programs, which build upon the strong relationships between government and "social partners" — employer associations and unions. As Task Force member Kathleen Thelen and co-author Christian Ibsen found in their analysis of German and Danish vocational education training (VET) programs, these programs can support national objectives around developing a skilled workforce for the private sector and increasing inclusion of those who may have weak ties to the labor market.[92] Though such programs are highly country-specific and do not readily translate to the highly decentralized U.S. context, these programs are worth study as apprenticeship programs are expanded in the United States.

While evidence on the general efficacy of apprenticeship programs is relatively thin, early evidence from experiments with apprentice-like sectoral employment programs is promising. [93] As with traditional apprenticeships, these programs emphasize on-the-job training, but they do not require the creation of formal or registered apprenticeship positions. Researchers have found short- to medium-run impacts on earnings of around 20% or more in the majority of evaluations of these programs, suggesting they are more effective than older training models that have been a "one size fits all" approach, which may be less effective in an economy that demands more specialized skills.

## Public-Private Partnerships: Detroit and Fiat Chrysler Automobiles

In recent years, Detroit has been adding automotive jobs — but not in assembly jobs for factory workers, rather in engineering and design work. That changed in February 2019 when Fiat Chrysler Automobiles (FCA) announced a deal with the state and city to convert an old engine plant and update an old assembly plant to produce new Jeeps.[97]

FCA enlisted the city's workforce agency — Detroit at Work — to recruit 5,000 workers and committed that United Auto Workers (UAW) members and Detroit residents would be considered first for jobs. As of October 2020, over 16,000 Detroiters were screened, over 10,000 completed an application, and more than 5,000 were invited for interviews. FCA has extended 4,100 job offers to Detroit residents.

The state and city offered FCA large incentive packages, including acquiring 200 acres of property near the old plants for the plant renewal and expansion. FCA also received a commitment for property tax abatement. This recruitment deal was controversial and is still viewed with some skepticism. It is an important test case for Detroit at Work, which is responsible for preparing Detroit residents for the new assembly jobs and establishing the city as a go-to source for manufacturing talent. To those leading the effort, the partnership among FCA, the city, and Detroit at Work demonstrates that Detroit's talent recruitment model can succeed.

Job seekers in Detroit have access to a wide range of supportive services, including document review, hands-on training in common manufacturing practice, math tutoring, interview practice, and transportation assistance. The Employment Service/One-Stops played a key role throughout this process. This deal also requires that FCA provide information that would enable an effective recruitment and pre-screening effort. FCA and Detroit at Work spent a year learning about each other's systems in order to identify and prepare a workforce that would succeed at FCA. A number of other commitments by FCA regarding further upskilling at the company and across the city further expanded the scope of the partnership.

Most of the new jobs at FCA are assembly line positions starting at around $17 an hour. This work is often repetitive and physically challenging. But these jobs lead to union- and employer-provided benefits. The very large number of applications submitted makes clear that these positions are attractive.

### 4.1.4 Dislocated Workers

A growing repertoire of experimentally verified training programs are effective in moving low-wage workers and young adults up the job ladder. But the understanding of what is effective for middle-aged employees who are dislocated by trade, by technological change, or even by COVID-19 is considerably weaker. Most experience with retraining middle-aged and older employees comes from programs funded through the federal Workforce Innovation and Opportunity Act and from training funded by a separate program that targets workers who lose their jobs as a result of trade (the Trade Adjustment Assistance Program, or TAA). Evaluations of these programs show mixed results: One suggested close to 75% of participants found jobs but with earnings replacement ratios of 75%–85%, depending on age. Other well-designed programs with community colleges reported significant positive employment gain .[95]

Much work remains to understand how to best serve dislocated workers. The U.S. should accordingly invest in developing and rigorously evaluating demonstration programs that offer promising approaches. In addition, particularly in the time of the COVID-19 crisis, a modernized public job-matching service, such as the U.S. Employment Service (USES), could play a more prominent role in helping displaced workers. Evaluations show that utilization of the USES does reduce unemployment spells, but the gains, while large enough to justify the cost, are still relatively small .[96]

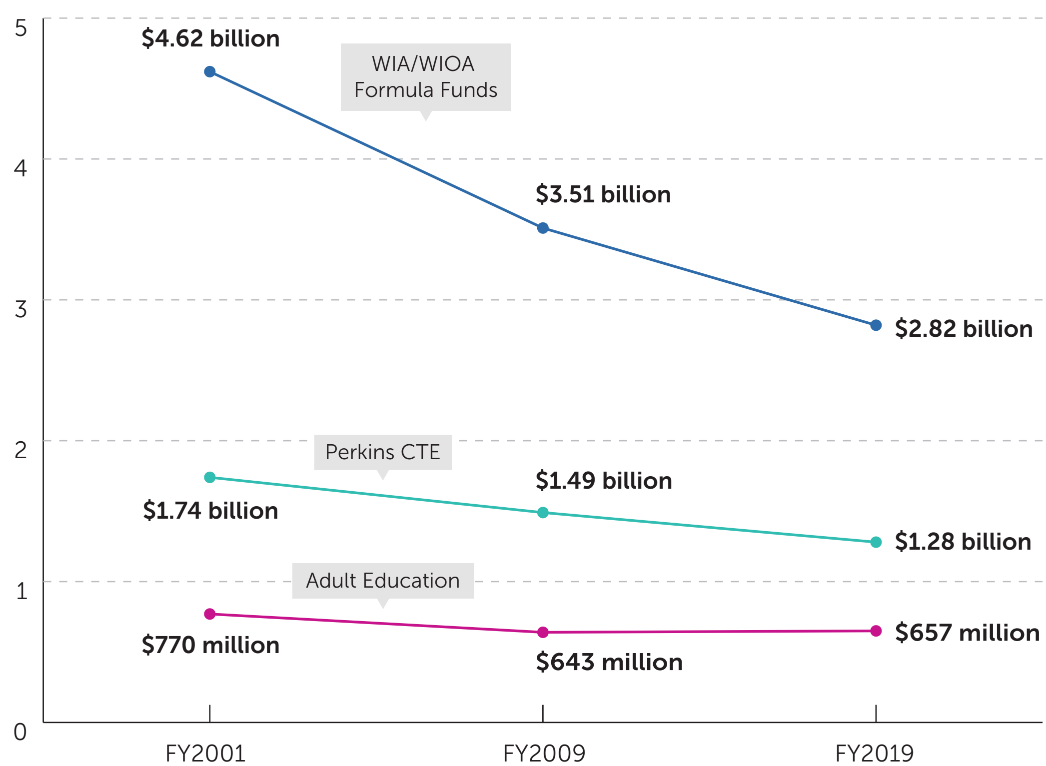
### 4.1.5 Moving Forward: Funding, Regional Commitment, and Innovation

While the U.S. lacks a firm social contract that drives cooperation between different stakeholders in the skills training system, it can build a stronger foundation for delivering quality training at scale. Below, we highlight three dimensions that are important to moving forward: (1) more funding, (2) better regional partnerships, and (3) more innovation.

### Funding

Education and training programs have faced declining support across the board, precisely the opposite of what is needed at this critical juncture for workers. For example, government funding accounts for just under 65% of community college revenue. Yet, between 2000 and 2019, total funding per full-time student from state, local, and federal sources for community colleges was flat in real (inflation-adjusted) terms, while demands on, and expectations for, the system increased considerably. Federal funding for adult job training, adult basic education, and high school career and technical education have all declined. The Workforce Investment Act/ Workforce Innovation and Opportunity Act (WIA/WIOA) formula spending between fiscal years 2001 and 2019 fell from $4.62 billion to $2.82 billion (see Figure 17). This decline is substantial, but even it overestimates the limited funds for training. Because WIOA funds are used along with Wagner-Peyser Act funding to support the job centers, estimates are that under 30% of WIOA funding is expended on training. The lack of resources for training is particularly troubling because the successful intermediaries described above require non-trivial investments.

**Figure 17. Workforce Investment Act/ Workforce Innovation and Opportunity Act Spending, Fiscal Years 2001–2019**




*Source: National Skills Coalition, https://www.nationalskillscoalition.org/news/blog/budget-analysis-2021-request-has-important-skills-proposals-but-big-cuts-to-labor-and-safety-net-programs*

## Regional Commitment: The Case of Boston

The City of Boston provides an example of concerted regional commitment over decades. In the late 1970s, state government and the high-tech business community came together to form the Bay State Skills Corporation which provided public and private dollars for job training. In 1982, the Boston business community more broadly supported the Boston Compact, an early example of current "Promise Programs" that provided financial support for post-secondary education to all Boston high school graduates. In 1996, Bay State Skills and another state economic development agency were merged to form the Commonwealth Corporation (CommCorp), which is funded by a state appropriation and which manages, among other training programs, an incumbent worker upskilling initiative financed by a portion of the state unemployment insurance tax. The state investments support a wide range of training efforts and cooperate with two large union programs, Local 1199's health training and the Hotel and Restaurant Employees Union BEST job training program.

Another important player is the Boston Private Industry Council (PIC), the oversight agency for WIOA funding. The Boston PIC membership includes high-level corporate leadership and is effective in helping to link training programs with jobs. Additionally, two of the most innovative intermediaries in the country, Jewish Vocational Services and Year Up, are based in Boston. In 2018, Massachusetts created a coordinated, statewide umbrella that unites the state's 16 regional workforce boards and 25–30 local workforce centers into a single coalition called MassHire. Announced in the fall of 2020, MassHire will provide a template for a new, state-based training and career pathway model in manufacturing sponsored by the U.S. Department of Defense (MassBridge).

### Regional Commitment

A focus on a regional commitment makes sense because labor markets are regional and because public labor market programs, adult education, community colleges, and school systems are all best managed by governors who can coordinate at the state level and operate at the regional level in the state (or in some cases, across state boundaries as in the Greater Washington area[98]). That said, there is a deeper requirement than good management: a shared commitment by employers, community groups and unions, and governmental and educational leaders to build and support a system. Several states exemplify this kind of commitment. For example, Massachusetts, North Carolina, and Tennessee are widely admired for their creative workforce development systems. But even in these best-practice states, limited resources constrain scale.[99]

### Innovation

Where research has identified specific programs and practices that work, the challenge ahead is scaling and replicating these successes. Meeting this challenge requires investment, institutional reforms, and a regional commitment by the full range of public and private actors. Alongside these successful examples, there is much room for innovation. Below, we summarize several promising directions.

#### SKILLS STANDARDS

Modeled on those in Germany, skills standards were introduced into the U.S. policy discussion during the Clinton administration. The rationale is that standardization of credentials would enable people to be more mobile across employers, and even geographies, while at the same time providing assurance to employers about the qualifications of a new hire. While attractive in the abstract, important questions remain about this idea. The deepest problem is that employers do not seem to pay attention to credentials except in tightly defined circumstances (e.g., some IT certifications), a limitation that has been demonstrated in two large-scale surveys.[100] For reasons that are not fully understood, employers simply do not seem to find the credentials relevant. For skills standards to succeed, training institutions and employers will need to collaborate to define standards that are job-relevant and credibly certified.

#### LABOR MARKET INFORMATION TRANSPARENCY

Many efforts by both public and private sector actors seek to better collect and promulgate information on the state of local labor markets: occupational openings, compensation, skills requirements, payoffs to different credentials, and the track record of different training providers in providing these credentials. Markets do not readily provide such information, leading to endemic information shortfalls, which if redressed, could lead to better decision-making by workers, employers, and training providers. New experiments are also underway with developing digital records of individuals' skills and competencies that can help them navigate the labor market over time.[101] While it is hard to argue against improved information, it is important to understand that information per se is not a substitute for investments in worker skills or in the quality of skills providers. Simply providing public data on the quality of skills providers may be insufficient to weed out weak providers.

#### INDIVIDUAL TRAINING ACCOUNTS

Adequate funding is a major problem for all components of the public job training and readjustment system. Individual Training Accounts (ITAs) aim to address these challenges by providing opportunities for adults to save for education and training using pretax dollars that would be matched by public contributions.[102] One issue here is how to structure the accounts so that low-paid workers, who may very well find contributions difficult, can benefit. The deeper issue is the same as that which we already identified: Absent careful quality certification and rigorous oversight, history suggests that low-quality providers will proliferate and absorb training dollars.[103] ITAs are an idea worth exploring, but they must be structured to ensure that ITA providers meet quality standards and that low-paid workers have sufficient funds to access training (possibly through subsidies).

### New Pedagogies: Online Education

Given the vast potential for innovation in online learning, which was essentially infeasible two decades ago, new ideas for pedagogy are proliferating. Examples are certificate programs such as those provided by Oracle and Microsoft, boot camps, online courses, blended online and in-person offerings, machine-supervised learning, and augmented and virtual reality learning environments. A full accounting of the number and scope of these new models is lacking, although efforts to classify and track them such as Credential Engine, a non-profit founded in 2016, are underway.

## AI and Online Learning at IBM

Over the last decade, IBM has installed a company-wide facility that uses artificial intelligence to recommend personalized learning content to employees. The new training and learning systems apply AI and the science of learning to understand what would most benefit each worker based on their current skills. The company says it expects every employee to spend a minimum of 40 hours in training and professional development each year.

Training is offered to all employees at every level of the firm, from the lowest paid to highest paid. Approximately 85% of the training is offered online. In 2019, IBM employees spent 77 hours in training on average, and the median trainee spent 52 hours. A preliminary study of this system by Professors Thomas Kochan and Fei Qin found that time spent in learning and achieving certifications, which the company calls "learning badges," is associated with higher earnings and faster promotions.[105]

Some of these innovations hold great promise for improving pedagogy, lowering costs, and facilitating scale. As an example, online classes enable community college students to more easily combine working with education and training. Indeed, the proportion of students studying fully online who are enrolled within 50 miles of their homes is increasing.[104]

While it remains in its early development, online education has evolved rapidly with the spread of broadband technology. Since they were first introduced by colleges and universities in 2012, "Massive Open Online Courses," or MOOCs, have grown and have enrolled 100 million people on a global basis.[106] Hybrids of online education are now emerging as well, in which students combine online work with in-person courses at an educational institution.

Task Force member and MIT Vice President for Open Learning Sanjay Sarma and Research Advisory Board member William Bonvillian studied the growth of the digital learning sector. They focused on tools that can be quickly scaled and delivered, often at lower cost than traditional programs. Much of workforce education must be "hands-on," so online elements work best when blended with in-person guidance and work on equipment. "While many colleges and universities had been reluctant online education adopters," they write, "the pandemic-induced switch to online created an online cascade from which there is probably no going back."[107] The COVID-19 crisis has accelerated the development of this field, as millions of students and teachers shifted to remote learning for health and safety reasons. In this scramble to move online amid the pandemic, many working adults "were forced to attend training sessions, conferences, and events over videoconferencing, further deepening the penetration of online modalities."

Given that most of the tools for online education are less than a decade old, it is unsurprising that online education faces many challenges on its way to achieving its full potential. The completion rate for individual, stand-alone online courses is quite low, though that may not be a meaningful metric since a large share of online enrollment is likely low-cost window shopping.

Of course, online education need not merely replicate traditional offerings. One innovative model involves offering groups of related courses with certificates that attest to work-related skills that can translate into job opportunities. As the workforce increasingly engages in lifelong learning, online skills provision is increasingly useful for upgrading skills and adding complementary know-how on top of an established background. YouTube, for example, offers an ever-expanding cornucopia of widely used "how to" videos. Online learning will likely be even more important for workforce education than for traditional educational venues, though the move to online schooling during the COVID-19 pandemic may tip that balance.

One result of the coronavirus-driven rush to online learning tools has been an acceleration in the study of what works best in this medium. Cognitive psychology and education studies provide extensive guidance on how to bring learning science into online education. One commonsense lesson is that video lectures that lack interactive content have limited learning value because students find it challenging to pay attention. A better approach is to intersperse lectures with participatory discussions and to restructure presentations into a series of "bite-size chunks," each lasting about 10 minutes or less. This is easier with pre-recorded, asynchronous videos, such as those on MIT's edX platform, than with Zoom lectures.

A second lesson is that creating "desirable difficulties," where the learner has to struggle a bit with the material, enhances learning. Additional effective techniques include introducing spaced practice, so that learning occurs and is reiterated over a period of weeks and months; and providing frequent low stakes assessments and feedback, which increase engagement. These practices can readily be built into online programs.

A revolution in educational content and delivery may well change how schooling and training are executed. A great deal of ongoing experimentation, a smattering of successes and failures, and much unrealized potential remain, as well as a clear need for evaluation to determine what is effective. Future workforce education will build on the capabilities of emerging technologies, including AI-powered tutoring systems, virtual and augmented reality, "gamified" and simulated learning environments, and collaborative tools. These tools will become increasingly central to skills training provision, may be virtuously combined with new delivery modalities that expand access, and offer the potential for broader access, lower cost delivery, and greater learner engagement at a time of growing need for workforce upskilling and lifelong learning.

## 4.2 Improving Job Quality

As documented in Chapter 2, the United States has not translated rising productivity into commensurate improvements in job opportunities and earnings for the majority of workers during the last four decades. The poor quality of jobs open to U.S. workers lacking four-year college degrees or specialized credentials provides one of the starkest examples of this failure. Low-wage U.S. workers earn substantially less than low-wage workers in almost all other wealthy industrialized countries. For example, the OECD estimates that they earn approximately 25% less than their Canadian counterparts (see Figure 7), despite the many commonalities between the countries, including their legal and institutional environments, education systems, and industrial structures, as well as their deep trade integration.

As argued above, this failure is not an inevitable consequence of technology, globalization, or market forces. Rather, a set of U.S.-specific institutional and policy choices failed to blunt — and in some cases magnified — the consequences of technological and globalization pressures on the U.S. labor market. To contend effectively with these challenges requires institutional and policy reforms that realign labor market opportunities with the rising productivity and societal wealth that the U.S. has reaped from decades of innovation and investments in human and physical capital. These reforms include crafting and enforcing fair labor standards, setting well-calibrated federal minimum wage policies, extending the scope and flexibility of the unemployment insurance system, and transforming the U.S. employer-based health insurance provision into a system with portable benefits.

We discuss policy recommendations in three of these areas here: (1) reforming unemployment insurance; (2) establishing meaningful minimum wage regulations; and (3) restoring workers as stakeholders in collective bargaining and corporate decision-making. The healthcare provision question, while critically important, is outside the scope of the Task Force's mandate. Similarly, because evidence on guaranteed income programs is highly preliminary, we omit discussion here and refer the reader to the brief by Task Force member Tavneet Suri.[108]

### 4.2.1 Unemployment Insurance Reforms

Unemployment insurance (UI) is America's first line of defense against the financial toll of job loss for workers who become involuntarily unemployed. The COVID-19 crisis has spotlighted the weaknesses of the UI system.

Task Force Advisory Board member Susan Houseman and Christopher O'Leary, of the W.E. Upjohn Institute for Employment Research, working with University of Maryland Professor Katharine Abraham, took a close look at the system.[109] Their work highlights overdue modifications in the rules determining who is covered by the system and what it takes to qualify for benefits among those who are nominally covered. The U.S. UI system excludes the self-employed, for instance. That category traditionally encompasses people who own their own businesses and employ others. However, increasingly it includes many relatively low-paid service workers, including maids, babysitters, and "gig" workers whose work is mediated by online platforms or mobile apps. "Changes in technology and other factors are likely to contribute to growing rates of self-employment in the coming years, and many of these workers are likely to be exposed to considerable income fluctuation risk," write the researchers.

Even when employed in UI-covered jobs, low-wage and part-time workers may have trouble qualifying for benefits. As of the beginning of 2019, a worker in Arizona, Indiana, Michigan, Ohio, or South Carolina who worked 20 hours per week at the state's minimum wage for a full half-year would have insufficient earnings to qualify for UI benefits. In an additional 23 states, working 20 hours per week for three months at the state's minimum wage would not generate sufficient earnings to qualify, even if other eligibility conditions were satisfied. These rules mean that the UI system fails to insure some of the lowest-paid workers in the most precarious jobs, even though these workers are employed in traditional direct-hire jobs that in theory are covered.

Within this restrictive system, states have implemented policies that have the effect of further limiting enrollment. Florida, for example, moved to an online system in 2011 that was available only in English and required applicants to complete a 45-question online skills assessment. Some of these requirements were later changed after legal challenges, but the filing process remains.

One indicator that the UI system has failed to keep pace with the changing structure of jobs is the declining share of the unemployed who receive benefits. That share has generally trended downward over the last four decades, only rising when the economy strengthens sufficiently to bring workers into full-time, direct-hire employment. Since 2011, the share of unemployed receiving UI benefits has remained below 30% (see Figures 18 and 19).

> These rules mean that the UI system fails to insure some of the lowest-paid workers in the most precarious jobs.

**Figure 18. Percent of Unemployed Workers Receiving Regular State Unemployment Insurance Benefits, 1979–2019 (Annual Averages)**

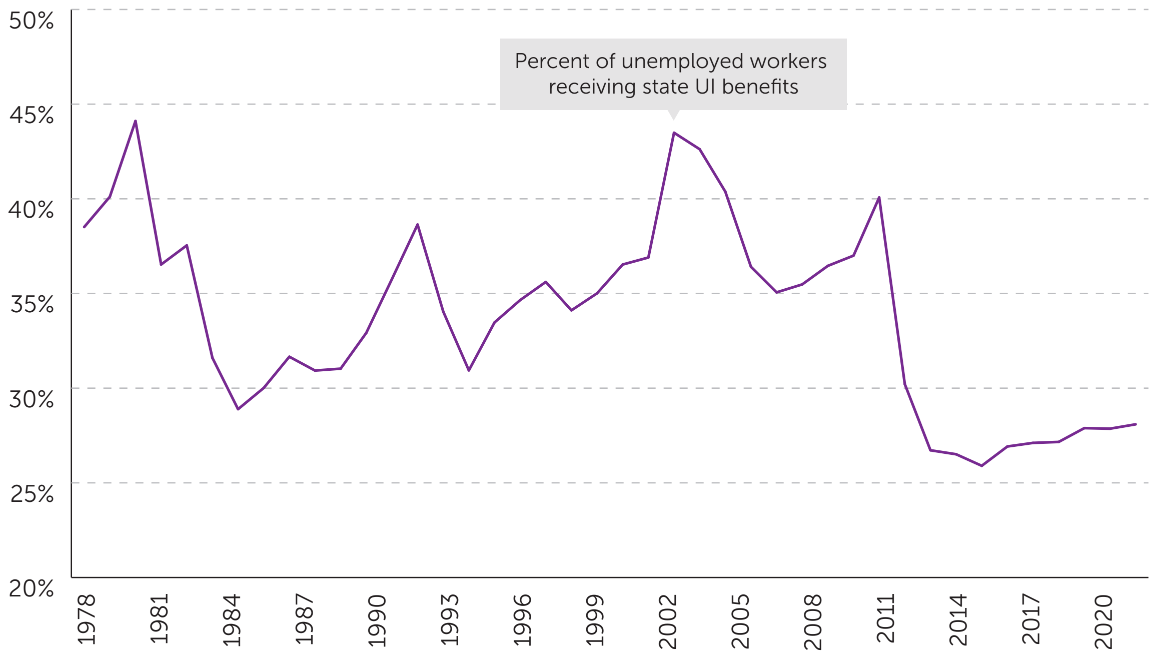
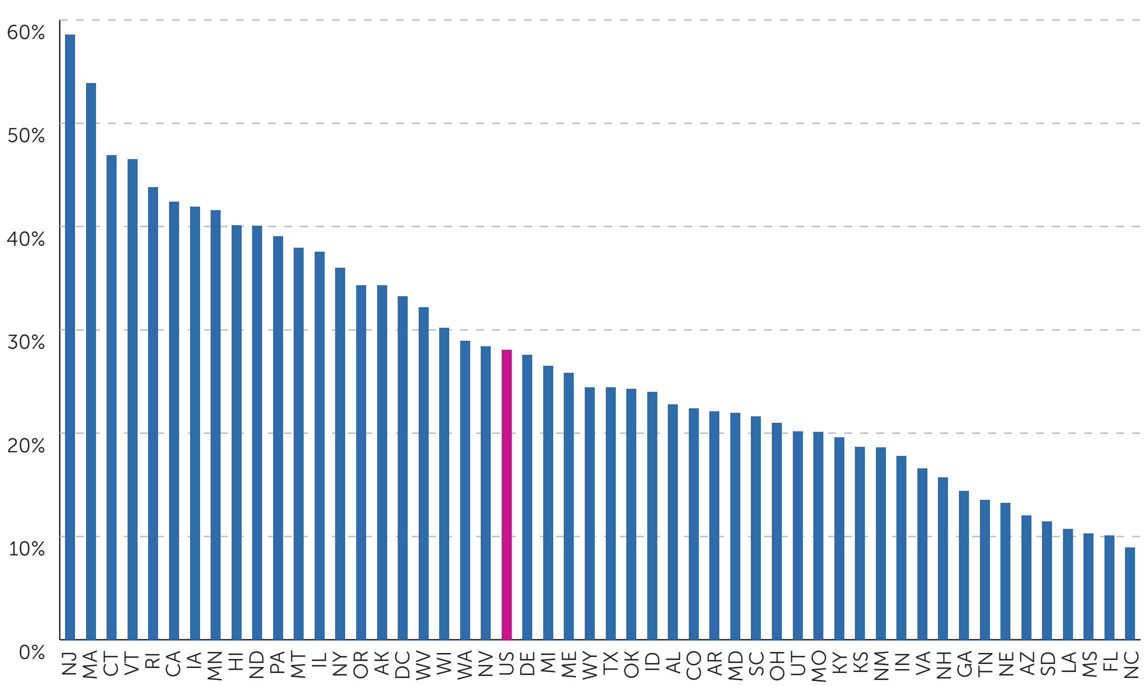



**Figure 19. Unemployment Insurance Recipiency Rates Among Unemployed by State, 2019**




*Source for Figure 18 and 19: U.S. Department of Labor, Employment and Training Administration, https://oui.doleta.gov/unemploy/data_summary/DataSum.asp*

This decline was driven by particularly sharp cutbacks in a handful of states: In just eight states, most in the Southeast, the share of unemployed workers receiving jobless benefits has fallen to between 10% and 15%. "Instead of viewing unemployment insurance as a program to support productive job search and improve the efficiency of job matches, the policy posture in some states is that unemployment insurance is simply a business cost to be minimized," Houseman and co-authors note.

These facts point to an urgent need for modernizing and reinforcing this crucial piece of the social safety net for workers. As the current COVID-19 crisis underscores, the causes of involuntary job loss are numerous, with technological displacement being only one of them. To its credit, the federal government enabled expanded jobless benefits in the spring of 2020 as part of its stimulus efforts in response to the crisis. But these expansions have already partly expired and will do so fully at the end of 2020.

Houseman and colleagues propose four sensible modifications to the unemployment insurance system to make the program more accessible and equitable: (1) allowing workers to count their most recent earnings toward eligibility determination; (2) establishing UI eligibility based on hours rather than earnings (which currently makes it harder for low-wage workers to obtain UI); (3) dropping the requirement that the unemployed seek full-time work; and (4) reforming partial unemployment insurance benefits to better protect workers who lose a substantial fraction of their work hours or earnings without losing their jobs. We explain the rationale for these recommendations in the concluding chapter.

Ultimately, the U.S. must reconsider how independent contractors are classified to assure that they are truly independent. The U.S. effectively applies two distinct sets of laws and regulations to employment: One guarantees unemployment insurance, workers compensation, and some mandatory benefits to traditional full-time direct-hire employees; the other provides few protections to "independent" worker categories, including contractors, domestic workers, gig workers, and, in many cases, part-time workers. The distinction between these two employment categories has arguably grown more ambiguous over time, while the incentive for employers to reclassify employees as independent workers has only increased. There is no ready solution to this problem, but it is clear that employment policy and regulation requires innovation to keep pace with the changing structure of work.

### 4.2.2 Establishing Meaningful Minimum Wage Regulations

As documented in Figure 14 above, the real value of the federal minimum wage in 2020 was essentially at the same level as in 1950, seven decades earlier — and it was approximately 35% below its real value in 1979. The best available evidence indicates that well-calibrated minimum wages exert modest to undetectable adverse effects on employment, reduce household poverty, and are particularly effective at bolstering the earnings of minority workers who are overrepresented at the lower tail of the U.S. wage distribution. The erosion of the U.S. federal minimum wage, itself a deliberate policy decision, has magnified U.S. earnings inequality, retarded the earnings growth of low-paid U.S. workers, and likely further weakened the hand of labor unions in negotiating on behalf of their members.

There is room for minimum wage increases that do not disrupt employment and instead create positive regional ripple effects that can enhance wages for low-paid workers. Restoring the real value of the federal minimum wage to a reasonable percentage of the current national median wage and indexing this value to inflation would benefit workers substantially at little net economic cost.[110] Localities should retain the ability to set higher statutes, as they do currently.

### 4.2.3 Workers as Stakeholders

Americans' greater anxiety about the adverse impact of automation relative to that of their counterparts in other advanced nations is arguably one of the social costs of the U.S. shareholder primacy model.[111] Workers rightly perceive that they are not guaranteed to share in the fruits of new advancements. As noted above, the typical (i.e., median) worker has been treading water for decades, despite substantial growth in productivity and vast increases in top incomes.

In the past, labor unions played a key role in counterbalancing management by representing worker interests. Indeed, there was a time in the post-World War II era when unions were arguably too strong — limiting flexibility, raising costs, and blunting incentives for technological improvements.[112] But as the shareholder primacy model gained ground, union membership — outside the public sector — declined. Research by the Task Force and others recognizes this decline as one of the causes of the failure of wages to rise in tandem with productivity, as it did from the end of World War II through most of the 1970s. Black workers are also overrepresented in labor unions and hence, as with minimum wage, are particularly disadvantaged by the fall in union wage bargaining.[113] Recognizing these considerations, the Task Force has explored mechanisms to rebuild worker voice and representation in ways that can help ensure the gains from technology and other sources of productivity growth are shared equitably.

A challenging but important place for innovation is to implement reforms to the National Labor Relations Act of 1935 (NLRA). In contrast to countries like Germany that mandate worker representation on some company boards and provide works councils that represent workers more broadly, the NLRA makes works councils illegal at nonunion businesses in the U.S. through its ban on company-dominated unions, and is silent on the question of whether workers can serve on corporate boards. The law also excludes agricultural and domestic workers — a legacy of racist attitudes during the New Deal, when Southern congressmembers successfully sought to exclude Black workers from new government-mandated protections and benefits. Blacks made up the overwhelming majority of agricultural and domestic workers in the South at the time. Despite this history, and distinct from other New Deal legislation that also excluded Black citizens from social protections, the NLRA has not been substantially amended in the 85 years since its passage, except by the Taft–Hartley Act in 1947, which restricted some union activities and powers.

Survey evidence confirms that U.S. workers feel inadequately represented in the workplace and desire more influence over working conditions, security, training, and job design, among other job attributes. Task Force member Thomas Kochan and colleagues at the MIT Sloan School of Management and Columbia University found that a majority of Americans feel they have less influence than they ought to have over a range of workplace issues, including compensation, job security, promotions, respect, and harassment, and — key for this report — over the way new technology is applied to their jobs and in their work organizations more broadly. They define this as a "voice gap." Between one-third and one-half of workers say they also see this gap in other job-related issues, including their employers' values, training, discrimination, the quality of their organization's products or services, and how workplace problems are resolved. The same survey found that worker interest in joining a union has gone up in recent years. Currently, about half of non-unionized workers say they would join a union if given the chance, compared to about one-third who said the same in the 1970s and 1990s. In a follow-up national survey, the authors used an experimental design to determine what forms of representation workers prefer. Collective bargaining at the firm or industry level, advising management about employment practices, and worker representation on corporate boards of directors were all cited as important.[114]

Workers' quest for representation is legitimate — indeed, it is unquestioned in most industrialized countries — but finding a way to extend their representation will require innovation. Though not one optimal model of worker representation, economic efficiency requires that workers are given some weight as stakeholders in the firms that employ them. Simultaneously, the framework provided by the NLRA governing how businesses interact with their workers is unduly restrictive and limits opportunities for cooperative bargaining between worker and employer representatives. The U.S. needs multiple forms of worker voice and representation that can be tailored to better match the features and needs of different industries, occupational groups, and employment relationships.[115]

In keeping with the overall approach of this report to build on existing features of the U.S. labor market system, we conclude that strengthening worker bargaining power requires both strengthening existing labor law and reforming it to be more effective in encompassing the technological and economic changes transforming the workplace and the culture of work. As one example, domestic workers in the U.S. fall outside the scope of the NLRA. But the NLRA's general provisions would be of little use to them if coverage were available since those provisions are designed to facilitate bargaining between a single employer and its many employees. In domestic work arrangements, however, the relationship is reversed: Each domestic worker serves multiple households, so there are many more employers than employees.[116] Analogous issues extend to gig economy work, to independent contracting, to temporary help agency employment, and more broadly to any group of workers that is too dispersed to collectively bargain using conventional means.

Perhaps responding to these needs, there is a surge of experimentation with approaches for giving workers a greater voice at work. The group "Fight for $15" has had success in pressing large corporations, including Amazon and Walmart, to raise starting wages even though there are no unions at those companies to coordinate these efforts. The tactics of these groups are often aimed at drawing the attention of consumers to poor working conditions or low pay at large companies.

Groups such as the Freelancers Union and the National Domestic Workers Alliance allow workers to band together by occupation. Jobs with Justice is a national organization with branches in communities that work on education, research, communication, political action, and projects that promote worker rights. Working Washington is a state-level organization which advocates for workers in that state, including advocating for higher minimum wages and paid sick leave.

Some of these new initiatives go well beyond the structures and processes established under current labor law. For example, the Coalition of Immokalee Workers, which advocates for farm workers who are not covered under the NLRA, has been successful in pressuring the retail companies that sell their produce to pay a few cents per pound to support improvements in farm workers' wages and benefits. This would be illegal if these workers were covered under the national labor law because they're employed by the farmers — not retailers — and the law bans workers from targeting the customers of their employers in labor disputes.

To date, none of these models of representation have reached national scale, gained power equivalent to what unions achieved in their heyday through collective bargaining, or developed a sustainable business model. Many of them rely on some form of foundation support to cover their costs.

While these alternative models of representation are undergoing rapid evolution, labor law needs to be updated to allow them to flourish as they compete with alternatives. Modernizing labor law is especially important at a time when new technologies and other structural innovations — such as reclassifying more workers as contractors and the rise of app-based businesses such as ridesharing — have made the definition of an "employer" ambiguous.[117]

UNITE HERE, the union that represents hospitality employees in the hotel, casino, and food ser-vice industries, provides an unusual case of negotiations specifically designed to deal with the introduction of new technology. Beginning in 2018, UNITE HERE negotiated agreements with all of the union's major employers for advance notice of up to six months prior to introducing new technology, the right to negotiate about technology with the employer, and the provision of retraining, severance pay and first consideration for new positions for workers laid off as a result of the new technology.

Broadly, our exploration of this topic suggests that three sets of changes in labor law and policy are overdue: (1) strengthening the law and more vigorously enforcing protections and processes for workers to gain access to collective bargaining; (2) opening up labor law to allow innovation in new forms of representation in workplace and corporate decision-making and governance; and (3) building legal protections that allow for organizing workers without risk of retaliation in non-traditional realms, such as domestic and home-care workers, farmworkers, and independent contractors.

## 4.3 Institutions and Policies that Support Innovation

A central lesson from the Task Force's studies of both the economics of the labor market and the current state of technology is how much of new job growth is concentrated in entirely new occupations and industries. Recall that most jobs today didn't exist in 1940, and that the driver of employment in industries like warehousing and distribution is driven by e-commerce, an internet-enabled innovation.

Historical evidence amply shows the power of U.S. federal support in seeding these innovations and the industries that evolved from them. From the earliest days of the republic, the federal government has been an intimate, patient supporter of technology development with broad implications for industry. Federal armories created the machine tool industry that manufactured guns for the Civil War and laid the groundwork for the post– World War I production of typewriters, bicycles, and the mass production of automobiles.

Since at least World War II, this support has been focused, systematic, and innovative. In a salient example, the U.S. Army, Navy, and Air Force funded the first digital computers, trained their first generation of engineers, and created the field of computer science. The Defense Advanced Research Projects Agency (ARPA, later DARPA, created in response to the Sputnik crisis) for decades supported research into networking, interactive computing, computer graphics, and robotics that similarly laid the foundation for the explosion of those technologies — and the creation of millions of jobs.

This R&D was a mix of mission-directed (to solve specific problems, particularly in the military) and fundamental (exploring basic phenomena). Similar stories can be told about the National Science Foundation (NSF), the National

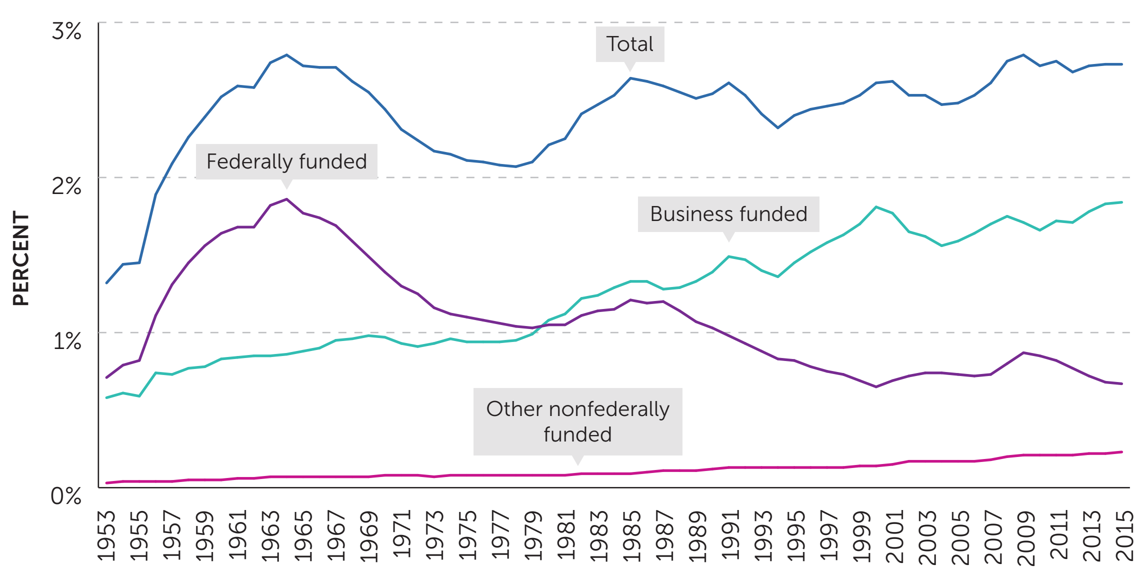
Institutes of Health (NIH), and numerous other agencies. Indeed, the COVID-19 vaccine response relies on an intellectual, institutional, and workforce infrastructure created by decades of patient federal investment. In each case, the nature and management of government support shaped the technologies that emerged, if only indirectly.

Government investment in the future of technology takes many forms. These include direct research grants, institutional support, graduate education, research in government labs, as well as large projects like the Apollo program or the Human Genome Project. Even government procurement at a crucial time in a technology's life cycle can be instrumental — for several years, NASA consumed 60% of all U.S. integrated circuit production for the Apollo program, giving the nascent technology a much-needed boost.

This R&D was not necessarily directed toward industrial applications or job creation, although these have been well-documented benefits for a long time. Nonetheless, by fostering experiments, training generations of young innovators, and providing institutional support, federal R&D investments have proved instrumental in both solving national problems and contributing to economic growth. While private capital and corporate R&D play crucial roles in bringing new technologies to market, neither has the consistency nor the patience to cultivate the fundamentally new over multiple decades.

Yet, America is losing this crucial competitive advantage. U.S. public investment in innovation has lagged even as that of other technologically advanced nations has advanced.[118] Combining both public and private R&D investment, Germany invested 2.9% of GDP in research and development in 2015, versus 2.7% in the U.S., and 2.1% in China, which, in turn, is expected to overtake the U.S. and Germany in the years ahead. Even while total U.S. R&D expenditure as a share of GDP has held relatively steady over the last three decades (though has not grown), the public investment share of R&D has fallen steeply over three decades, from approximately 40% in 1985 to approximately 25% (one-quarter) in 2015 (Figure 20).

**Figure 20: US Research and Development as a Share of GDP, by Source of Funds: 1953–2015**




*Source: This figure displays data from figure 4-3 of National Science Board (2018), chap. 4. The original data are drawn from the National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).*
*Notes: The figure shows how spending on R&D performed in the United States, presented as a share of GDP, has evolved over time from 1953 to 2015, in total and broken down by source of R&D funding.*

> The United States is unique among market economies in venerating pure shareholder capitalism — the notion that the sole purpose of firms is to maximize shareholder value.

Since public R&D expenditure tends to focus on basic science and technologies that may be decades from reaching commercial potential whereas private R&D expenditure tends to focus on technologies that are closer to market, these expenditures should probably be viewed as complements rather than substitutes. If so, the adverse effect of declining public R&D effort on innovation is unlikely to be fully offset by the rise in private R&D effort, even if total expenditures as a share of GDP remain relatively constant. As the brief by Task Force member Yasheng Huang and Political Science graduate student Meicen Sun discusses, the Chinese "whole of government" approach to fostering innovation and achieving scale provides an alternative model of all-in innovation.[119] This model is reminis-cent of the mega-project approach that the U.S. has favored at various times including the Manhattan Project, the Apollo Program and the Human Genome Project, but here applied to industrial policy.

Prescribing the specific mix of R&D programs and agencies to address the future of work is beyond the scope of this paper. It is, however, explored in the research brief by Task Force member Erik Brynjolfsson, Seth Benzell, and Daniel Rock. The Task Force's research points to several broad directions the U.S. should take. A first is to identify the technologically enabled health of the future U.S. labor market as a national problem, worthy of study and solution by a variety of innovators and researchers. Already, the NSF has a program on "Future of Work at the Human-Technology Frontier," as one of its 10 big ideas for future investments. The principles of that program offer a template for a broader set of investments, including understanding and advancing the human-technology partnership and promoting technologies to augment human performance.

## 4.4 A Critical Role for Employers: Improving Job Quality and Productivity Simultaneously

The United States is unique among market economies in venerating pure shareholder capitalism — the notion that the sole purpose of firms is to maximize shareholder value. Shareholder capitalism dictates that employees should be valued like all other intangible assets — that is, compensated at market prices and scrapped if their value to the firm falls below their cost to the firm. Within this paradigm, the personal, social, and public costs of layoffs and plant closings should not play a critical role in decision-making. While shareholder capitalism can plausibly be credited with some of the productive dynamism of the U.S. economy, pure shareholder capitalism is due for reevaluation.

Increasingly, U.S. businesses are engaging in that reevaluation. In August of 2019, the Business Roundtable — a group made up of the CEOs of many of the U.S.'s largest corporations — issued a new "Statement on the Purpose of a Corporation," signed by 181 CEOs, committing to lead their companies for the benefit of all stakeholders — customers, employees, suppliers, communities, and shareholders. It's the first time since 1997 that the organization's principles did not state that corporations exist principally to serve shareholders. Jamie Dimon, chairman and CEO of JPMorgan Chase & Co. and chairman of the group, said at the time: "The American Dream is alive, but fraying."[120]

Bold statements are easy to make. It remains to be seen whether they are followed by meaningful change in boardrooms. There are prominent examples of large companies raising base pay levels above statutory minimum wage levels. In September of 2020, for example, Walmart raised the wages of 165,000 employees as part of a plan to create new job categories that require store clerks to learn additional skills in order to shift more seamlessly between departments or specific tasks. Walmart's move follows a 2018 decision by Amazon to raise its base pay to $15 per hour, a step that was estimated to increase earnings for approximately 350,000 workers. The benefits of such steps extend beyond the workers employed at these firms. When Amazon, Walmart, and Target raise their starting wages, competing firms operating in the same labor markets also improve their wage and benefit offers.[121]

Nonetheless, we should be skeptical that firms will raise pay simply because they recognize "workers as stakeholders." This is a costly action, and if higher pay is not matched by higher productivity, it's unclear whether managers can justify these steps to their boards or shareholders.[122] As two of America's largest employers of low-paid labor, both Amazon and Walmart had come under considerable public criticism for their employment practices prior to raising their base pay. Public pressure strengthens the business case for higher pay (i.e., to avert negative publicity), but it's unlikely to work for the vast majority of firms that are less visible and less profitable than Amazon and Walmart. There is clearly a role for policy in creating incentives that make these steps attractive (or unavoidable) for employers.[123]

Creating better jobs for workers requires firms to pay higher wages and use labor more effectively. Absent the latter firms may find that providing higher pay is unprofitable or even infeasible.

The need for productivity to match pay points to a second channel by which employer practices affect job quality: management. Meticulous studies of management practices demonstrate that the quality of a firm's management has large and persistent effects on its productivity and profitability. This same research finds that management quality varies vastly across countries, industries, firms, and ownership types (e.g., corporate, founder run, family run, etc.).[124]

Better-managed firms have the capacity to pay higher wages, meaning that, in theory, workers and employers have a shared interest in boosting productivity. But this is easier said than done. Management is not simply a set of good intentions but rather a technology that enables firms to best use resources (labor, capital, energy, materials, technology). And, as with most technologies, some firms are much more proficient with the technology than others. Fortunately, as with other technologies, good management practices can be taught, adopted, and mastered.[125]

One example of good management in facilitating the workplace impacts of new technologies is the practice of engaging workers in the process of introducing technological change. Research on the relationships among technology, work systems, and management practices and their effects on firm performance go back 70 years. Case studies from the 1980s and 1990s on the U.S. automotive industry, which was faltering in the face of Japanese competition, highlighted the differences between American and Japanese engineers. Americans saw the hardware features of technology and production systems as separate from their human features. Japanese production engineers viewed technology as embodying both hardware and human features. To the Japanese, humans were not seen as a source of error variance but as a force for "giving wisdom to the machines."[126]

As Ari Bronsoler, Joseph Doyle, and Task Force member John Van Reenen outline in their research brief on healthcare information technology (HIT), engaging workers early in the process promotes acceptance of the new systems and improves their functioning.[127] Conversely, top-down imposition of new technologies and ways of working are often counterproductive. Many stakeholders can resist change, especially when there are large differences between the IT decision-makers (senior managers) and those who are using the tools (physicians, nurses, etc.). Bronsoler, Doyle, and Van Reenen find that greater worker involvement in harnessing the new capabilities of health IT throughout the healthcare system could improve the acceptance of these technologies while speeding productivity gains and mitigating negative workforce effects.

Employers can also harness emerging technologies to assist in making well-informed and consistent hiring decisions that are potentially purged of unintended (or intentional biases), as outlined in the brief by Frida Polli, Sara Kassir, Jackson Dolphin, Lewis Baker, and Task Force member John Gabrieli.[128] Their research calls for a fundamental change in the science of hiring, fueled by pragmatic insights from cognitive science and related disciplines, with the goal of increasing productivity, inclusion, and job satisfaction. Employers play a critical gatekeeping role in determining which candidates are offered opportunities and which are turned away. While AI-based candidate selection systems can clearly replicate human biases with mechanistic efficiency, well-designed tools can instead discipline decision-making and focus attention on relevant candidate strengths that may not fit the standard template.

We see the virtuous interplay among management practices, productivity, and worker pay in the work of MIT scholar Zeynep Ton, whose research confronts the question of how to improve the quality of frontline jobs in the retail sector.[131] A key takeaway from Ton's work is that to make higher pay viable in retail establishments, firms need to restructure their work practices to use labor more efficiently. In retail firms, this often means simplifying inventory to cut down on the number of poorly selling products, running fewer complex promotions, and streamlining stocking and inventory-taking to conserve labor hours.

## Collaboration Between Management and Workers Around Technology Adoption

Kaiser Permanente, one of the largest managed care systems in the United States, has opened over a dozen new outpatient clinics in Southern California to advance patient-centered healthcare. Personnel from across the healthcare system were actively engaged in the design, testing, and subsequent roll-out of the new clinics, called Health Hubs. Based on approximately 70 interviews with a cross section of those involved in the design, roll-outs, and operation of the new clinics, Task Force member Thomas Kochan and colleagues Anubhav Arora and Barbara Dyer found that familiar technology is used in conventional and novel ways as new advances are introduced.[129] Health Hubs make extensive use of:

- Self-service kiosks for patient check-in
- Electronic dashboards that allow care provider teams and patients to track patient flow
- Smart exam chairs and exam rooms to enhance efficiency and patient communication
- Tablets, laptops, and other mobile devices for care team providers
- Expanded use of telemedicine to serve patients remotely

A key part of implementation was winning the trust of incumbent workers by making clear that the technology was not intended to replace them and that there would be ample training in the new systems. Some of the steps the company took to secure that confidence include:

1. Holding focus groups with patients, Kaiser Permanente staff, and medical personnel deepened the understanding of aspirations for care transformation.
2. Running workshops with healthcare leaders, technology experts, and employees refined a vision for the new clinics.
3. Seeking early consultation with labor unions about potential changes in work processes and job descriptions was followed by negotiations to reach agreement on changes in compensation, training, and scope of practices.
4. Engaging physicians, nurses, and other employees in testing and refining the new technologies, patient flow, and work arrangements through simulations well in advance of opening.
5. Elevating workforce members who participated in simulations as peer-trainers. This "train-the-trainer" approach built needed initial capacity and forged a learning culture.
6. Fostering continuous improvements in operations after the clinics open with "Unit-based team" meetings and other informal group sessions.

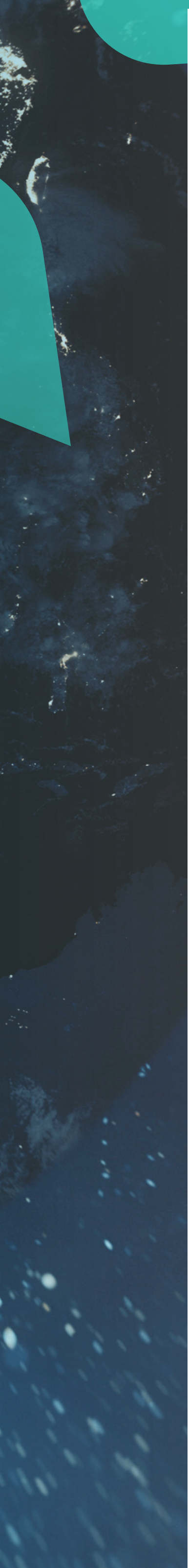
Health Hubs reflect a shift from a physician-centered to a patient-centered system. This case offers an illustration of a strategy that integrates new technologies and work practices through active engagement of the workforce and its representatives.[130]

These radical changes in business practices are inherently challenging for firms to adopt, and not all adopters are successful, as Ton documents. This latter point again highlights that raising pay often requires raising productivity, and the latter often requires improving management practices.

Recent evidence from Germany provides an interesting corollary to Ton's work: Higher pay mandates put inefficient firms at a competitive disadvantage.[132] A substantial national minimum wage hike in 2015 forced inefficient firms to shrink and enabled efficient firms to grow at their expense. While this policy change was beneficial to workers who received a pay increase and to larger firms that gained market share, it also squeezed out the smaller firms that were insufficiently productive to cover higher labor costs. This, as well as the presumably higher costs of goods that are passed on to consumers, serves as a reminder that policy choices necessarily require tradeoffs.

## CHAPTER 5

# Conclusion and Recommendations



The 21st century will see a rising tide of new technologies, some of which are now emerging and some of which will surprise us. If those technologies deploy into the labor institutions of today that were designed for the last century, we will see familiar results: stagnating opportunity for the majority of workers accompanied by vast rewards for a fortunate minority.

The divergence between economic growth and labor market opportunity exacts high costs: political and regional divisions, distrust of institutions, and a fear of innovation itself. The price of allowing these problems to fester far exceeds the costs of addressing them.

Too many Americans fear that technological progress will make the country wealthier while threatening their livelihoods.

The remarkable history of American innovation was powered not by fear or fatalism, but by a profound sense of possibility. Those possibilities remain. We see no tradeoff between improving economic security for workers and embracing ongoing technological change and innovation. Achieving both goals will require both technological and institutional innovation.

We must first invest in workers and their skills, bringing to bear the full weight of modern teaching methods and training technology, as well as new institutions, to help them drive the jobs of the future. Simultaneously, we must improve the systems that employ them, the laws that protect and support them, and the jobs that we are training them to do. And we need to continue innovating, both in the institutional structures of our labor markets and in the technologies and new industries that create new jobs.

We possess the skills, resources, and innovative capacity to create many possible futures. Just as the majority of today's jobs had yet to be invented a century ago, much of the work of the 21st century has yet to be invented today. The challenge and the opportunity of the present is to build the work of the future.

Below, we offer three groups of policies that the Task Force believes the next U.S. presidential administration should pursue. These policies seek to accelerate and shape innovation while bringing the employment rates, earnings levels, and economic mobility of rank-and-file U.S. workers back into alignment with the trajectory of U.S. innovation and productivity growth.

## 5.1 Policy Area One: Invest And Innovate In Skills And Training

Technological innovation will require workers to have strong foundational skills as well as specialized training. The current U.S. system for training workforce entrants, the currently employed, and displaced workers is fragmented and uneven in quality. It does, however, provide flexibility that allows workers to move in and out of the system at different points in their careers. Numerous exemplary public, private, and not-for-profit training initiatives exist throughout the country, though many more are less successful or have not been evaluated. Those models that have been proven successful based on rigorous evaluation should be scaled to serve many more workers. New technologies, including online instruction, AI-based guided learning systems, and virtual reality tools, offer innovative ways to make training more accessible, affordable, and engaging for students, workers, and job seekers at all stages of the lifecycle.

### Recommendations

- **Foster private sector investment in training**, particularly to facilitate upward mobility among lower-wage and less-educated workers, a category in which minority workers are over-represented. Incentives could be provided through judiciously designed tax code provisions (see below) or with matching funds. The Task Force's research finds that only about half of U.S. workers receive some kind of training from their employers in a given year, and this skews toward higher-educated and non-minority workers.
- **Significantly increase federal funding for training programs** that can lead to middle-class jobs for workers without four-year degrees. Support should be offered on a competitive basis to **community colleges and labor market intermediaries** that can demonstrate they are working closely with employers, providing support services to participants (i.e., coaching, advising, child care, and transportation), and investing in innovative training programs that include work-based learning. Those elements have been shown to be the key to success. Another key success factor is the formation of **regional compacts** formed by employers, governments, community colleges, and community groups that come together with a shared commitment to build a real skills development system that meets employer needs.
- **Support policies that raise the degree completion rate at community colleges**. Policies should include funding and incentives to redesign the curriculum to integrate remedial education and vocational training (rather than have them be sequential); creating shorter courses that provide usable credentials on the path to a degree; and providing more financial support over shorter intervals to allow adults to focus on studies rather than work while enrolled.
- **Require, and fully fund rigorous evaluations** of training programs to gauge efficacy in achieving employment and earnings outcomes.
- **Invest in demonstration programs that test innovative ideas for retraining and reemploying dislocated adult workers**, a challenge where policy and programs have thus far had limited success.
- **Improve labor market information to support workers seeking jobs and jobs seeking workers**. Invest in the modernization of traditional one-stop career centers for unemployed workers, while also creating online databases that provide real-time information about job opportunities. Continue to develop ways for workers to have easy access to their own data regarding skills, competencies, and credentials, bearing in mind that job search assistance is a complement to, rather than a substitute for, effective education and training programs.
- **Invest in developing and field-testing innovative methods and tools for delivering training**. The evidence so far is that online training works best when paired with in-person offerings. Support instructional models that include **hands-on learning**, potentially using augmented and virtual reality.

## 5.2 Policy Area Two: Improve Job Quality

As in other countries, a growing share of U.S. employment is in traditionally low-paid service jobs: cleaning and groundskeeping, food service, security, entertainment and recreation, and home health assistance. Unlike other countries, U.S. workers in these occupations receive extremely low pay and very rarely have access to employer-provided health insurance, family or medical leave, or vacation time. Adjusting for purchase power, low-paid Americans are paid 26% less than low-paid Canadians. This needn't be the case. Government policy in the United States simply fails to ensure adequate pay, a modicum of economic security, and access to basic social benefits for workers in low-paid jobs.

### Recommendations

- **Restore the real value of the federal minimum wage** to at least 40% of the national median wage and **index this value** to inflation. Localities should be able to set higher levels, as they can currently. The best available economic evidence indicates that well-calibrated minimum wages exert only modest to undetectable adverse effects on employment, while reducing household poverty. In addition, minimum wages are particularly effective at bolstering the earnings of minority workers who are overrepresented at the lower tail of the U.S. wage distribution.
- **Modernize unemployment insurance (UI) benefits and extend them** to workers that have not been covered traditionally:
  - **Allow workers to count their most recent earnings toward determining eligibility:** At the start of 2019, 37 states allowed workers who did not qualify for benefits using the standard approach to use earnings during a more recent period to establish benefit eligibility. This policy should be adopted nationally.
  - **Determine UI eligibility based on hours rather than earnings:** Already in place in the state of Washington, all states should be required to enable workers to qualify for unemployment benefits by having worked a minimum number of hours rather than having made a minimum level of earnings. At present, low-wage workers must work more hours than high-wage workers to qualify for UI.
  - **Drop the requirement that the unemployed seek full-time work:** Whether because of family responsibilities or the nature of their jobs, many workers hold part-time positions. Any unemployed worker who searches for part-time work of 20 hours or more per week and who otherwise qualifies for unemployment insurance benefits should be allowed to collect benefits.
  - **Reform partial unemployment insurance benefits:** States should be required to reevaluate their partial unemployment benefits formulas to better protect workers who lose a substantial fraction of their work hours, including in the case where this occurs because the worker has lost a second job. In most states, a low-wage worker whose earnings are cut in half would currently receive no benefits.
- **Strengthen and adapt labor laws** and better enforce them. As private sector labor unions have contracted, rank-and-file workers have lost the capacity to bargain for wage growth to match productivity growth. Innovation is badly needed in worker representation, but provisions of U.S. labor law retard the development of alternative approaches. In contrast to the situation in countries like Germany, for example, it is illegal in the United States for workers to create works councils at nonunion businesses, and it is unclear whether workers can legally serve on corporate boards. Key sectors of the workforce, namely domestic workers and agricultural workers, are excluded from collective bargaining, a legacy of racial politics during the New Deal. The National Labor Relations Act, which has only been amended once in the 85 years since its passage (and in that case, to weaken it), requires an overhaul. The U.S. needs to enable new institutions for collective bargaining to form without undermining the strength of current unions. Action is needed on three fronts:
  - Strengthen the law and more vigorously enforce protections and processes for workers to gain access to collective bargaining.
  - Open up labor law to allow innovation in new forms of representation in workplace and corporate decision-making and governance.
  - Build legal protections that allow for organizing workers without risk of retaliation in non-traditional realms, such as domestic and home-care workers, farmworkers, and independent contractors.

## 5.3 Policy Area Three: Expand and Shape Innovation

Innovation is key to creating jobs and wealth, and to meeting rising competitive challenges from abroad. The country needs to commit to an innovation agenda that is targeted toward creating social benefits and augmenting (rather than replacing) workers.

Today, too few of the benefits of innovation-driven growth are flowing to workers. There is a need to steer innovation for the benefit of all stakeholders. Federal policy has clearly been shown to be valuable in seeding innovation, generating economic growth, building areas of educational and research excellence, and spurring new work creation. But publicly directed U.S. innovative effort is slackening, measured either relative to historical levels of public R&D investment or in comparison to other countries, such as Germany and China.

Innovation is also needed in tax law. A series of tax law changes enacted over the last four decades has increasingly skewed the U.S. tax code toward subsidizing machinery purchases rather than investing in labor. Tax policy offers firms an incentive to automate tasks that, absent the distortions of the tax code, they would accomplish with workers. The U.S. should bring its tax code back into balance to align incentives for innovation in skills development, capital formation, and R&D investment.

### Recommendations:

- **Increase federal research spending and direct it toward areas neglected by the private sector.** The private sector underinvests in longer-term, basic research, and is less concerned with research that addresses the social impacts of technologies. Public investments should focus on technologies and their application to address pressing national problems, including climate change and human health. Additional national priorities should include enhancing human capabilities and supporting equitable labor markets through research areas such as human-centered AI, collaborative robotics, and the science of learning and education.
    - **Offer targeted assistance to small and medium-sized businesses** to enable them to increase productivity through the adoption of new technologies. Explore ways that federal programs or departments could assist in technology upgrading, particularly in manufacturing SMEs.
- **Expand the geography of innovation in the United States.** Innovation has become increasingly concentrated geographically. Yet, the country has significant assets in its universities, entrepreneurs, and workers that are dispersed throughout the country. With relatively modest amounts of funds and building on existing assets, the U.S. innovation agenda should look to spread the benefits of innovation not only to a broader set of workers, but also to a broader set of regions.
- **Rebalance taxes on capital and labor** by altering the ways in which the tax code currently unduly favors investments in capital.
    - Eliminate accelerated depreciation allowances. When enacted, these were intended to be temporary.
    - Apply the corporate income tax equally to all corporations, including S corporations. The differential tax treatment of C and S corporations leads to extensive tax arbitrage that relabels labor income as tax-favored capital income. Expanding the tax base is always the most efficient way of raising tax revenue.
    - While maintaining the federal R&D tax credit, enact an employer training tax credit, akin to the R&D tax credit, which can be applied exclusively toward training investments in workers that lead to externally recognized certifications.

## MIT Task Force on the Work of the Future Research Briefs

1. **EXTENDING UNEMPLOYMENT INSURANCE BENEFITS TO WORKERS IN PRECARIOUS AND NONSTANDARD ARRANGEMENTS**
   by Katherine Abraham, Susan Houseman and Christopher O'Leary
2. **TAXES, AUTOMATION AND THE FUTURE OF LABOR**
   by Daron Acemoglu, Andrea Manera and Pascual Restrepo
3. **THE FALTERING ESCALATOR OF URBAN OPPORTUNITY**
   by David Autor
4. **MANUFACTURING IN AMERICA: A VIEW FROM THE FIELD**
   by Suzanne Berger
5. **THE IMPACT OF NEW TECHNOLOGY ON THE HEALTHCARE WORKFORCE**
   by Ari Bronsoler, Joseph Doyle and John van Reenen
6. **UNDERSTANDING AND ADDRESSING THE MODERN PRODUCTIVITY PARADOX**
   by Erik Brynjolfsson, Seth Benzell and Daniel Rock
7. **GOOD JOBS**
   by Joshua Cohen
8. **ADDITIVE MANUFACTURING: IMPLICATIONS FOR TECHNOLOGICAL CHANGE, WORKFORCE DEVELOPMENT AND THE PRODUCT LIFECYCLE**
   by John Hart and Haden Quinlan
9. **CHINA'S DEVELOPMENT IN ARTIFICIAL INTELLIGENCE**
   by Yasheng Huang and Meicen Sun
10. **GROWING APART: EFFICIENCY AND EQUALITY IN THE GERMAN AND DANISH VET SYSTEMS**
    by Christian Ibsen and Kathleen Thelen
11. **WORKER VOICE, REPRESENTATION, AND IMPLICATIONS FOR PUBLIC POLICIES**
    by Thomas Kochan
12. **AUTONOMOUS VEHICLES, MOBILITY, AND EMPLOYMENT POLICY: THE ROADS AHEAD**
    by John Leonard, David Mindell and Erik Stayton
13. **WAREHOUSING, TRUCKING, AND TECHNOLOGY: THE FUTURE OF WORK IN LOGISTICS**
    by Arshia Mehta and Frank Levy
14. **SKILL TRAINING FOR ADULTS**
    by Paul Osterman
15. **COGNITIVE SCIENCE AS A NEW PEOPLE SCIENCE FOR THE FUTURE OF WORK**
    by Frida Polli, Sara Kassir, Jackson Dolphin, Lewis Baker and John Gabrieli
16. **AI & THE FUTURE OF WORK**
    by Daniela Rus, Thomas Malone and Robert Laubacher
17. **THE STATE OF INDUSTRIAL ROBOTICS: EMERGING TECHNOLOGIES, CHALLENGES, AND KEY RESEARCH DIRECTIONS**
    by Lindsay Sanneman, Christopher Fourie and Julie Shah
18. **APPLYING NEW EDUCATION TECHNOLOGIES TO MEET WORKFORCE EDUCATION NEEDS**
    by Sanjay Sarma and William Bonvillian
19. **UNIVERSAL BASIC INCOME: WHAT DO WE KNOW?**
    by Tavneet Suri
20. **ROBOTS AS SYMBOLS AND ANXIETY OVER WORK LOSS**
    by Christine Walley

## Endnotes

1. Institutional factors are also essential in determining what technologies are invented, how they are applied, and how they are distributed (Deaton 2013).

2. As Moses Finley remarked in a 1976 article on the "peculiar institution" of slavery, "In the context of universal history, free labor, wage labor, is the peculiar institution."

3. By more productive, we mean performing the same work at lower total cost. At present, it is infeasible for humans to be more productive than computers in performing standard mathematical calculations, though this was not the case a century ago. Computers are now more productive at this task not only because they are faster but also because they are cheaper than workers at any reasonable wage. The concern is that this will become true in an expanding fraction of all work tasks.

4. The U.S. employment to population rate has fallen by several percentage points since the year 2000. A substantial driver of this trend is the aging of the U.S. population, which has increased the fraction of adults who are approaching or in retirement. Of course, citizens in high-income countries work fewer annual hours, take more vacations, and retire earlier (relative to death) than a century ago — implying that they choose to spend part of their rising incomes on increased leisure. See Stephanie Aaronson, Tomaz Cajner, Bruce Fallick, Felix Galbis-Reig, Christopher L. Smith, and William Wascher,"Labor Force Participation: Recent Developments and Future Prospects." *Brookings Papers on Economic Activity* (2014): 197–275, and David H. Autor, "Why Are There Still So Many Jobs? The History and Future of Workplace Automation." *Journal of Economic Perspectives* 29-3(2015):3–30.

5. Though it can certainly fall in the short and immediate term, with substantial adverse consequences for workers. See, for example, Daron Acemoglu and Pascual Restrepo. "Robots and Jobs: Evidence from US Labor Markets." *Journal of Political Economy* 128, no. 6 (2019): 2188–2244.

6. To construct this figure, Autor, Salomons, and Seegmiller (2020) use historical data to catalog the introduction of new jobs into the U.S. Census Bureau's occupational coding manuals in each decade between 1940 and 2018.

7. See Daniel P. Gross, and Bhaven N. Sampat. "Inventing the Endless Frontier: The Effects of the World War II Research Effort on Post-War Innovation." NBER Working Paper No. 27375, June 2020, and Daniel P Gross and Bhaven N. Sampat. "Organizing Crisis Innovation: Lessons from World War II." NBER Working Paper No. 27909, October 2020.

8. See David Autor, Anna Salomons, and Bryan Seegmiller,"New Frontiers: The Origins and Content of New Work, 1940–2018." MIT Mimeo, 2020.

9. See Christine Walley, "Robots as Symbol and Social Reality", MIT Work of the Future Research Brief (October 2020).

10. See Daron Acemoglu and Pascual Restrepo, "The Race between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment." American Economic Review 108-6 (2018): 1488–1542. https://doi.org/10.1257/aer.20160696.; Daron Acemoglu and Pascual Restrepo ,"Automation and New Tasks: How Technology Displaces and Reinstates Labor." *Journal of Economic Perspectives* 33-2 (2019): 3–30. David Autor, Anna Salomons, and Bryan Seegmiller,"New Frontiers: The Origins and Content of New Work, 1940–2018." MIT Mimeo, 2020. for theoretical analysis and empirical evidence of these ideas.

11. Approximately 60% of national income is paid in wages and benefits, https://fred.stlouisfed.org/series/LABSHPUSA156NRUG.

12. Edward Lazear, "Productivity and Wages: Common Factors and Idiosyncrasies Across Countries and Industries." Cambridge, MA: NBER Working Paper No. 26428, November 2019.

13. See Table 2.1 of OECD. "Decoupling of Wages from Productivity: What Implications for Public Policies?" In *OECD Economic Outlook*, Volume 2018, Issue 2. The OECD report studies data for the years 1995 through 2013.

14. Wages do not merely reflect productivity; they also determine how productively workers are used. When minimum wages are higher, for example, employers must find ways to make low-paid workers more productive to justify their higher cost. Our argument is not that most wage differentials reflect institutional factors rather than productivity differentials. Rather, we view productivity differentials as joint outcome of skills investments, technology investments, and institutions. Moreover, skill and

technology choices are themselves shaped by institutions and vice versa. For discussion, see the Task Force Brief by Brynjolfsson, Benzell, and Rock as well as Acemoglu, Daron, and Restrepo. “The Race Between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment.” *American Economic Review* 108, no. 6 (June 2018): 1488–1542.

15. Florian Hoffman, David S. Lee, and Thomas Lemieu, “Growing Income Inequality in the United States and Other Advanced Economies.” *Journal of Economic Perspectives* 34-4 (2020):52–78.

16. Marcus Stanley, “College Education and the Midcentury GI Bills.” *The Quarterly Journal of Economics* 118-2 (2003)671–708.

17. David Autor, Claudia Goldin, and Lawrence F. Katz,. “Extending the Race between Education and Technology.” *AEA Papers and Proceedings* 110 (May 2020): 347–51.

18. In 1979, 60 percent of U.S. males at the median of the wage distribution possessed a high school or lower education, whereas only 20 percent had a bachelor’s degree or above. By 2018, fully 35 percent of males at the median of the earnings distribution had attained a four-year college degree — a 75 percent increase — and only one-third had high school or less education. The gain among the median working woman was even larger: the four-year degree attainment rate tripled from 13 to 45 percent, while the fraction with high school or below dropped from 68 to 22 percent. Statistics refer to workers at the 45th to 55th percentile of the gender-specific hourly wage distribution in the respective year. They are from Table 5 of Sarah A Donovan and David H Bradley, “Real Wage Trends, 1979 to 2018.” Congressional Research Service, July 2019, 35.

19. Michael WL Elsby, Bart Hobijn, and Ayşegül Şahin. “The Decline of the US Labor Share.” *Brookings Papers on Economic Activity* 2013, no. 2 (2013): 1-63, http://www.frbsf.org/economic-research/files/wp2013-27.pdf; Loukas Karabarbounis and Brent Neiman. “The global decline of the labor share.” *The Quarterly Journal of Economics* 129, no. 1 (2014),: 61-103, https://doi.org/10.1093/qje/qjt032.; Thomas Philippon, *The Great Reversal: How America Gave Up on Free markets*. Cambridge, Massachusetts: Belknap Press (2019); David Autor, David Dorn, Lawrence F. Katz, Christina Patterson, and John Van Reenen. “The Fall of the Labor Share and the Rise of Superstar Firms.” *The Quarterly Journal of Economics* 135, no. 2 (2020): 645-709, https://doi.org/10.1093/qje/qjaa004.

20. Germán Gutiérrez and Sophie Piton. “Revisiting the Global Decline of the (Non-Housing) Labor Share.” *American Economic Review: Insights* 2, no. 3 (2020): 321-38.

21. Erik Brynjolfsson, Seth Benzell, Daniel Rock. “Understanding and Addressing the Modern Productivity Paradox”, MIT Work of the Future Research Brief (forthcoming);

22. Chad Syverson, “Challenges to mismeasurement explanations for the US productivity slowdown”, *Journal of Economic Perspectives* 31, no. 2 (2017): 165-86, https://doi.org/10.1257/jep.31.2.165

23. To be clear, this decline is not due solely to digitalization, as international trade added substantially to the displacement of middle-skill production and operative jobs during the 2000s. See David H. Autor David Dorn, and Gordon H Hanson,“The China Shock: Learning from Labor Market Adjustment to Large Changes in Trade.” *Annual Review of Economics* 8-1 (2016.) 205–240.

24. See our discussion of autonomous vehicles in Chapter 3 and the Task Force research brief : John Leonard, David Mindell, Erik Stayton, “Autonomous Vehicles, Mobility, and Employment Policy: The Roads Ahead”, MIT Work of the Future Research Brief, 22 July 2020, https://workofthefuture.mit.edu/research-post/autonomous-vehicles-mobility-and-employment-policy-the-roads-ahead

25. https://www.bls.gov/emp/tables/occupations-most-job-growth.htm.

26. The next four occupations on this list are also illustrative: office clerks; executive secretaries and executive assistants; inspectors, testers, sorters, samplers, and weighers; and bookkeeping, accounting, and auditing clerks.

27. While these projections should be understood as educated guesses, BLS has a good track record of projecting employment trends at the level of broad occupations. See Andrew Alpert and Jill Auyer, 2003. “Evaluating the BLS 1988–2000 Employment Projections.” *Monthly Labor Review*, October.

28. Due to the nation’s aging population, employment in healthcare occupations is predicted to grow by 18% from 2016 to 2026 — more than seven times more rapidly than overall employment — and to add 2.4 million jobs.

29. Ari Bronsoler, Joseph Doyle and John van Reenen, “The Impact of New Technology on the Healthcare Workforce: A White Paper,” MIT Work of the Future Research Brief, October 2020.

30. "Measuring and Assessing Job Quality: The OECD Job Quality Framework." OECD Social, Employment and Migration Working Papers. Vol. 174. OECD Social, Employment and Migration Working Papers, December 18, 2015.

31. For purposes of this comparison, the OECD defines low-skill workers as those with less than a high school diploma. Performing the same comparison for medium-skill workers, which the OECD defines as having completed secondary education (i.e., high school), the United States ranks 10th among 21 countries, where countries 11 through 14 are the United Kingdom, Japan, Finland, and Canada, and countries 6 through 9 are Korea, the Czech Republic, Portugal, and Ireland. https://stats.oecd.org/Index.aspx?QueryId=82334.

32. Jérôme Gautié and John Schmitt. "Low wage work in wealthy countries." New York: Russell Sage (2009).https://www.russellsage.org/publications/low-wage-work-wealthy-world

33. Nicholas Kristof, "McDonald's Workers in Denmark Pity Us", New York Times, 8 May 2020, https://www.nytimes.com/2020/05/08/opinion/sunday/us-denmark-economy.html

34. Given the COVID-19 pandemic now sweeping the globe, it bears note that every Dane also has healthcare and paid sick leave, though these benefits are publicly provided rather than employer provided, as is typical in the United States.

35. In 2015, only one-in-six white non-college adults lived in the densest quartile of urban CZs versus one-in-four non-college Hispanics, and nearly one-in-three (29%) non-college Blacks lived in these same places. In short, many minority workers are situated in the declining urban middle of the U.S. labor market. On a more positive note, Black and Hispanic college graduates are also over-represented in the densest quartile of urban labor markets. These shares are 34% of Hispanic college workers and 35% of Black college workers versus 26% of white college workers.

36. More encouragingly, among most subgroups of college graduates, polarization was reflected in a rise in employment in both high- and low-paying occupations. An exception to this generalization is the experience of Black male college graduates, however. Their employment share in medium-paying occupations fell by seven percentage points, and their share in low-paying occupations rose by almost five percentage points. Thus, despite high levels of educational attainment, they exhibited downward occupational mobility in urban relative to non-urban labor markets. This stark finding is consistent with Derenoncourt (2019), who shows that upward mobility deteriorated among urban Black residents following the Great Migration, and with Chetty et al. (2020), who document the exceptionally poor labor market outcomes of Black men raised in poor urban U.S. neighborhoods. See Derenoncourt, Ellora. 2019. "Can You Move to Opportunity? Evidence from the Great Migration." Princeton University Working Paper, December; Chetty, Raj, Nathaniel Hendren, Maggie R. Jones, and Sonya R. Porter. 2020. "Race and Economic Opportunity in the United States: An Intergenerational Perspective." *The Quarterly Journal of Economics* 135 (2): 711–83.

37. We note that Figure 9 reports changes in urban relative to non-urban wage changes by demographic group. The steep decline in the non-college wage premium could reflect a fall in urban wages among non-college workers, a rise in non-urban wages among non-college workers, or a combination of the two.

38. See Facundo Alvaredo, Lucas Chancel, Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, eds. World Inequality Report 2018. Belknap Press, 2018

39. Erik Brynjolfsson, Seth Benzell, Daniel Rock, "Understanding and Addressing the Modern Productivity Paradox." ,MIT Work of the Future Research Brief (forthcoming); Thomas Piketty, Emmanuel Saez, and Stefanie Stantcheva. "Optimal Taxation of Top Labor Incomes: A tale of Three Elasticities." *American Economic Journal: Economic policy* 6, no. 1 (2014): 230-71; Josh Bivens and Lawrence Mishel. "The Pay of Corporate Executives and Financial Professionals as Evidence of Rents in Top 1 Percent Incomes." *Journal of Economic Perspectives* 27, no. 3 (2013): 57–78, https://doi.org/10.1257/jep.27.3.57.

40. See Facundo Alvaredo, Lucas Chancel, Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, eds. World Inequality Report 2018. Belknap Press, 2018. Anglophone countries include Australia, Canada, Ireland, the United Kingdom, and the United States. Western European countries include France, Germany, Italy, and Spain. Northern European countries include Denmark, Finland, the Netherlands, Norway, and Sweden. The top one percent share does not exceed 15% in any of these countries and is generally much

lower (below 10% in Northern Europe). In no other country did it rise by nine percentage points, though the United Kingdom comes close to that level.

41. "American inequality reflects gross incomes as much as taxes." *The Economist*, April 13, 2019.

42. Abhijit V Banerjee and Esther Duflo. "Inequality and Growth: What Can the Data Say?" *Journal of Economic Growth* 8 (3), (2003): 267–99.

43. Raj Chetty, David Grusky, Maximilian Hell, Nathaniel Hendren, Robert Manduca, and Jimmy Narang. "The Fading American Dream: Trends in Absolute Income Mobility Since 1940." Science 356, no. 6336 (2017): 398–406.

44. The corresponding figures for the UK and Denmark are 9% and 11.7%, respectively.

45. Lawrence F. Katz and Alan B. Krueger. 2017. "Documenting Decline in U.S. Economic Mobility." Science 356 (6336): 382–383. https://doi.org/10.1126/science.aan3264.

46. Bart Van Ark, Mary O'Mahoney, and Marcel P. Timmer. "The Productivity Gap between Europe and the United States: Trends and Causes." Journal of economic perspectives 22, no. 1 (2008): 25–44. https://www.aeaweb.org/articles?id=10.1257/jep.22.1.25

47. Erik Brynjolfsson, Seth Benzell, Daniel Rock, Understanding and Addressing the Modern Productivity Paradox, MIT Work of the Future Research Brief (forthcoming).

48. Philippe Aghion, Ufuk Akcigit, Antonin Bergeaud, Richard Blundell, and David Hemous, "Innovation and Top Income Inequality." *The Review of Economic Studies* 86–1( 2019): 1–45.

49. Indeed, one could make a stronger argument: It is necessary to preserve opportunity and economic mobility for the vast majority of citizens so as to maintain the public consensus on which a democratic free market system stands.

50. Erik Brynjolfsson, Seth Benzell, Daniel Rock, Understanding and Addressing the Modern Productivity Paradox, MIT Work of the Future Research Brief (forthcoming);

51. David Autor, David Dorn, Gordon Hanson, and Kaveh Majlesi. 2020. "Importing Political Polarization? The Electoral Consequences of Rising Trade Exposure." *American Economic Review* 110(10), 3139–3183.

52. Barry Naughton. *The Chinese Economy: Transitions and Growth*. Cambridge, MA: MIT Press, 2007.

53. For further evidence that institutional differences play a key role in inequality among median and below median-wage workers, see Stijn Broecke, Glenda Quintini, and Marieke Vandeweyer. "Wage Inequality and Cognitive Skills: Reopening the Debate." In *Education, Skills, and Technical Change: Implications for Future US GDP Growth*, edited by Charles R. Hulten and Valerie A. Ramey, Vol. 77. *Studies in Income and Wealth*. Chicago: University of Chicago Press, 2018.

54. Lawrence Mishel, Lynn Rhinehart, and Lane Windham. "Explaining the Erosion of Private-Sector Unions," Economic Policy Institute, October 2020..

55. See David H. Autor, Alan Manning, and Christopher L. Smith. 2016. "The Contribution of the Minimum Wage to US Wage Inequality over Three Decades: A Reassessment." *American Economic Journal: Applied Economics* 8 (1): 58–99. Doruk Cengiz, Arindrajit Dube, Attila Lindner, and Ben Zipperer. 2019. "The Effect of Minimum Wages on Low-Wage Jobs." *The Quarterly Journal of Economics* 134 (3): 1405–54 ; Ellora Derenoncourt, and Claire Montialoux. 2020. "Minimum Wages and Racial Inequality." *Quarterly Journal of Economics*, forthcoming. Ellora Derenoncourt, and Claire Montialoux. 2020. "Opinion | To Reduce Racial Inequality, Raise the Minimum Wage." *The New York Times*, October 25, 2020.

56. See Christine Walley, "Robots as Symbol and Social Reality", MIT Work of the Future Research Brief (October 2020); Greenhouse, Steven. *Beaten Down, Worked Up: The Past, Present, and Future of American Labor,* 2019, Albert A. Knopf; and Weil, David. *The Fissured Workplace*. Harvard University Press, 2014.

57. Christine J. Walley, "Robots as Symbols and Social Technology," MIT Work of the Future Research Brief, October, 2020.

58. Daniela Rus, Thomas Malone, and Robert Laubacher, "Artificial Intelligence and the Future of Work," MIT Work of the Future Research Brief (forthcoming).

59. Elisabeth Reynolds and Anna Waldman-Brown, "Digital Transformation in a White Collar Firm: Implications for Workers Across a Continuum of Jobs and Skills," MIT Work of the Future Working Paper, 2020.

60. Ari Bronsoler, Joseph Doyle, and John Van Reenen, "The Impact of New Technology on the Healthcare Workforce,"MIT Work of the Future Research Brief, October 2020

61. Paul Osterman, Who Will Care For Us?: Long-Term Care and the Long-Term Workforce (New York: Russell Sage Foundation, 2017).

62. Margot Sanger-Katz. "Why 1.4 Million Health Jobs Have Been Lost During a Huge Health Crisis." *The New York Times*, May 10, 2020, sec. The Upshot. https://www.nytimes.com/2020/05/08/upshot/health-jobs-plummeting-virus.html.

63. Nicholas Bloom, Renata Lemos, Raffaella Sadun, and John Van Reenen. "Healthy Business? Managerial Education and Management in Health Care." *Review of Economics and Statistics* 102, no. 3 (2020): 506-517.

64. Richard Hillestad, James Bigelow, Anthony Bower, Federico Girosi, Robin Meili, Richard Scoville, and Roger Taylor. "Can electronic medical record systems transform health care? Potential health benefits, savings, and costs." *Health Affairs* 24, no. 5 (2005): 1103–1117.

65. Arthur L. Kellermann, and Spencer S. Jones. "What it will take to achieve the as-yet-unfulfilled promises of health information technology." *Health affairs* 32, no. 1 (2013): 63–68.

66. Xiaoming Zeng, The impacts of electronic health record implementation on the health care workforce. *North Carolina Medical Journal*, 77-2, (2016): 112–114.

67. John J. Leonard, David A. Mindell, and Erik L. Stayton, "Autonomous Vehicles, Mobility, and Employment Policy: The Roads Ahead," MIT Work of the Future Research Brief, 22 July 2020, https://workofthefuture.mit.edu/research-post/autonomous-vehicles-mobility-and-employment-policy-the-roads-ahead/

68. For a review of recent models that estimate the adoption of EVs and their impact on jobs, see Anuraag Singh, "Modeling Technological Improvement, Adoption and Employment Effects of Electric Vehicles: A Review", MIT Work of the Future Working Paper, forthcoming.

69. See Russell Glynn, Mario Goetz, and Kevin Shen, "Avenues of Institutional Change: Technology and Urban Mobility in Southeast Michigan"MIT Work of the Future Working Paper, forthcoming.

70. Erica L. Groshen, Susan Helper, John Paul MacDuffie, and Charles Carson. "Preparing U.S. Workers and Employers for an Autonomous Vehicle Future." W.E. Upjohn Institute, June 1, 2018.

71. David A. Mindell, *Our Robots, Ourselves: Robotics and the Myths of Autonomy*. Viking Penguin, 2015. Chapter 4.

72. Arshia Mehta and Frank Levy, "Warehousing, Trucking, and Technology: The Future of Work in Logistics," MIT Work of the Future Research Brief, 8 September 2020, https://workofthefuture.mit.edu/research-post/warehousing/

73. Bridget McCrea, "Reader Survey: There's No Stopping Warehouse Automation": *Modern Material Handling*, July 8, 2020. https://www.mmh.com/article/theres_no_stopping_warehouse_automation

74. Formally this would imply that the product has changed not that productivity has fallen per se: Warehousing firms have not gotten worse at what they traditionally do, but they are now asked to do something harder.

75. Arshia Mehta and Frank Levy, "Warehousing, Trucking, and Technology: The Future of Work in Logistics," MIT Work of the Future Research Brief, 8 September 2020, https://workofthefuture.mit.edu/research-post/warehousing/

76. Julie Shah, "Lessons from the Robotics Ecosystem: Enablers, Hurdles, and Next Directions," MIT Work of the Future Research Brief (forthcoming).

77. Susan Helper, Raphael Martins, and Robert Seamans. "Who Profits from Industry 4.0? Theory and Evidence from the Automotive Industry." *SSRN Electronic Journal* (2019).

78. Suzanne Berger, "Manufacturing in America: A View from the Field", MIT Work of the Future Research Brief Future Research Brief (forthcoming).

79. Anna Waldman-Brown, "Redeployment or robocalypse? Workers and automation in Ohio manufacturing SMEs." *Cambridge Journal of Regions, Economy and Society* 13.1 (2020): 99–115.

80. John Hart, "Additive Manufacturing and the Factory of the Future," MIT Work of the Future Research Brief (forthcoming).

81. In economic terms, this depends on whether demand for industry output is elastic or inelastic — that is, whether a fall in price generates a more than or less than proportionate increase in demand.

82. Torben M. Andersen, "The Danish Labor Market, 2000–2018." IZA World of Labor, December, 2019.

83. Alan M. Garber, and Jonathan Skinner, "Is American Health Care Uniquely Inefficient?" *Journal of Economic Perspectives* 22 (4), . 2008.: 27–50.

84. For references related to this section, see Paul Osterman, "Skill Training for Adults," MIT Work of the Future Research Brief, October, 2020.

85. Paul Osterman, "How Americans Obtain Their Work Skills," MIT Sloan School Working Paper, 2020.

86. GAO (Government Accountability Office), "Employment and Training Programs: Department of Labor Should Assess Efforts to Coordinate Services Across Programs. GAO-19–200," March 2019, https://www.gao.gov/assets/700/698080.pdf.

87. See Thomas J. Kane, and Cecilia Elena Rouse. "Labor-Market Returns to Two- and Four-Year College." *American Economic Review* 85, no. 3 (1995): 600–614; also Christopher Jepsen, Kenneth Troske, and Paul Coomes. "The Labor-Market Returns to Community College Degrees, Diplomas, and Certificates." *Journal of Labor Economics* 32, no. 1 (January 1, 2014): 95–121. https://doi.org/10.1086/671809.

88. Eli Zimmerman, Major Companies Partner with Colleges for Education Opportunities in Emerging Tech. *EdTech: Focus on Higher Education*, 2018.

89. As Bertrand et al. (2019) discuss, high school vocational education has a controversial history in the United States, largely due to a perceived trade-off between teaching readily deployable occupational skills versus shunting mostly disadvantaged students away from the educational and career flexibility afforded by general academic courses.

90. For examples of this and other new delivery models, see William Bonvillian, Sanjay Sarma, Meghan Purdue and Jenna Myers, The Workforce Education Project Preliminary Report, MIT Office of Open Learning, April, 2020.

91. Robert Lerman, "Scaling Apprenticeships to Increase Human Capital," in Melissa Kearney and Amy Ganz, eds., *Expanding Economic Opportunity for More Americans*, Aspen Institute, February, 2019, pp. 56–75.

92. Kathleen Thelen and Christian Ibsen, "Growing Apart: Efficiency and Equality in the German and Danish VET Systems", MIT Work of the Future Research Brief, October, 2020.

93. David Autor, Anran Li, and Matthew Notowidigdo. "Preparing for the Work of the Future: A Research Agenda." J-PAL: North America, April 2019. Other relevant citations: Marianne Bertrand, Magne Mosgstad, and Jack Mountjoy, "Reconceptualizing Vocational Education: Evidence from Norway's Reform 94", NBER Working Paper No. 25679, March 2019; Indivar Dutta-Gupta, Lessons Learned from 40 Years ofSubsidized Employment Programs: A Framework, Review of Models, and Recommendations for Helping Disadvantaged Workers, Georgetown Law, Center on Poverty and Inequality, 2016; Lola Fadulu, "Why is the US so bad at worker retraining?," *The Atlantic*, 2018. Retrieved from https://www.theatlantic.com/education/archive/2018/01/why-is-the-us-so-bad-at-protecting-workers-from- automation/549185/

94. For details on this example and additional overview of the US workforce education and training system and emerging delivery models, see William Bonvillian and Sanjay Sarma, *Workforce Education: A New Roadmap*, MIT Press, forthcoming, 2021.

95. For a review of these programs, see Paul Osterman, "Skill Training for Adults," MIT Work of the Future Research Brief, October, 2020.

96. Ibid.

97. For details about the FCA, see the following news articles: https://www.detroitnews.com/story/business/autos/chrysler/2020/10/21/detroiters-filling-half-available-jobs-fcas-new-assembly-plant/6004528002; https://www.detroitnews.com/story/business/autos/chrysler/2020/10/21/detroiters-filling-half-available-jobs-fcas-new-assembly-plant/6004528002/

98. For an example of multi-state collaboration around skills development across stakeholders, see the Greater Washington Partnership: http://www.greaterwashingtonpartnership.com/.

99. For more examples of worker-supporting regional partnerships, including their use of employer engagement techniques to shape technological change in the workplace, see Nichola Lowe, Putting Skill to Work: How to Create Good Jobs in Uncertain Times, Cambrige: MIT Press, forthcoming, 2021.

100. See a 2018 survey by NIST National Manufacturing Extension Partnership, utilizing an on-line survey of the MEP national network as well as focus groups which concluded

that credentials are "not routinely required or used" by firms. These results are consistent with a nationally representative survey conducted in 2012 and 2013 that found that only 7.4% of manufacturing firms responded affirmatively to the question, "Do you use any formal industry skill credentials system, such as those provided by industry associations or national testing services, for hiring core employees?" See Paul Osterman, "Skill Training for Adults," MIT Work of the Future Research Brief, October, 2020.

101. The U.S. Chamber of Commerce Foundation has recently put forth a proposal for Learning and Experience Records (LER). See https://www.commerce.gov/americanworker/american-workforce-policy-advisory-board

102. Alistair Fitzpayne and Ethan Pollack, "Lifelong Training and Training Accounts: Helping Workers Adapt and Succeed in a Changing Economy", May, 2018.

103. David J. Deming, Claudia Goldin, and Lawrence F Katz. "The For-Profit Postsecondary School Sector: Nimble Critters or Agile Predators?" Journal of Economic Perspectives 26, no. 1 (February 2012): 139–164. https://doi.org/10.1257/jep.26.1.139.
David J. Deming, Noam Yuchtman, Amira Abulafi, Claudia Goldin, and Lawrence F. Katz. "The Value of Postsecondary Credentials in the Labor Market: An Experimental Study." American Economic Review 106, no. 3 (March 2016): 778–806.

104. Doug Lederman. "Online is (Increasingly) Local," Inside Higher Ed, June, 5, 2019.

105. Fei Qin and Thomas Kochan, "The Learning System at IBM: A Case Study." Draft report, MIT Sloan School of Management, September, 2020.

106. Dhawal Shah,Year of MOOC-based Degrees: A Review of MOOC Stats and Trends in 2018, January 6, 2019, https://www.classcentral.com/report/moocs-stats-and-trends-2018/ accessed on October 5,2020/

107. Sanjay Sarma and Bill Bonvillian, " Applying New Education Technologies to Meet Workforce Education Need", MIT Work of the Future Research Brief, October, 2020.

108. Tavneet Suri, "Universal Basic Income: What Do We Know?", MIT Work of the Future Research Brief (2020).

109. Susan Houseman, Katherine Abraham, Christopher O'Leary, "Technological Change, Job Loss, and the Adequacy of Unemployment Insurance: Extending Benefits to Workers in Precarious and Nonstandard Arrangements", MIT Work of the Future Research Brief, November, 2020.

110. We do not specify a number here, but research offers guidance on this choice. See Arindrajit Dube. "Impacts of Minimum Wages: Review of the International Evidence." Report prepared for Her Majesty's Treasury (UK), 2019.

111. See "In Advanced and Emerging Economies Alike, Worries About Job Automation." Pew Research Center's Global Attitudes Project (blog), September 13, 2018. https://www.pewresearch.org/global/2018/09/13/in-advanced-and-emerging-economies-alike-worries-about-job-automation/.

112. See for example Schmitz Jr., James A. "What Determines Productivity? Lessons from the Dramatic Recovery of the U.S. and Canadian Iron Ore Industries Following Their Early 1980s Crisis." *Journal of Political Economy* 113, no. 3 (June 2005): 582–625.

113. In 2018, 13.8 percent of black versus 11.5 percent of white workers were represented by a union. Conversely, only 10.1 percent of Hispanic workers had union representation. See BLS Economic New Release: Union Members Survey, 1/22/2020, Table 1, https://www.bls.gov/news.release/union2.nro.htm

114. Thomas A. Kochan, Duanyi Yang, William T. Kimball, and Erin L. Kelly, "Worker Voice in America: Is There a Gap Between What Workers Expect and What They Experience?" *ILR Review*, 72, 1, 3–38 (2019); Alexander Hertel-Fernandez, William T. Kimball, and Thomas A. Kochan, "What Forms of Representation Do American Workers Want? Implications for Theory, Policy, and Practice." *ILR Review* September 2020.

115. Thomas Kochan, Worker Voice, Representation, and Implications for Public Policies,MIT Work of the Future Research Brief, 8 July 2020, https://workofthefuture.mit.edu/research-post/worker-voice-representation-and-implications-for-public-policies/, p.2

116. The NLRA has specific provisions to encourage collective bargaining in labor markets where the employer-employee relationship is neither permanent nor exclusive, but these provisions are limited to the construction sector.

117. Full enforcement of existing labor law is also essential. It's extremely difficult for workers who want a union to gain representation, especially if the employer fights the organizing effort, which employers often do. A 2008 study — still one of the most complete looks at this issue — found that only 20% of unions that file the documentation to hold a union election in a workplace make it through to a contract. If management fights the union drive to a point where an unfair labor practice charge is filed by organizers, the success falls to just 10%. See John-Paul Ferguson, "The Eyes of the Needles: A Sequential Model of Union Organizing Drives, 1999–2004," *ILR Review* 62, 1, 3–21 (2008).

118. This section draws from multiple perspectives on this topic. See Erik Brynjolfsson, Seth Benzell and Daniel Rock, "Understanding and Addressing the Modern Productivity Paradox," MIT Work of the Future Research Brief, November, 2020. ; John Van Reenen, "Innovation Policies to Boost Productivity." Policy Proposal. The Hamilton Project, June 2020; Nicholas Bloom, John Van Reenen, and Heidi Williams. "A Toolkit of Policies to Promote Innovation." Journal of Economic Perspectives 33, no. 3 (August 2019): 163–84. https://doi.org/10.1257/jep.33.3.163; Jonathan Gruber and Simon Johnson. *Jump-Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream.* New York, NY: PublicAffairs, 2019.

119. Yasheng Huang and Meicen Sun. "China's Development in Artificial Intelligence", MIT Work of the Future Research Brief, forthcoming.

120. Business Roundtable, "Statement on the purpose of the corporation", 2019, https://opportunity.businessroundtable.org/wp-content/uploads/2019/08/Business-Roundtable-Statement-on-the-Purpose-of-a-Corporation-with-Signatures.pdf

121. Ellora Derenoncourt, Clemens Noelke, and David Weil., "Spillover Effects from Voluntary Employer Minimum Wages", presentation at NBER Labor Studies Summer Institute, July 2020.

122. See Paul Osterman, "In Search of the High Road: Meaning and Evidence." *ILR Review* 71, no. 1 (January 2018): 3–34.

123. See Binyamin Appelbaum, "50 Years of Blaming Milton Friedman. Here's Another Idea." *The New York Times*, September 18, 2020, sec. Opinion.

124. See Nicholas Bloom, and John Van Reenen. "Why Do Management Practices Differ across Firms and Countries?" Journal of Economic Perspectives 24, no. 1 (March 2010): 203–24; and Nicholas Bloom, Erik Brynjolfsson, Lucia Foster, Ron Jarmin, Megha Patnaik, Itay Saporta-Eksten, and John Van Reenen. "What Drives Differences in Management Practices?" *American Economic Review* 109, no. 5 (May 2019): 1648–83.

125. See Nicholas Bloom, Benn Eifert, Aprajit Mahajan, David McKenzie, and John Roberts. "Does Management Matter? Evidence from India." *Quarterly Journal of Economics* 128, no. 1 (February 1, 2013): 1–51.

126. Thomas Kochan, John Van Reenen, Susan Helper and Alex Kowalski, "Independence of Technology and Work Systems," MIT Work of the Future Working Paper, 2020.

127. Ari Bronsoler, Joseph Doyle and John van Reenen, "The Impact of New Technology on the Healthcare Workforce: A White Paper," MIT Work of the Future Research Brief, October, 2020.

128. Sara Kassir, Jackson Dolphin, Lewis Baker, John Gabrieli. "Cognitive Science as a New People Science for the Future of Work", MIT Work of the Future Research Brief, forthcoming.

129. Anubhav Arora, Barbara Dyer, and Thomas Kochan, *A Case Study of Integrating Technology and Work Systems at Kaiser Permanente's "Health Hubs"*. MIT Work of the Future Working Paper, forthcoming.

130. Anubhav Arora, Barbara Dyer, and Thomas Kochan, *A Case Study of Integrating Technology and Work Systems* at Kaiser Permanente's "Health Hubs". Task Force Working Paper, forthcoming.

131. Zeynep Ton, *The Good Jobs Strategy: How the Smartest Companies Invest in Employees to Lower Costs and Boost Profits*. Boston and New York: Houghton Mifflin Harcourt, 2014.

132. Christian Dustmann, Attila Lindner, Uta Schönberg, and Matthias Umkehrer. 2020. "Reallocation Effects of the Minimum Wage." CReAM Discussion Paper, no. CDP 07/20 (February 2020): 60.

## Acknowledgements

We would like to thank our Advisory Board and Research Advisory Board for their guidance, insight and commitment to this effort. We are grateful to our Task Force and additional contributors from the MIT community for their valuable participation over the course of two-plus years and for their contributions in 2020 to 20+ research briefs and this final report. A special thank you to David Goldston, head of the MIT Washington, D.C. office, for his excellent contributions to our discussions and reports; Tim Aeppel, our Chief Editor, for his valuable input to this report from beginning to end, and Linda Walsh, our Copy Editor, for her high standards and attention to detail. Thank you to our internal communications team, Suzanne Pinto and Stefanie Koperniak, office administrators Laura Guild and Jody Gilbert, and in particular the Associate Director of the Work of the Future, SJ Maxted, who provided invaluable support throughout the production of this report. Additionally, we thank Strange Brew Communications and the designers at Opus, and the many more friends and colleagues who were involved in the production of this report. Finally, we'd like to thank the dozens of students and researchers who were part of a thoughtful, engaging community over the past two years that generated excellent research and provided valuable insight and support throughout this effort.


### Task Force Staff


**TIM AEPPEL**
Chief Editor

**SARAH JANE MAXTED**
Associate Director

**SUZANNE PINTO**
Communications Director

**STEFANIE KOPERNIAK**
Communications

**LINDA WALSH**
Copy Editor

**LAURA GUILD**
Senior Administrative Assistant

**JODY GILBERT**
Administrative Assistant


### Task Force


**DAVID AUTOR**
Co-Chair
Task Force

**SUZANNE BERGER**
Department of Political Science

**ERIK BRYNJOLFSSON**
Stanford Digital Economy Lab

**JOHN GABRIELI**
Department of Brain and Cognitive Sciences

**JOHN HART**
Department of Mechanical Engineering

**YASHENG HUANG**
Sloan School of Management

**JASON JACKSON**
Department of Urban Studies and Planning

**THOMAS KOCHAN**
Sloan School of Management

**JOHN LEONARD**
Department of Mechanical Engineering

**DAVID MINDELL**
Co-Chair
Task Force

**PAUL OSTERMAN**
Sloan School of Management

**IYAD RAHWAN**
MIT Media Lab

**ELISABETH REYNOLDS**
Executive Director
Task Force

**DANIELA RUS**
Department of Electrical Engineering

**SANJAY SARMA**
Department of Mechanical Engineering

**JULIE SHAH**
Department of Aeronautics and Astronautics

**TAVNEET SURI**
Sloan School of Management

**KATHLEEN THELEN**
Department of Political Science

**JOHN VAN REENEN**
Sloan School of Management

**KRYSTYN VAN VLIET**
Materials Science and Engineering

**CHRISTINE WALLEY**
Department of Anthropology

## Task Force Advisory Board

**ROGER C. ALTMAN**
Founder & Senior Chairman
Evercore

**ANA BOTIN**
Executive Chairman
Santander Group

**CHARLIE BRAUN**
President
Custom Rubber Corp.

**ERIC CANTOR**
Vice Chairman
Moelis & Company

**VOLKMAR DENNER**
Chairman of the Board
Robert Bosch GMBH

**WILLIAM CLAY FORD, JR**
Executive Chairman
Ford Motor Company

**JENNIFER GRANHOLM**
Former Governor of Michigan

**FREEMAN A. HRABOWSKI**
President
University of Maryland, Baltimore County

**DAVID H. LONG**
Chairman and CEO
Liberty Mutual Insurance

**KAREN MILLS**
Senior Fellow
Harvard Business School

**INDRA NOOYI**
Former Chairman and CEO
PepsiCo

**ANNETTE PARKER**
President
South Central College, Minnesota

**DAVID ROLF**
Founder and President Emeritus
SEIU 775

**GINNI M. ROMETTY**
Executive Chairman
IBM Corporation

**JUAN SALGADO**
Chancellor
City Colleges of Chicago

**ERIC E. SCHMIDT**
Technical Advisor and Member of the Board
Alphabet Inc.

**ELIZABETH SHULER**
Secretary — Treasurer
AFL-CIO

**DAVID M. SIEGEL**
Co-Chairman
Two Sigma

**ROBERT SOLOW**
Professor Emeritus
MIT Economics

**DARREN WALKER**
President
Ford Foundation

**JEFF WILKE**
CEO
Amazon Worldwide Consumer

**MARJORIE YANG**
Chairman
ESQUEL Group

## Task Force Research Advisory Board

**WILLIAM BOONE BONVILLIAN**
Lecturer
MIT

**RODNEY BROOKS**
Founder, Chairman, and CTO
Rethink Robotics

**JOSHUA COHEN**
Distinguished Senior Fellow in Law, Philosophy, and Political Science
University of California, Berkeley

**VIRGINIA DIGNUM**
Professor of Social & Ethical AI
UMEA University

**SUSAN HELPER**
Professor
Case Western Reserve University

**SUSAN HOUSEMAN**
Vice President & Director of Research
W.E. Upjohn Institute

**MARTIN KRZYWDZINSKI**
Principal Investigator
WZB Berlin Social Science Center

**FRANK LEVY**
Rose Professor Emeritus
MIT

**NICHOLA J. LOWE**
Associate Professor of City & Regional UNC, Chapel Hill

**JOEL MOKYR**
Professor of Economics & History
Northwestern University

**JOHN IRONS**
Director, Future of Work
Ford Foundation

**FEI-FEI LI**
Professor, Computer Science Department
Stanford University

**MICHAEL PIORE**
Professor Emeritus
MIT

**GILL PRATT**
Executive Technical Advisor & CEO
Toyota

## Additional Task Force Contributors

Barbara Dyer

Allison Forbes

Timothy Sturgeon

George Westerman

## Task Force Researchers and Students

Cory Adkins

Zachary Wayne Avre

Ben Armstrong

Ari Bronsoler

Anna Waldman-Brown

Brandon Enriquez

Christopher Fourie

Kaitlyn Gee

Russell Glynn

Mario Goetz

Jihye Gyde

Qiangqiang Huang

Jessica Ingabire

Claire McKenna

Arshia Mehta

Gabriel Nahmias

Alexander Kowalski

Anastasia Ostrowski

Adelynn Paik

Georgios Petropoulos

Rida Qadri

Frank Ryan

Lindsay Sanneman

Simon Schumacher

Ankit Shah

Edlar Shakirov

Kevin Shen

Anuraag Singh

Erik Stayton

Meicen Sun

Aarti Sunder

Daniel Martin Traficonte

Inez Freiin von Weitershausen

Reimar Weissbach

Lukas Wolters

Di Wu

Margaret Yellen

## Task Force Project Sponsors

The MIT Task Force on the Work of the Future thanks the following sponsors for their generous support.

FORD FOUNDATION

Google.org

THE JOYCE FOUNDATION

JPMorgan Chase & Co.

Lumina™ FOUNDATION

RALPH C. WILSON, JR. FOUNDATION

SCHMIDT FUTURES

SIEGEL FAMILY ENDOWMENT

**CONTACT**

**Massachusetts Institute of Technology**
Industrial Performance Center
400 Main Street (Building E19-733)
Cambridge, MA 02142

(617) 253-8171
workofthefuture@mit.edu
@workofthefuture