WOMEN, AUTOMATION, and the Future of Work

INSTITUTE FOR
WOMEN'S POLICY RESEARCH

ABOUT THIS REPORT

This report presents the first comprehensive gender analysis of the potential impact of technological change on women and men's employment in the United States, with an emphasis on the likely effects for women, given the jobs where women predominantly work and given the disproportionate share of home and family care done by women. It continues IWPR's gender analysis of the labor market and the divergent experiences of women of different races and ethnicities. The report also reviews gender specific trends in the gig economy and contingent work arrangements, analyzes the earnings gains of working with computers and digital content for women compared with men, assesses the recent progress of women and people of color in the three largest technical occupations, and discusses the opportunities new technologies create for balancing work and family as well as the new risks. The report ends with policy recommendations for improving the outcomes of this wave of technological change, sometimes called the fourth industrial revolution. An executive summary of this report (IWPR #C477), which highlights the study's main findings and summarizes the policy recommendations, is available on IWPR.org.

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The Institute for Women's Policy Research (IWPR) conducts and communicates research to inspire public dialogue, shape policy, and improve the lives and opportunities of women of diverse backgrounds, circumstances, and experiences. The Institute's research strives to give voice to the needs of women from diverse ethnic and racial backgrounds across the income spectrum and to ensure that their perspectives enter the public debate on ending discrimination and inequality, improving opportunity, and increasing economic security for women and families. The Institute works with policymakers, scholars, and public interest groups to design, execute, and disseminate research and to build a diverse network of individuals and organizations that conduct and use women-oriented policy research. IWPR's work is supported by foundation grants, government grants and contracts, donations from individuals, and contributions from organizations and corporations. IWPR is a 501(c)(3) tax-exempt organization that also works in collaboration with the Program on Gender Analysis in Economics, Department of Economics, College of Liberal Arts and Sciences, American University.

WOMEN, AUTOMATION,
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INTRODUCTION
Why the Analysis of Technological Change Needs a Gender Perspective

Automation, artificial intelligence, and other technological changes are already affecting the number and quality of jobs. The number of workers employed in brick and mortar retail stores has fallen while the number employed in fulfillment centers preparing online orders for shipping increased by 400,000 between 2007 and 2017 (Mandel 2017). In retail stores there are fewer cashiers and more self-checkout machines, more people today find work using online labor platforms, and the number of bank tellers is falling as the public does much of its banking online. These changes and others have led to a rash of research studies on the future of work and what it will mean for workers. One widely cited 2013 study found that 47 percent of all jobs in the United States are at risk of automation with the technology we currently have over "some unspecified number of years, perhaps a decade or two" (Frey and Osborne 2013, p. 38). The Bureau of Labor Statistics, however, projects that the total number of jobs will actually increase by seven percent between 2016 and 2026 (Lacey et al. 2017). Yet other researchers focus on how the content of jobs will change, and the potential for technology to generate new jobs both in current occupational categories and in completely new categories we cannot yet imagine.

It is not clear which of these predictions and projections are correct. What the research does make clear is that the world of work is changing, it will continue to change, and it will require that the labor force and our systems of labor market supports change with it. Given that women and men often work in different occupations and given that women are much more likely than men to do unpaid care work—a large part of our economy—any analyses and public policies developed to address technological change need to take account of gender differences. Some predict that women will gain with respect to overall rates of employment but will become even more highly represented among the growing number of low-quality human service jobs in the new economy than they are now, and also may have trouble entering the generally male-dominated 'high-tech' occupations that are expected to grow, such as Software Engineer. In contrast, others suggest that even low-paid jobs like Home Health

Care Aide may be transformed by new technologies becoming available in the home, and that women who are well prepared will indeed join the high-tech workforce in larger numbers, as suggested by the many projects designed to interest girls and young women in coding, robotics, and software development. These predictions are complicated even more by the racial and ethnic differences among women in access to training and employment opportunities, another place where social policy is needed to improve equity going forward.

The outcome of these ongoing changes—whether there will be large numbers of unemployed and underemployed people or a thriving economy in which everyone participates—will depend on the policies that are implemented. A thriving economy will require substantial investment in new technologies and public policies to ensure that the jobs of the future are high quality jobs that pay a living wage and provide workers with security and benefits, including workers in the gig economy who may increasingly find employment through online platforms.

The goal of this report is to improve understanding of the potential impact of technological change on women and men's employment, with an emphasis on the likely effects for women, given the jobs where women predominantly work and given the disproportionate share of home and family care done by women. Only a small number of studies to date have estimated the risk of automation separately for men and women, and none for the United States. In the coming years, technological changes are likely to have a substantial impact on the need for training and education, with workers likely to have to retrain and reskill repeatedly during their lifetimes. A better understanding of how women and men may be affected differentially by technological change can lead to more effective policies that share the benefits of technological change more equitably.

This report first summarizes, in Chapter 1, the existing literature on the future of work, specifically on forecasts of the changing number and content of jobs associated with technological change. Chapter 2, drawing on the IWPR Future of Work database, developed to analyze the impact of automation and digitalization on employment for women and men by race and ethnicity from 2000 into the future, provides an original analysis of the potential quantitative impact of technological change on occupations typically done by women or men. Chapter 3 discusses several of the broader aspects of the future of work looking at how automation and technology are changing the qualitative nature of work and the manner in which work is done, providing both new opportunities and raising new risks for workers. The chapter examines how this shift differentially affects women and men and what the likely consequences will be in terms of decreased economic security and increased inequality. Chapter 4 takes a closer look at one qualitative aspect of job content, specifically the digitalization of women's and men's jobs and how, over time,

many jobs—disproportionately women's jobs—have come to require at least some work with digital technology, but how women's digital skills are rewarded less than men's. This chapter also discusses how women are participating in designing the future of work. Chapter 5 examines how automation and technological change may change the dynamic of work and family obligations through both a change in how families provide care to children and aging parents and a change in how work is actually done that can help alleviate the conflict between work and family obligations for many workers. At the same time, those employed as paid family caregivers may face new risks. The final chapter highlights the study's main findings, noting challenges posed by technological change and providing a menu of policy options.

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Will Automation Mean the End of Work?

KEY FINDINGS

- There are widely varying estimates of how new technologies may potentially affect employment, ranging from half of all jobs shifting from human labor to machines or computers within the next 15 years to seven percent employment growth by 2026.

- Different job growth estimates reflect different methodologies.

- Technology is only one factor influencing job growth. Other factors include economic trends, the costs of technology, labor market dynamics (and skills), the regulatory and social acceptability of new technologies, and demographic change.

- Whatever the impact on the number of jobs, technological change is likely to replace many tasks, leading to the disappearance of some occupations and the growth of others, and requiring substantial retraining for many workers.

The existing literature on the future of work differs substantially in its predictions of the quantity of jobs, but most suggest job content will be transformed in many occupations and workers will need new training.

The prospect of driverless cars, factories operated by robots, and stores without cashiers—or need for cash—conjures up visions of a jobless future. Up to half of all U.S. based jobs could be automated within a 5-to 15-year time horizon, according to a 2013 research study by Frey and Osborne. Yet, another study estimates that risk at "just" nine percent of all jobs over broadly the same time horizon (Arntz, Gregory, and Zierahn 2016), while the U.S. Bureau of Labor Statistics predicts that instead of declining, the overall number of jobs will grow (Lacey et al. 2017). Automation, artificial intelligence (AI), and digitalization[1] are ongoing processes that are eliminating some jobs, creating new jobs, and changing the nature of work in yet others, while also increasing the returns on digital skills. This section reviews the major approaches to assessing the future of work.

Estimates of Job Change are Wide-Ranging

The available studies largely fall into three types: 1) those that estimate that in a large share of jobs—possibly half—technology can replace human labor; 2) those that argue that automation will cause a major shift in the types of jobs done by humans, or transform the content of occupations, but won't have a major destructive impact on the number of jobs; and 3) those that find that automation/machines and labor are complementary or at least not incompatible, and will require a shift in skills used on the job, along with some job destruction; but that the increased productivity and innovation that come as a result of technological change will create many new jobs or allow for new demands to be met by newly available labor.

Some Studies Find that Automation Can Replace Many Jobs

In their seminal analysis of skills and the technological potential, and limitations, of substituting machines and computers for humans, Autor, Levy, and Murname (2003) differentiate between tasks that are routine, and open to replacement, and nonroutine tasks requiring "flexibility, creativity,

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1   Throughout this report, we follow Muro et al. (2017) and use the term 'digitalization' as a shorthand for describing the growing requirement for knowledge and use of computers and related digital tools at work. Digitalization is the process of making data capable of being used by machines (e.g. computers and other electronic tools). Data can be numbers, words, speech, video or other media, and there are multiple methods of converting complex data into simple digital form.

generalized problem-solving, and complex communications" that will remain in the domain of human labor. Fifteen years on, artificial intelligence and machine learning have advanced to taking on many tasks that were previously thought too complex for computers and increasingly subsume professional and creative tasks (Brynjolfsson, Mitchell, and Rock 2018; Nedelkoska and Quintini 2018). These two studies point to the sheer speed at which machine learning technology is advancing and the number of tasks once thought to be beyond automation that computers now match or exceed human abilities to do, including image and speech recognition, natural language processing, and predictive analytics. Computers beat humans at lip reading (Condliffe 2016), outperform dermatologists at detecting melanomas (*The Guardian* 2018), and achieve financial performance as high as human hedge fund managers (Harvey et al 2017).

Technological potential is projected to accelerate substantially during the coming decades (see for example Autor 2015; Frey and Osborne 2013; Manyika et al. 2017a, b; Muro et al. 2017). Schwab (2016) argues that these transformations are happening at a speed that is unmatched historically, and that together they constitute a fourth industrial revolution that is evolving at an exponential pace. There is substantial disagreement among experts in the research literature, however, about the ultimate outcome of these changes (Smith and Anderson 2014).

One of the earliest and most influential studies setting out to quantify the impact on employment of the ongoing technical revolution, by Frey and Osborne (2013), focuses on the potential for technological substitution and automation by occupation. They conclude that, given current technology, 47 percent of total U.S. jobs are at high risk of automation within "a decade or two" (by now a 5- to 15-year time horizon). Based on detailed task descriptions for occupations from the U.S. Department of Labor's O*Net and reviews of the potential for automating different tasks from a panel of technological experts that they assembled, Frey and Osborne (2013) calculate the risk of automation for each of more than 700 detailed U.S. occupations. In subsequent analyses they have applied their methodology at the city and regional level in the United States (Citi GPS 2016). Their study finds strong negative correlations between automation risk and earnings, and automation risk and educational requirements, suggesting that the jobs of workers in low-wage occupations and in occupations requiring less education are particularly at risk of technological displacement.

For example, Packaging and Filling Machine Operators, Cashiers, and Cooks are at high risk of automation, while Doctors and Nurses, Engineers, Managers, and Teachers are at low risk. Automation risk, however, is certainly not limited to low-wage occupations. Frey and Osborne (2013) also find that many Office and Administration occupations are at very high risk of automation.

Technological potential is projected to accelerate substantially during the coming decades, constituting a fourth industrial revolution.

Other Research Finds that Job Loss Will Not Be Severe

Arntz, Gregory, and Zierahn (2016) also focus on the technological potential of automation of different tasks. Instead of analyzing tasks within occupational groups like Frey and Osborne (2013) and the McKinsey study by Manyika et al. (2017a), they draw on the Programme for the International Assessment of Adult Competencies (PIACC) Survey, a dataset that is directly based on workers' reports of the tasks they perform in their jobs. Arntz et al. (2016) argue that Frey and Osborne's (2013) whole-occupational analysis overestimates the homogeneity of work performed within occupations, particularly in large ones, and underestimates the extent of interpersonal interactions and other non-routine activities that are hard to automate, at least given current technical know-how. Their resulting estimate is substantially lower, finding that nine percent of U.S. jobs are at high risk of automation.

Manyika et al. (2017a, b) and Bughin et al. (2018) from the McKinsey Institute, like Frey and Osborne (2013), draw upon the detailed occupational task descriptions provided in the O*Net database, but their analysis is focused more strongly on the complexity of tasks within occupations. They divide work tasks into seven broad buckets and estimate the distribution of all work that is performed across these seven groups. Three tasks groups have high potential for automation: predictable physical work (81 percent automatable), data processing (69 percent automatable), and data collection (64 percent automatable); these jointly account for more than half (51 percent) of all performed work hours, according to their estimates. The other four task groups—which account for just under half of work done—have, in contrast, a sharply lower automation potential. These are unpredictable physical work (26 percent automatable); 'interface' (personal interactions; 20 percent automatable); 'expertise,' including decision making, planning, and creative tasks (18 percent automatable), and 'manage,' including managing and developing people (seven percent automatable). They estimate that in 60 percent of occupations at least 30 percent of activities could be automated. Altogether they estimate that 46 percent of work hours, translating into the equivalent of 61 million full-time equivalent jobs, may be at risk from automation in the United States by 2030.

There are some notable differences between Frey and Osborne (2013) and the McKinsey Institute projections (Manyika et al. 2017a,b), because of differential assessment of difficulties posed by unpredictable physical environments as well as different assessments of the speed of likely adoption of automation. For example, Manyika et al. (2017a) suggest that just 12 percent of activities in Building and Grounds-keeping easily lend themselves to automation, compared with an estimated probability by Frey and Osborne (2013) of 94 percent.

One study estimates that 61 million full-time equiavlent jobs in the United States may be at risk of automation by 2030.

Overall, Manyika et al. (2017a,b) project that, if the United States "steps up" its public policies to anticipate the effects of technological change, enough jobs would be created to employ the growing labor force and offset losses due to automation. In either their midpoint scenario or their accelerated scenario, the content of many occupations changes and workers need considerable retraining. Stepping up requires that nations invest in rapid technological change to gain the most growth in productivity, raising incomes and freeing up workers for other uses, and that they provide the needed training and methods of assuring job security to workers so that the labor market works efficiently. Other factors influencing job growth include an aging population that is cared for by paid workers and greater investment in real estate development, infrastructure, and energy efficiency.

U.S. Bureau of Labor Statistics Projects Job Growth

The most recent employment projections prepared by the U.S. Bureau of Labor Statistics (BLS); (Lacey et al. 2017) show few occupations with actual job losses and overall employment growth of 11.5 million jobs (or 7.4 percent) between 2016 and 2026. Every two years, the BLS has published detailed occupational projections for the next decade. The projections are based on estimates of the future labor force participation of men and women, macro-economic projections of productivity growth, detailed industry input-output analyses, reviews of technical trends, and interviews with industry and occupational experts. Most notably the BLS method assumes full employment. This is done for two reasons: first, to minimize the employment effects of business cycles so the data across time can be compared to consistent benchmarks; and second, because more than 100 years of BLS employment data show no instance of substantial, longstanding employment loss due to technological change.[2] Moreover, in the current period, BLS staff's examination of the research literature and their interviews with technical, industry, and occupational experts do not support a finding of substantial job displacement due to fundamental structural changes in the economy as would result from massive automation.[3]

It is notable that the BLS assessment of occupational growth differs substantially from other assessments of job change in several fields. For example, Frey and Osborne (2013) include Personal Care Assistants in their high-risk-of-automation category, whereas, according to the BLS, Personal Care Aides are among the fastest growing occupations. The BLS estimates reflect analysis of growth in demand for care work in response to the aging of the population, an aspect that is not included in the purely technical assessment of automation potential by Frey and Osborne.

BLS projects job growth of 11.5 million by 2026.

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2   Personal communication of Heidi Hartmann with BLS staff, December 2018.

3   Personal communication of Heidi Hartmann with BLS staff, June and December 2018.

The BLS estimates implicitly assume that technological change and employment growth are typically not incompatible. Some of the ways in which automation and job growth complement each other are discussed below.

Technology is Not the Only Factor Shaping the Speed of Automation

Manyika et al. (2017a) highlight four factors that are important in affecting the impact of technological innovation on future job growth – economic factors, the costs of technology, labor market dynamics (and skills), and the regulatory and social acceptability of new technologies. Each of these factors can speed up or slow down the adoption of a particular technological innovation and will influence how many jobs will be lost or created.

Take the economic factors. As Autor (2015) explains, when human labor is replaced by technology, this typically reduces the price of whatever is produced; when a product or service becomes cheaper, the quantity demanded may increase, and, thus, even though it now takes fewer people to make the product or provide the service, the increase in demand may mean that the need for labor remains unchanged. Alternatively, the falling price of one product may free funds in people's budgets to spend on alternative goods or services, and, thus, while fewer workers are needed to produce the first good, they may now shift to produce alternative products or services.

Furthermore, technology may eliminate the mundane parts of work, and this may free workers up to focus on the creative, interactive, problem-solving parts of their jobs, shifting from routine—easy to automate work—to non-routine work. Black and Spitz-Oener (2010), for example, show that in the two decades up to 2000 (the early stages of computerization), women's work particularly benefitted from a shift from routine towards more cognitive, interactive, and less routine work; these shifts took place primarily within, rather than between, occupations. In other words, what workers do in some occupations changes over time. Bank tellers, for example, spent most of their time taking deposits and cashing checks before the ATM was introduced in the 1970s (Bessen 2015). After ATMs became common in the 1990s, and this routine administrative work had shifted from humans to machines, tellers, according to Bessen, became part of the "relationship banking team" focusing on aspects of their jobs that could not be automated, such as forming relationships with small business customers and selling them financial services and products. Yet, during the Great Recession, employment of Tellers began to decline, and has not recovered since.[4]

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4   By 2013, a third of tellers had earnings low enough to qualify for public assistance (CBS News 2013). Job loss has continued since the end of the Great Recession, and by 2017, employment levels were 35 percent below what they had been in 2007 (Authors' calculations based on U.S. Bureau of Labor Statistics 2018f).

Another factor in the speed of automation is the price of new technologies compared with having the same work done by human labor. Frey and Osborne (2013) find that the risk of automation may be highest in low wage occupations, but that risk is based purely on their assessment of the technological potential to replace human labor with machines or computers. Thus, while it is possible to replace fast food workers with cooking robots, or cashiers with self-checkout machines, the fact that these jobs are low paid may slow the speed of adoption. Brynjolfsson and McAfee (2011) point to the long-term decline in workers' wages and note that employers will likely delay replacing workers with technology to the extent that they can lower workers' wages instead. They also note, however, that employers can only lower workers' wages so much before they reach the minimum wage (or are below subsistence), and at that point they will replace workers with new technology if the technology then presents a cheaper alternative. As Manyika et al. (2017) point out, the higher hourly earnings of administrative workers in bookkeeping, accounting, and other administrative work may provide greater incentives to replace their work with new technologies, because every hour saved yields greater saving in labor costs than it would in a low-wage job. The determining fact here is the cost of labor compared with the cost of technology, along with expectations of future costs in both realms.

The implementation of new technologies also depends on having a workforce with the skills necessary to work with new machines. Manufacturers in the United States, for example, report high skill shortages; the implementation of new production methods may require fewer workers, but often these workers need higher skills (Deloitte and Manufacturing Institute, 2018). Gender norms of desirable and appropriate work for men and women are often slow to change and can slow down transitions in the workforce. In spite of high vacancy levels in many middle skill technical occupations, for example, employers have found it hard to create a working environment that is attractive and inviting to women (Hegewisch, Bendick, Gault, and Hartmann 2016).

Changing to a new way of doing things—such as driverless cars, robots to monitor and provide company for someone with dementia, or waiterless restaurants—depends as much on social acceptability, both at the individual level and at the societal level (through regulations) as it depends on perfecting the underlying technology (Manyika et al 2017b).

Last but not least, factors such as demographic change—including the projected doubling of the number of Americans ages 65 and older between 2016 and 2060 from 49.2 to 94.7 million—from 15 to 23 percent of the population (Vespa, Armstrong, and Medina 2018)–will affect the demand and supply of goods and services, and of workers, and may increase the demand for technological change in caregiving .

How quickly new technologies are adopted depends on social acceptability, especially likely changes in women's and men's roles, and in changing regulations and public policies.

Whatever the specific job growth estimate and timeline of each these studies, all of them suggest that technological advances will cause substantial change within and between occupations, which points to the need for many workers to develop new skills. The World Economic Forum (2018) highlights the point that for many occupations that are projected to decline, occupations with some overlapping tasks and skill sets may grow, reducing the costs of changing occupations. Basic digital literacy will be required in almost all jobs; high levels of demand are predicted both for technical skills—to develop, implement and work with new technologies—and for social skills such as leadership, teamwork, and social interaction (Bughin et al. 2018). While individual willingness to learn new skills is essential, commentators highlight the need for public policies to provide guidance and financial supports to those whose jobs may be at risk from automation.

The BLS (Lacey et al. 2017), in contrast with the other studies reviewed, projects much less change and disruption between occupations, a projection that suggests that technological changes may occur primarily within occupations or may take substantially longer to arrive than some authors predict. Technological change may be accommodated by many workers who retain their jobs but use new technologies to do them, possibly changing the scope or scale of their jobs as well as ways in which work is performed. The further spread of some technical advances, such as voice recognition, may simplify the interface with new technologies, reducing the need for new learning. The following chapters consider these projections and potential changes from a gendered perspective and take into account racial and ethnic differences among women and men as well.

All of the studies suggest that technological advances will cause substantial change within and between occupations. Many workers will need to develop new skills.

2 Women's Work, Men's Work, and the Risk of Automation

The authors forecast the potential impact of technological change on the number of jobs by gender, race, and ethnicity, and compare these to job growth projections in the economy overall.

KEY FINDINGS

- Women and men often work in different jobs and sectors and will be affected differently by technological change.

- Given job segregation in the U.S. labor market, women are substantially more likely than men to be in occupations with both the lowest and the highest risk of technological substitution.

- Women make up just under half (47 percent) of the workforce, but they are 58 percent of workers at the highest risk of automation. There are 20.2 million women who work in high-risk occupations, compared with 14.4 million men. For every seven men who work in high-risk occupations, there are 10 women who do.

- The risk of job substitution for women varies by race and ethnicity, but for all the largest race/ethnic groups women are at higher risk of displacement than men in the same group. Hispanic women are most at risk from automation/AI; one in three Hispanic women work in high-risk occupations.

- Women workers are also the majority (52 percent of workers) in jobs least likely to be replaced by technology, such as child care, elder care, and teaching. The large majority of jobs in the group of the lowest-risk occupations require at least a bachelor's degree. Women are more likely than men to have BA degrees, but the likelihood of higher levels of education varies sharply by age, race, and ethnicity.

- Automation will affect men the most in low-earning occupations, while women's risk is more equally spread across better- and lower-paid occupations, indicating that women's access to jobs that pay well will be particularly affected.

The Potential Impact of Technological Disruption Differs for Women's and Men's Jobs

Occupational gender segregation is a marked feature of the labor market in the United States and most other countries. Women are only five percent of Truck and Cab Drivers (Hegewisch and Williams-Baron 2018), and thus will not be as affected by job loss as men if driverless cars become widespread. Women are also less likely than men to work in factories (Hegewisch, Bendick, Gault, and Hartmann 2016), and are thus less immediately affected than men by the automation of tasks in production. Many women's manufacturing jobs were lost in response to earlier rounds of technological and economic change, when jobs in textile and light manufacturing, where women tended to be concentrated, were exported to countries with lower labor costs. Women are much more likely than men, however, to work in secretarial and administrative jobs, involving the type of routine data processing and data collection tasks highlighted by Frey and Osborne (2013) and Manyika et al. (2017a) as the type of tasks that Artificial Intelligence can

soon take over. Women are also more likely than men to work in childcare, education, and other fields that require the type of non-routine emotional interactions that are difficult to automate.

Yet, while most studies note that gender differences in occupations suggest that women and men will be affected differently, only a small number of studies to date have estimated the risk of automation separately for men and women, and none by occupation for the United States. A German study, applying a similar methodology to that of Frey and Osborne (2013), but based on German occupational descriptions, found men to be much more at risk than women, primarily because Germany still has a large (and male-dominated) manufacturing sector which is particularly at risk of automation (Dengler and Matthess 2016). Researchers at the International Monetary Fund, in contrast, found women to be at slightly higher risk than men from automation; based on PIACC (Programme for the International Assessment of Adult Competencies) Survey data discussed above, and sector and occupational analysis across 30 high income countries, they suggest that 11 percent of women's jobs and nine percent of men's jobs are at risk of automation given current technological knowhow (they do not provide country-specific estimates; Brussevich et al. 2018).

To highlight the potential of technological disruption for U.S. workers, this chapter examines women's and men's distributions across occupations with different risks of automation. These analyses draw upon two databases created by the authors. The first, the occupational projections database, combines 10-year occupational projections from the Bureau of Labor Statistics, probability of automation scores developed by Frey and Osborne (2013), digitalization scores from Muro et al. (2017), and employment and earnings data from the American Community Survey.[5] This database enables the authors to project employment growth and the shares of workers by sex, race, and ethnicity in the occupations with the highest and lowest risk of automation and the highest and lowest levels of digitalization.

The second database is a historical database that enables the authors to examine changes over time in women's and men's employment and earnings, including for women and men of color. This database compares data for 2000, 2005-07, and 2014-16. See the methodological appendix for more detail.

These two databases (referred to collectively as the IWPR Future of Work Database) are used to compare one of the largest projections of potential job displacement due to automation (Frey and Osborne 2013) with the lowest (Lacey et al. 2017). Occupational growth projections for the largest occupations for women and men are compared, and for women and men in the largest racial and ethnic groups.

> **Women are more likely than men to work in childcare, education, and other fields that require the type of non-routine emotional interactions that are difficult to automate.**

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5   The American Community Survey data are taken from Integrated Public Use Microdata Series (IPUMS) at the Minnesota Population Center.

Figure 1 provides an overview of women's and men's employment in the occupations with the lowest and highest risk of automation. The analysis draws on the 2013 Frey and Osborne assessment of the risk of automation in different occupations, but adopts a more restrictive definition of high-risk occupations, defined as occupations with a 90 percent or higher probability of automation (Frey and Osborne define high risk as 75 percent and higher); correspondingly, low-risk is defined as a 10 percent or lower probability of automation. Even with this tighter definition, 34.6 million women and men, close to a quarter of the total workforce (23.5 percent), are employed in occupations with a high technological potential for automation; the share of workers at very low risk of technological substitution is 27 percent (Table 1).

Women outnumber men in occupations with high risk of automation by 10 to 7.

FIGURE 1 — **Women Outnumber Men in Occupations with the Highest and Lowest Risk of Automation**

The Number of Women and Men in Occupations with Low and High Risk of Automation, and in the Total Workforce, 2014-16

■ Women   ■ Men

Workers in Low-Risk Occupations: Women 20.9M, Men 19.0M
Workers in the Total Workforce: Women 69.9M, Men 77.6M
Workers in High-Risk Occupations: Women 20.2M, Men 14.4M
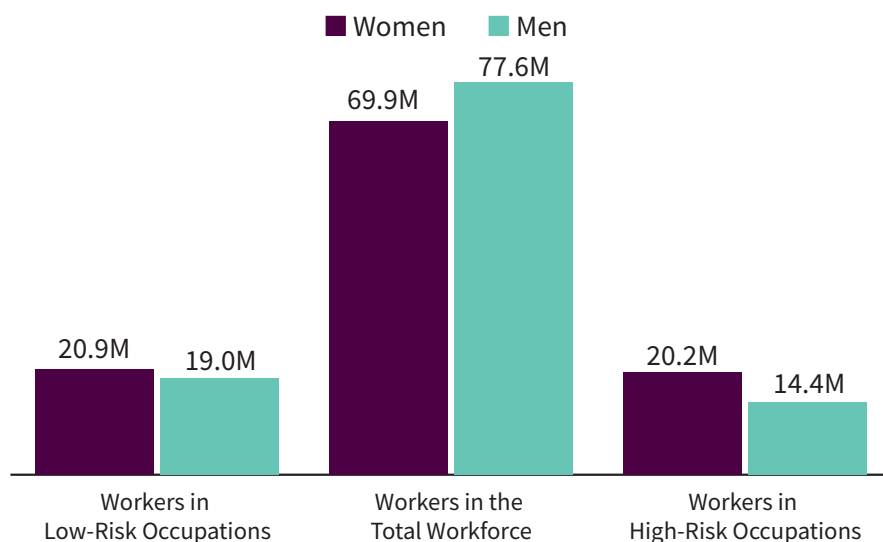
Notes: A high-risk occupation has a probability of automation score of 90 percent or more while a low-risk occupation has a probability of automation score of 10 percent or less.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Figure 1 shows that while men outnumber women in the workforce, women outnumber men among workers both in occupations with the highest risk of automation and in those with the lowest risk. Women make up just under half (47 percent) of the workforce, but they are 58 percent of workers at the highest risk of automation, and 52 percent of workers in the lowest risk occupations.

Of all women workers, 28.9 percent work in the high-risk occupations compared with just 19 percent of men. Women in each racial and ethnic group

are more likely to work in high-risk occupations than men of the same race or ethnicity; Hispanic women are the most likely of all groups of women to work in these occupations (32.2 percent) while White men are the least likely of all to do so (16.5 percent). Hispanic women are particularly likely to work in manufacturing and transportation (Hegewisch and Williams-Baron 2018), both industries with a comparably high share of routine, low-skill jobs potentially subject to displacement (Table 1).

TABLE 1 — Women are More Likely to Work in High-Risk Jobs than Men in Each of the Largest Racial and Ethnic Groups

The Share of Workers in High Risk Occupations by Gender, Race, and Ethnicity, 2014-16

		Share of Workers in High-Risk Occupations	Number of Workers in High-Risk Occupations	Share of Workers in Low-Risk Occupations	Number of Workers in Low-Risk Occupations
Total Workers		23%	34,589,555	27%	39,928,865
All Women		29%	20,228,953	30%	20,875,467
All Men		19%	14,360,602	25%	19,053,398
WHITE	Women	29%	12,680,589	33%	14,675,282
	Men	17%	8,246,002	28%	13,836,403
BLACK	Women	28%	2,529,504	26%	2,300,523
	Men	22%	1,682,848	18%	1,339,581
HISPANIC	Women	32%	3,404,185	19%	2,058,832
	Men	24%	3,317,162	13%	1,816,418
ASIAN	Women	26%	1,087,408	33%	1,357,614
	Men	17%	757,558	37%	1,655,571
OTHER	Women	30%	527,267	27%	483,216
	Men	20%	357,032	23%	405,425

Notes: High-risk occupations are defined as occupations with a 90 percent or higher probability of automation, low-risk occupations have probability scores of 10 percent or less. Asian includes Pacific Islanders; Whites, Blacks and Asians/Pacific Islanders are non-Hispanic, Hispanics may be of any race. Due to small sample sizes, 'Other' includes Native Americans, persons of two or more races, and anyone else not separately classified.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

The majority of jobs in the high-risk category are not terribly well paid (the median earnings across all of these occupations are just $32,900 for all, $30,900 for women, and $36,200 for men, IWPR Future of Work Database, data not shown elsewhere), but this group also includes Accountants and Auditors, with median annual earnings of $60,800.

Women of each of the largest racial and ethnic groups (except for Asians) are also more likely to work in the lowest risk occupations than men in the same demographic groups. Compared with other demographic groups, Hispanic women are least likely to be in this low-risk group, as are Hispanic and Black men (Table 1). While the low-risk occupations include some low-wage occupations, such as Childcare Workers and Hairdressers, Hairstylists, and Cosmetologists, on the whole earnings are much higher in the high-risk group of occupations, with median annual earnings for full-time work of $67,100 ($55,200 for women and $80,000 for men; IWPR Future of Work Database, data not shown elsewhere). The large majority of occupations in this group require at least a bachelor's degree. Low-risk occupations include many in education, social care, and healthcare, sectors where many women work, as well as jobs involved in producing new technologies in STEM fields (see Chapter 3 for a more in-depth discussion). Low risk for the most part does not mean low technology; technological innovation is likely to change the way work is done in many of these jobs, but by enhancing rather than supplanting human labor.

Women are as likely as men to have at least a BA degree, and among those younger than 35, outnumber men with higher levels of education in each of the largest racial/ethnic groups (Hess et al. 2015; Ryan and Bauman 2016). Yet altogether, only a minority of all women, 30 percent in 2014, have at least a BA degree, and such high levels of educational attainment are much less common for Hispanic and Black women than for White and Asian women. Fewer than one in six Hispanic women and just slightly over one in four Black women have at least a BA degree, compared with a third of White and almost half of Asian women (Hess et al. 2015).

Women and Men Face Different Risks of Automation in their Largest Occupations

The differences in exposure for women and men are further demonstrated when the largest occupations for women and men are considered (Table 2a and 2b). While there is some overlap, many of the largest occupations for each gender are nontraditional for the other gender (that is, women are fewer than 25 percent of workers in many of the top male occupations, and men are fewer than 25 percent in the top female occupations). For both women and men, these common occupations range across the spectrum of low paid, moderately paid, and highly paid occupations (though it is notable, of course, that three of the top 20 male occupations have median annual earnings for men of $80,000

The large majority of low-risk occupations require at least a bachelor's degree.

per year or more, while none of the most common occupations for women have such high median annual earnings for women).

The largest 20 occupations for women employ more than four in ten women workers (but fewer than two in ten men). They include both some of the occupations at highest risk of automation—such as Secretaries and Administrative Assistants, Cashiers, and Receptionists and Information Clerks—as well as some of the lowest risk occupations, such as Elementary and Middle School Teachers and Registered Nurses. Across these occupations, more than 18 million jobs for women are at potential risk of automation, according to Frey and Osborne's risk probability analysis in 2013.

The top twenty occupations for men employ just more than a third of men, and a fifth of women. Nine of the twenty occupations are nontraditional for women. 17.4 million jobs are potentially at risk for men in these occupations (Table 2b). Many of these large occupations have a comparatively high risk of automation. The highest-risk large occupations for men are Retail Salespersons and Cashiers (both occupations that also employ a large number of women), and Grounds Maintenance Workers; the lowest risk occupations for men are very well paid: Software Developers and Chief Executives and Legislators, both with median annual earnings for full-time year-round work above $100,000.

As discussed in Chapter 1, focusing solely on the potential for technological substitution, as done by Frey and Osborne in their 2013 study, is likely to overestimate the actual impact on employment because it does not take into account the economic factors that shape the adoption of new technology, nor does it address factors related to demographic change; instead, it highlights which occupations may be most prone to technological change and, possibly, the need for retraining. BLS employment growth projections are shown for comparison for the largest occupations (Tables 2a and 2b and 3a, 3b, 3c, and 3d). Unlike the dramatic estimates of potential employment decline based on the Frey and Osborne analysis, BLS identifies only four among the largest 20 occupations for all women, and two among the largest 20 occupations for all men, that are likely to shrink in absolute terms between 2016 and 2026. The two most common occupations for men that are projected to decline are in lower paying occupations: Cashiers, with median annual earnings of $22,284 for men, and Miscellaneous Production Workers, with median annual earnings for men of $36,000, Table 2b). Yet, three of the four most common occupations for women with projected declines are better paying (relative to women's earnings distribution). Apart from Cashiers (with median annual earnings for women of $20,000), the other three occupations are Secretaries and Administrative Assistants ($36,000), Office Clerks ($32,919), and Bookkeeping, Accounting, and Auditing Clerks ($37,477, Table 2a).

Unlike men's large declining occupations, three of the four most common occupations for women with projected declines are in better paying occupations.

The 20 Largest Occupations for Women: Earnings and Different Measures of Potential Job Change

Occupation	Numbers Employed, 2014–2016	Median Annual Earnings (women)	Percent of Workers who are Women, 2014–2016	Probability of Automation (Frey and Osbourne)	Possible Number of At-Risk Jobs for Women	2016-2026 BLS Projected Change in Employment	BLS Projected Job Change 2016-2026	BLS Potential Job Change for Women
Secretaries and administrative assistants	3,249,809	$36,300	94.7%	0.92	2,838,882	(4.8%)	(192,200)	(182,058)
Elementary and middle school teachers	3,560,583	$49,000	79.0%	0.06	159,740	7.4%	152,300	120,294
Registered nurses	3,092,820	$62,799	89.4%	0.01	24,895	14.8%	438,100	391,820
Cashiers	3,096,980	$20,000	74.3%	0.97	2,228,638	(0.8%)	(30,000)	(22,277)
Nursing, psychiatric, and home health aides	2,054,357	$25,100	87.5%	0.40	711,752	24.0%	613,100	536,431
Customer service representatives	2,690,378	$31,600	65.2%	0.55	964,593	4.9%	136,300	88,851
Retail salespersons	3,440,490	$26,000	50.7%	0.92	1,605,337	1.7%	79,700	40,422
Miscellaneous managers, including funeral service managers and postmasters and mail superintendents	4,276,601	$65,971	35.2%	0.26	387,062	7.6%	78,400	27,604
Waiters and waitresses	2,132,958	$20,258	69.9%	0.94	1,400,765	7.0%	182,500	127,502
First-line supervisors of retail sales workers	3,079,223	$32,919	45.5%	0.28	392,204	3.8%	57,700	26,248
Maids and housekeeping cleaners	1,583,614	$20,258	88.0%	0.69	961,994	6.1%	87,900	77,386
Accountants and auditors	1,930,165	$55,709	61.5%	0.94	1,115,976	10.0%	139,900	86,050
Childcare workers	1,263,731	$20,299	93.7%	0.08	99,499	6.9%	84,300	79,016
Personal care aides	1,372,357	$21,314	83.3%	0.74	845,790	38.6%	777,600	647,620
Office clerks, general	1,314,410	$32,919	81.4%	0.96	1,027,080	(1.0%)	(31,800)	(25,884)
Bookkeeping, accounting, and auditing clerks	1,196,373	$37,477	87.1%	0.98	1,021,407	(1.5%)	(25,200)	(21,954)
Receptionists and information clerks	1,159,481	$27,500	89.8%	0.96	999,214	9.1%	95,500	85,729
Cooks	2,261,929	$19,284	40.8%	0.90	826,406	6.1%	145,900	59,504
Teacher assistants	1,021,733	$21,271	88.5%	0.56	506,285	8.4%	109,500	96,891

Occupation	Numbers Employed, 2014-2016	Median Annual Earnings (women)	Percent of Workers who are Women, 2014-2016	Probability of Automation (Frey and Osbourne)	Possible Number of At-Risk Jobs for Women	2016-2026 BLS Projected Change in Employment	BLS Projected Job Change 2016-2026	BLS Potential Job Change for Women
First-line supervisors of office and administrative support workers	1,351,711	$44,758	61.4%	0.01	11,615	3.4%	51,200	31,426
All in top 20 occupations	45,129,703				(18,129,134)		2,950,700	2,270,621

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Occupation	Numbers Employed, 2014-2016	Median Annual Earnings (men)	Percent of Workers who are Men, 2014-2016	Probability of Automation (Frey and Osbourne)	Possible Number of At-Risk Jobs for Men	2016-2026 BLS Projected Change in Employment	BLS Projected Job Change 2016-2026	BLS Potential Job Change for Men
Driver/sales workers and truck drivers	3,492,513	$41,500	94.0%	0.79	2,586,162	5.0%	163,600	153,728
Miscellaneous managers, including funeral service managers and postmasters and mail superintendents	4,276,601	$81,194	64.8%	0.26	712,262	7.6%	78,400	50,796
Laborers and freight, stock, and material movers, hand	2,205,168	$30,448	81.3%	0.85	1,524,493	7.6%	199,700	162,421
Construction laborers	1,760,288	$30,500	97.1%	0.88	1,504,356	12.4%	150,400	146,060
Retail salespersons	3,440,490	$38,000	49.3%	0.92	1,559,913	1.7%	79,700	39,278
Janitors and building cleaners	2,519,081	$30,000	67.1%	0.66	1,116,081	9.9%	236,500	158,760
First-line supervisors of retail sales workers	3,079,223	$45,200	54.5%	0.28	469,978	3.8%	57,700	31,452
Cooks	2,261,929	$22,000	59.2%	0.90	1,199,876	6.1%	145,900	86,396
Grounds maintenance workers	1,312,141	$25,000	94.0%	0.94	1,163,261	11.2%	144,600	135,944
Carpenters	1,197,550	$35,451	98.0%	0.72	844,991	8.2%	83,800	82,124
Stock clerks and order fillers	1,622,128	$27,403	65.2%	0.64	676,372	5.0%	100,900	65,737
Sales representatives, wholesale and manufacturing	1,389,593	$68,000	72.0%	0.74	736,516	5.2%	94,100	67,736
Software developers, applications and systems software	1,189,514	$101,290	80.2%	0.07	68,479	24.1%	302,400	242,563
Customer service representatives	2,690,378	$35,523	34.8%	0.55	515,115	4.9%	136,300	47,449
Chief executives and legislators	1,199,108	$131,941	75.1%	0.02	13,515	2.3%	8,200	6,161
Miscellaneous production workers, including semiconductor processors	1,237,060	$36,000	72.3%	0.87	773,850	(2.3%)	(1,200)	(868)

The 20 Largest Occupations for Men: Earnings and Different Measures of Potential Job Change

Occupation	Numbers Employed, 2014-2016	Median Annual Earnings (men)	Percent of Workers who are Men, 2014-2016	Probability of Automation (Frey and Osbourne)	Possible Number of At-Risk Jobs for Men	2016-2026 BLS Projected Change in Employment	BLS Projected Job Change 2016-2026	BLS Potential Job Change for Men
First-line supervisors of non-retail sales workers	1,209,091	$65,000	70.0%	0.08	63,455	4.9%	20,000	13,995
Automotive service technicians and mechanics	854,613	$35,523	98.5%	0.59	496,438	6.1%	45,900	45,191
Cashiers	3,096,980	$22,284	25.7%	0.97	772,598	(0.8%)	(30,000)	(7,723)
Security guards and gaming surveillance officers	991,904	$30,200	77.6%	0.84	647,644	6.3%	71,000	55,120
All in top 20 occupations	41,025,353				17,445,352		2,087,900	1,582,320

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Overall, Frey and Osborne's 2013 projections, when disaggregated for men and women for the first time here, yield estimates of potential job losses due to automation of 18.1 million for women in the 20 largest occupations for women, compared with job gains of 2.3 million when the BLS projections are disaggregated by gender. Similarly, for men, the gender disaggregation yields potential job losses due to automation of 17.4 million for Frey and Osborne's projections, compared with job gains of 1.6 million for the BLS projections (Lacey et al. 2017) in the 20 largest occupations for men.

The Risk of Automation in the Most Common Occupations Varies for Women of Different Racial and Ethnic Groups

Women in the labor force are not as segregated from one another on the basis of race and ethnicity as women are from men, but there are considerable differences in women's occupational distributions by race and ethnicity (Hegewisch and Hartmann 2014). Tables 3A-D provide data on the 10 largest (most common) occupations for White, Black, Hispanic, and Asian women. Some occupations, such as Secretaries and Administrative Assistants and Retail Salespersons, are among the top ten occupations for women in each racial or ethnic group. Others, such as Childcare Workers for Hispanic women, Licensed Practical and Vocational Nurses for Black women, and Software Developers, Application and System Software for Asian women and

Accountants and Auditors for Asian and White women, have a less integrated workforce.

These differences reflect unique labor market positions. While White women are the largest group of women in the labor force, Black women have historically and continue to have the highest level of labor force participation (60.3 percent compared with 56.4 percent for White and Asian women and 57 percent for Hispanic women in 2018; US Bureau of Labor Statistics 2018f). Despite having high labor force participation rates, Black and Hispanic women are over-represented in low-wage service jobs as shown in Table 3A-D below. While there are a number of factors that produce the occupational distributions of women by race and ethnicity, it reflects in part that Black and Hispanic women have a lower likelihood of having postsecondary degrees compared with White and Asian women (DuMonthier, Childers, and Milli 2017).

These different occupational concentrations imply different risks and opportunities from technological change. Hispanic women face the largest risk of job automation according to Frey and Osborne's 2013 assessment of risk, with 73 percent of jobs in their ten most common occupations at risk of technological substitution (IWPR calculation based on Table 3C). The occupation that has the highest median annual earnings among the most common occupations for Hispanic women, Secretaries and Administrative Assistants ($33,700), has a very high risk of technological replacement, and is the occupation projected to have the largest absolute decline in employment by the BLS, as discussed above. The occupations with the lowest risk of replacement for Hispanic women, Childcare Workers and Nursing, Psychiatric, and Home Health Aides, have very low earnings ($19,893 and $24,309, Table 3c).

Asian women also face a comparatively high risk in their top 10 occupations, of 60 percent; but their jobs include a greater mix of high- and low-risk occupations, including well-paid/low-risk/high-growth occupations such as Registered Nurses ($80,000) and Software Developers, Applications and Systems Software ($91,344; Table 3d). The corresponding risk White and Black women face is lower at 53 and 54 percent respectively. One factor explaining their lower risk compared to Asian women is that White and Black women are more likely to work in education as Elementary and Middle School Teachers (Tables 3 a, b).

Different occupational concentrations among women by race and ethnicity imply different risks and opportunities from technological change.

TABLE 3A — The 10 Largest Occupations for White Women: Earnings and Different Measures of Potential Job Change

Occupation	Number of White Women Employed 2014–2016	Median Annual Earnings (White Women)	Percent of All Workers who are White Women, 2014–2016	Probability of Automation (Frey and Osbourne)	Possible Number of At-Risk Jobs for White Women	2016–2026 BLS Projected Change in Employment	BLS Projected Job Growth 2016–2026	BLS Potential Job Change for White Women
Secretaris and administrative assistants	2,288,193	$36,464	70.4%	0.92	2,110,212	(4.8%)	(192,200)	(135,309)
Elementary and middle school teachers	2,195,100	$49,328	61.7%	0.06	124,681	7.4%	152,300	93,969
Registered nurses	1,998,622	$60,896	64.6%	0.01	17,988	14.8%	438,100	283,013
Cashiers	1,158,590	$20,258	37.4%	0.97	1,122,772	(0.8%)	(30,000)	(11,220)
Miscellaneous managers, including funeral service managers and postmasters and mail superintendents	1,079,885	$67,864	25.3%	0.26	277,590	7.6%	78,400	19,835
Retail salespersons	1,073,789	$28,361	31.2%	0.92	987,886	1.7%	79,700	24,866
Customer service representatives	1,005,725	$33,493	37.4%	0.55	553,149	4.9%	136,300	50,976
Waiters and waitresses	973,977	$20,299	45.7%	0.94	915,538	7.0%	182,500	83,403
First-line supervisors of retail sales workers	969,846	$33,493	31.5%	0.28	271,557	3.8%	57,700	18,176
Accountants and auditors	808,138	$56,000	41.9%	0.94	759,650	10.0%	139,900	58,618
All in top 10 occupations	13,551,865				7,141,023		1,042,700	486,327

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week. Whites are non-Hispanic.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

TABLE 3B The 10 Largest Occupations for Black Women: Earnings and Different Measures of Potential Job Change

Occupation	Number of Black Women Employed 2014-2016	Median Annual Earnings (Black Women)	Percent of All Workers who are Black Women, 2014-2016	Probability of Automation (Frey and Osbourne)	Possible Number of At-Risk jobs for Black Women	2016-2026 BLS Projected Change in Employment	BLS Projected Job Growth 2016-2026	BLS Potential Job Change for Black Women
Nursing, psychiatric, and home health aides	623,668	$25,322	30.4%	0.40	246,958	24.0%	613,100	186,382
Cashiers	428,296	$19,200	13.8%	0.97	415,055	(0.8%)	(30,000)	(4,140)
Customer service representatives	320,946	$30,000	11.9%	0.55	176,520	4.9%	136,300	16,220
Registered nurses	305,467	$60,896	9.9%	0.01	2,749	14.8%	438,100	43,372
Secretaries and administrative assistants	260,716	$36,000	8.0%	0.92	240,437	(4.8%)	(192,200)	(15,376)
Personal care aides	257,119	$21,314	18.7%	0.74	190,268	38.6%	777,600	145,411
Elementary and middle school teachers	238,220	$47,702	6.7%	0.06	13,531	7.4%	152,300	10,204
Retail salespersons	217,261	$24,100	6.3%	0.92	199,880	1.7%	79,700	5,021
Maids and housekeeping cleaners	199,155	$20,258	12.6%	0.69	137,417	6.1%	87,900	11,075
Licensed practical and licensed vocational nurses	187,504	$38,000	22.1%	0.06	10,875	12.3%	88,900	19,647
All in top 10 occupations	3,038,352				1,633,691		2,151,700	417,817

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week. Blacks are non-Hispanic.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

The 10 Largest Occupations for Hispanic Women: Earnings and Different Measures of Potential Job Change

Occupation	Number of Hispanic Women Employed 2014-2016	Median Annual Earnings (Hispanic Women)	Percent of All Workers who are Hispanic Women, 2014-2016	Probability of Automation (Frey and Osbourne)	Possible number of At-Risk Jobs for Hispanic Women	2016-2026 BLS Projected Change in Employment	BLS Projected Job Growth 2016-2026	BLS Potential Job Change for Hispanic Women
Maids and housekeeping cleaners	662,326	$19,284	41.8%	0.69	457,005	6.1%	87,900	36,742
Cashiers	501,201	$18,472	16.2%	0.97	485,706	(0.8%)	(30,000)	(4,860)
Secretaries and administrative assistants	373,178	$33,700	11.5%	0.92	344,151	(4.8%)	(192,200)	(22,103)
Retail salespersons	308,224	$23,094	9.0%	0.92	283,566	1.7%	79,700	7,173
Customer service representatives	306,622	$29,000	11.4%	0.55	168,642	4.9%	136,300	15,538
Janitors and building cleaners	301,928	$20,800	12.0%	0.66	199,272	9.9%	236,500	28,380
Cooks	275,136	$18,200	12.2%	0.90	246,472	6.1%	145,900	17,800
Nursing, psychiatric, and home health aides	271,802	$24,309	13.2%	0.40	107,627	24.0%	613,100	80,929
Waiters and waitresses	263,736	$19,284	12.4%	0.94	247,912	7.0%	182,500	22,630
Childcare workers	255,713	$19,893	20.2%	0.08	21,480	6.9%	84,300	17,029
All in top 10 occupations	3,519,866				2,561,835		1,344,000	199,258

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week. Hispanics may be of any race.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

| **TABLE 3D** | **The 10 Largest Occupations for Asian Women: Earnings and Different Measures of Potential Job Change** | | | | | | | |

Occupation	Number of Asian/ Pacific Islander Women Employed 2014-2016	Median Annual Earnings	Percent of All Workers in Occupation who are Asian/ Pacific Islander Women	Probability of Automation (Frey and Osbourne)	Possible Number of Jobs At-Risk for Asian/Pacific Islander Women	2016-2026 BLS Projected Change in Employment	BLS Projected Job Growth 2016-2026	BLS Potential Job Change for Asian/Pacific Islander Women
Registered nurses	235,248	$80,000	7.6%	0.01	2,117	14.8%	438,100	33,323
Miscellaneous personal appearance workers	154,036	$20,299	46.2%	0.72	111,458	13.4%	28,600	13,205
Accountants and auditors	142,320	$60,774	7.4%	0.94	133,781	10.0%	139,900	10,315
Cashiers	138,211	$21,879	4.5%	0.97	133,938	(0.8%)	(30,000)	(1,339)
Miscellaneous managers, including funeral service managers and postmasters and mail superintendents	104,594	$81,032	2.4%	0.26	26,886	7.6%	78,400	1,917
Retail salespersons	96,557	$26,335	2.8%	0.92	88,832	1.7%	79,700	2,237
Software developers, applications and systems software	93,066	$91,344	7.8%	0.07	6,679	24.1%	302,400	23,659
Secretaries and administrative assistants	90,761	$41,000	2.8%	0.92	83,701	(4.8%)	(192,100)	(5,365)
Waiters and waitresses	88,886	$21,271	4.2%	0.94	83,553	7.0%	182,500	7,605
Personal care aides	88,468	$22,800	6.4%	0.74	65,466	38.6%	777,600	50,127
All in top 10 occupations	1,232,147				736,413		1,805,100	135,686

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week. Asians include Pacific Islanders, and are non-Hispanic.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Automation is More Likely to Affect Women's Better Paid Occupations than Men's

As discussed above, Frey and Osborne (2013) find an inverse relationship between the risk of automation and earnings, with the risk particularly high for workers in low-wage occupations. When plotting earnings against the risk of automation separately for women's and men's largest occupations (Figures 2A and 2B), such a relationship between risk and low wages is found only in men's top 20 occupations.[6] There is no such systematic relationship between earnings and the risk of automation in women's top 20 occupations.

In other words, the occupations most at risk of automation for men are also the occupations with the lowest earnings. For women, such risk is more equally spread across better- and low-paid occupations. Thus, women potentially face a higher economic risk from automation because technological change is more likely to replace middle and well-paid jobs in their top 20 than it is for men.

This finding is not limited to the most common occupations. Across all occupations, the analysis of the correlation between earnings and automation risk finds that even though both women and men face a much higher risk of automation in lower wage occupations, the reduction in the risk of automation in higher earning jobs is almost twice as strong for men as it is for women.[7]

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6   The relationship is statistically significant for men, at the 0.5 level.

7   The authors ran simple linear models regressing annual wages on the probability of automation scores developed by Frey and Osborne (2013) for women and men employed full-time, year-round separately. Results showed that in 2016 a one percentage point increase in the probability of automation for men was associated with a $631 decline in men's median annual wages while a one percentage increase in the probability of automation for women was associated with a $316 decline in median annual wages (see Methodological Appendix).

Men's Jobs with the Highest Risk of Automation are Concentrated in Low-Paid Occupations

The Relationship between Earnings and the Probability of Automation among the 20 Most Common Occupations for Men, 2014-2016
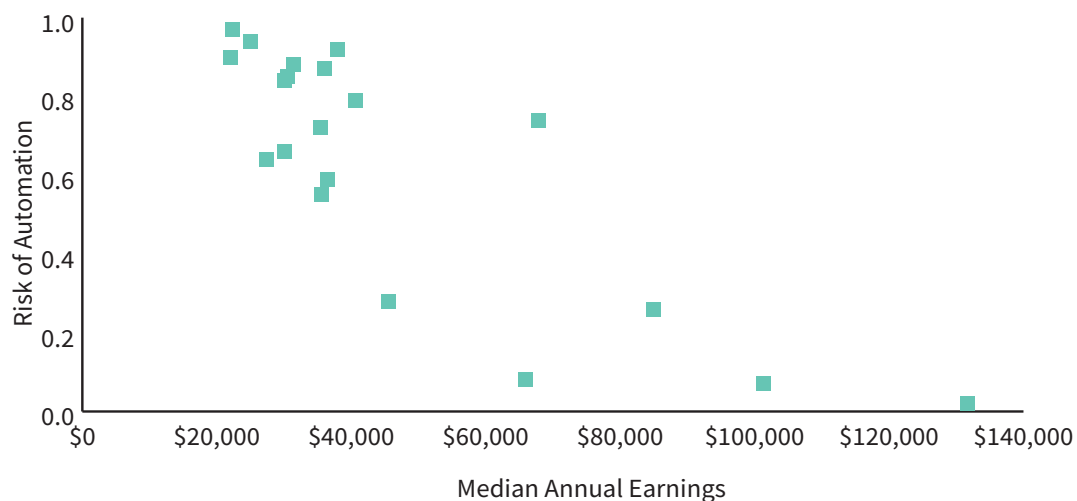
Notes: Median annual full-time year-round earnings for men in the largest 20 occupations for all men workers.

Sources: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Women's Jobs with High Risk of Automation include Higher Paying Jobs

The Relationship between Earnings and the Probability of Automation among the 20 Most Common Occupations for Women, 2014-2016
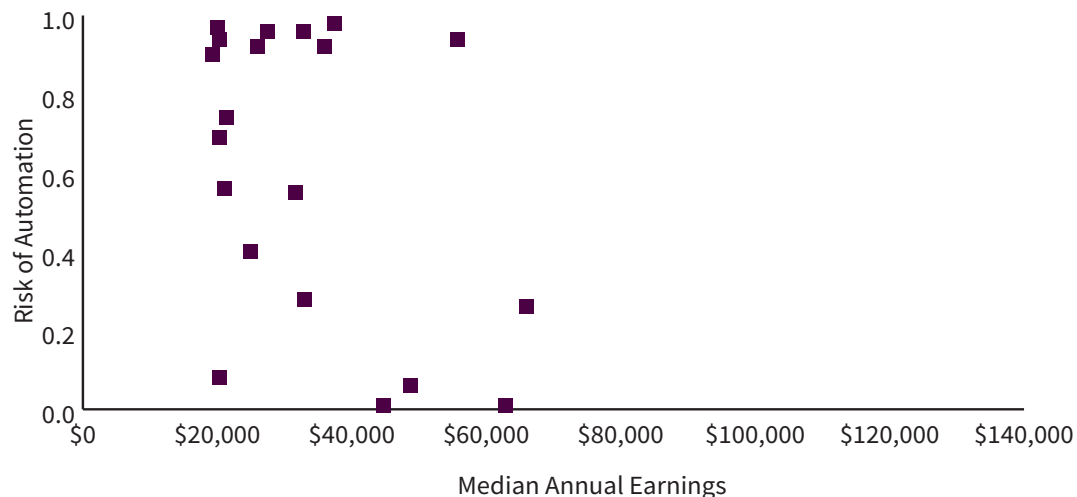
Notes: Median annual full-time year-round earnings for women in the largest 20 occupations for all women workers.

Sources: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

How Women's Jobs Are Being Affected by Technological Change: Two Examples

To provide additional insight on how technological change is affecting women's jobs, two large occupational fields are chosen for further analysis. One, Office and Administrative work, which employs 13.6 million women, is disproportionately done by women, includes many sub-occupations with a high risk of automation, and is experiencing slow growth overall and negative growth in several sub-occupations. The other, retail work, which employs 8.3 million women, is a gender-integrated occupation that faces an uncertain future, reflected in slower growth overall, and, like office work, includes several occupations that are projected to decline even in the BLS projections.

Office and Administrative Occupations: Declining Middle-Skilled Jobs

One in five women in the United States, but just over one in twenty men, work in the almost fifty office and administrative occupations listed by BLS. Several of the largest occupations for women, such as Secretaries and Administrative Assistants, Customer Service Representatives, General Office Clerks, Bookkeeping, Accounting, and Auditing Clerks, and Receptionists are office occupations, and with few exceptions—such as Shipping, Receiving, and Traffic Clerks, which are only 30 percent women — the large majority of workers in these occupations are women (Table 4).

Women may face a higher economic risk from automation than men because technological change is more likely to replace women's middle and well-paid jobs.

Common to many of these jobs is a comparatively high risk of technical substitution, and more so for women than for men. Almost two-thirds of women in office and administrative work, compared with only 38 percent of men in these occupations, work in occupations with a 90 percent or higher probability of technological replacement according to the Frey and Osborne 2013 study (authors' calculations based on the IWPR Future of Work Database). Manyika et al. (2017b) of the McKinsey Institute estimate that 64 percent of tasks in office and administrative work can be automated. While employment projections from the BLS are less dramatic (Lacey et al. 2017), they also find that many of these occupations are shrinking or declining relative to other occupations (Table 4). Employment in occupations such as Secretaries and Administrative Assistants, Bookkeeping and Accounting Clerks, Postal Service Mail Workers, and Data Entry Keyers are expected to decline in absolute terms. In 24 of the 46 Office and Administrative occupations shown in Table 4, a total of 511,703 jobs are expected to be lost by 2026, 407,194 for women and 104,509 for men.[8] Across all office occupations, therefore, the BLS expects a small growth of about one percent, far below the expected growth in overall employment, of seven percent.

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8   Men are the majority of workers among Stock Clerk and Order Fillers, Postal Service Mail Carriers, Shipping, Receiving, and Traffic Clerks, Weighers, Measurers, Checkers, and Samplers, Recordkeeping, Couriers and Messengers, and Computer Operators.

For many of the office and administrative occupations where the BLS projects a decline in employment, job loss has already been in evidence, and typically has been more pronounced between 2000 and 2016 than in projections to 2026. In 2016, for example, there were 29.5 percent fewer Bookkeeping, Accounting, and Auditing Clerks than in 2000, a decline of half a million jobs; 13 percent fewer Secretaries and Administrative Assistants, a decline of 460,000 jobs; and 20 percent fewer First-line Supervisors of Office and Administrative Support Workers, a decline of 330,000 jobs (Table 4). Moreover, declines in the data were observed in 192 of the 440occupations in the IWPR Future of Work Database, almost half (44 percent).

The expansion of Clerical and Administrative work in the first half of the 20th century played a major role in opening modern workspaces to women. The typewriter, bookkeeping machines, and the shift toward more standardized work organization made clerical work more routinized and expanded the demand for clerical workers as the scale of business grew in modern organizations which required recordkeeping and communication. Indeed, technological changes in the office undoubtedly helped to expand the scale of organizations since they contributed to making communication and recordkeeping cheaper and faster. Some argue that the introduction of technology and routinization made previously male clerical jobs into occupations that were, and are, perceived as quintessentially women's work with lower upward mobility (Strom 1992). It continues to be an important sector for women, employing 17.3 million people in 2016.

The death of office work has been foretold several times. Contrary to common expectations of the impact of word processors and computers, employment in office and administrative jobs recovered after the recessions of the 1980s and continued to grow through the 1990s, although at a slower pace than the workforce overall (Wyatt and Hecker 2006). Yet employment levels have fallen strongly in several of these occupations in both absolute and relative terms since the early 2000s, with the decline starting well before 2007, the beginning of the Great Recession. Technological changes led to the reduction in employment in these jobs in the United States, both directly—through automation of tasks previously done by humans—and by making it possible to outsource these tasks to countries where labor is cheaper while restructuring of work practices reduced levels of supervision (Acemoglu and Autor 2011).

Technological and sectoral restructuring of office work has led to a shift from better to less well-paid office and clerical occupations, a trend that is projected to continue. Many office and administrative jobs are middle skilled jobs, typically not requiring a four-year college degree; while the median annual earnings are not high—in 2016 they were $34,300 for women working full-time, year-round (IWPR calculation), they are substantially above earnings in other middle skilled female-dominated occupations (Hegewisch et al 2016). Earnings

TABLE 4 Office Occupations and Women's Employment 2000-2026: Different Measures of Potential Job Change

Office and Administrative Occupations	All Workers, 2000		All Workers, 2014-2016		Employment Change 2000 to 2014-2016		BLS Projected Employment Change, 2016-2026				Frey and Osborne Projected Automation Impact		
	Number	Percent Women	Number	Percent Women	Number	Percent	Number	Percent	Men	Women	Automation Probability	Men	Women
Secretaries and administrative assistants	3,716,388	96.5%	3,249,809	94.7%	(466,579)	(12.5%)	(192,200)	(4.8%)	(10,142)	(182,058)	0.92	(158,149)	(2,838,882)
Customer service representatives	1,946,077	70.4%	2,690,378	65.2%	744,301	38.2%	136,300	4.9%	47,449	88,851	0.55	(515,115)	(964,593)
Stock clerks and order fillers	1,140,882	36.9%	1,622,128	34.8%	481,246	42.2%	100,900	5.0%	65,737	35,163	0.64	(676,372)	(361,790)
First-line supervisors of office and administrative support workers	1,681,172	67.4%	1,351,711	61.4%	(329,461)	(19.6%)	51,200	3.4%	19,774	31,426	0.01	(7,309)	(11,615)
Office clerks, general	1,397,455	84.1%	1,314,410	81.4%	(83,045)	(5.9%)	(31,800)	(1.0%)	(5,916)	(25,884)	0.96	(234,754)	(1,027,080)
Bookkeeping, accounting, and auditing clerks	1,695,886	89.6%	1,196,373	87.1%	(499,513)	(29.5%)	(25,200)	(1.5%)	(3,246)	(21,954)	0.98	(151,039)	(1,021,407)
Receptionists and information clerks	1,051,088	93.1%	1,159,481	89.8%	108,393	10.3%	95,500	9.1%	9,771	85,729	0.96	(113,888)	(999,214)
Miscellaneous office and administrative support workers, including desktop publishers	N/A	N/A	618,825	76.2%	618,825	N/A	(2,000)	(14%)	(477)	(1,523)	0.16	(23,607)	(75,405)
Shipping, receiving, and traffic clerks	628,158	29.8%	609,930	30.3%	(18,228)	(2.9%)	100	0.0%	70	30	0.98	(416,906)	(180,826)
Billing and posting clerks	377,039	88.5%	490,744	88.7%	113,705	30.2%	70,700	14.1%	8,012	62,688	0.96	(53,388)	(417,727)
Insurance claims and policy processing clerks	214,083	86.1%	381,110	80.7%	167,027	78.0%	34,100	11.1%	6,572	27,528	0.98	(71,978)	(301,510)
Data entry keyers	579,596	82.6%	345,316	76.1%	(234,280)	(4.0%)	(43,300)	(21.2%)	(10,359)	(32,941)	0.99	(81,787)	(260,076)
Tellers	399,173	50.5%	344,384	84.1%	(54,789)	(13.7%)	(41,800)	(8.3%)	(6,659)	(35,141)	0.98	(53,766)	(283,731)
Production, planning, and expediting clerks	333,488	52.7%	329,921	58.3%	(3,567)	(1.1%)	18,000	5.5%	7,513	10,487	0.88	(121,177)	(169,154)
Postal service mail carriers	351,954	33.4%	318,736	39.9%	(33,218)	(9.4%)	(38,200)	(12.1%)	22,943	(15,257)	0.68	(130,172)	(86,568)
Word processors and typists	176,674	93.2%	309,597	85.4%	132,923	75.2%	(24,800)	(33.1%)	(3,611)	(21,189)	0.81	(36,514)	(214,260)
Dispatchers	250,698	52.8%	287,552	55.6%	36,854	14.7%	8,000	2.7%	3,553	4,447	0.81	(102,889)	(128,786)
File clerks	303,117	80.1%	249,886	76.2%	(53,231)	(17.6%)	(14,000)	(10.4%)	(3,326)	(10,674)	0.97	(57,591)	(184,799)
Couriers and messengers	189,554	21.0%	218,292	16.2%	28,738	15.2%	10,900	11.5%	9,134	1,766	0.94	(171,950)	(33,245)
Bill and account collectors	210,534	71.1%	164,295	70.1%	(46,239)	(22.0%)	(9,100)	(3%)	(2,721)	(6,379)	0.95	(46,674)	(109,407)
Payroll and timekeeping clerks	208,491	88.9%	162,225	87.5%	(46,266)	(22.2%)	(1,600)	(0.9%)	(200)	(1,400)	0.97	(19,627)	(137,731)

TABLE 4 Office Occupations and Women's Employment 2000-2026: Different Measures of Potential Job Change (Continued)

Office and Administrative Occupations	All Workers, 2000		All Workers, 2014-2016		Employment Change 2000 to 2014-2016		BLS Projected Employment Change, 2016-2026				Frey and Osborne Projected Automation Impact		
	Number	Percent Women	Number	Percent Women	Number	Percent	Number	Percent	Men	Women	Automation Probability	Men	Women
Interviewers, except eligibility and loan	199,931	72.4%	135,519	80.6%	(64,412)	(32.2%)	11,000	5.7%	2,136	8,864	0.94	(24,737)	(102,651)
Correspondence clerks and order clerks	172,197	64.8%	135,235	58.4%	(36,962)	(21.5%)	(3,500)	(1.9%)	(1,456)	(2,044)	0.98	(54,888)	(77,014)
Reservation and transportation ticket agents and travel clerks	186,441	65.9%	130,253	59.6%	(56,188)	(30.1%)	5,600	3.8%	2,264	3,336	0.61	(32,122)	(47,332)
Loan interviewers and clerks	112,562	84.9%	120,993	78.8%	8,431	7.5%	28,400	12.3%	6,017	22,383	0.92	(23,583)	(87,730)
Postal service clerks	163,064	53.4%	110,721	54.7%	(52,343)	(32.1%)	(9,500)	(12.1%)	(4,300)	(5,200)	0.95	(47,609)	(57,576)
Library assistants, clerical	146,717	82.9%	104,175	81.9%	(42,542)	(29.0%)	9,800	9.4%	1,771	8,029	0.95	(17,889)	(81,078)
Computer operators	263,103	52.1%	92,685	46.3%	(170,418)	(64.8%)	(11,800)	(22.8%)	(6,339)	(5,461)	0.78	(38,839)	(33,456)
Mail clerks and mail machine operators, except postal service	156,075	53.1%	80,452	53.0%	(75,623)	(48.5%)	(7,100)	(7.4%)	(3,340)	(3,760)	0.94	(35,578)	(40,047)
Weighers, measurers, checkers, and samplers, recordkeeping	74,952	45.5%	78,962	47.2%	4,010	5.4%	1,400	1.8%	739	661	0.95	(39,602)	(35,412)
Eligibility interviewers, government programs	61,602	81.4%	77,599	80.1%	15,997	26.0%	8,500	6.0%	1,688	6,812	0.70	(10,786)	(43,534)
Court, municipal, and license clerks	74,454	78.6%	72,627	78.0%	(1,827)	(2.5%)	8,800	6.5%	1,935	6,865	0.46	(7,344)	(26,064)
Postal service mail sorters, processors, and processing machine operators	124,262	49.7%	65,163	50.7%	(59,099)	(47.6%)	(17,500)	(16.5%)	(8,624)	(8,876)	0.79	(25,368)	(26,110)
Human resources assistants, except payroll and timekeeping	59,915	75.1%	56,242	81.3%	(3,673)	(6.1%)	(2,600)	(1.8%)	(485)	(2,115)	0.90	(9,441)	(41,177)
Credit authorizers, checkers, and clerks	51,634	77.8%	42,446	72.6%	(9,188)	(17.8%)	(1,100)	(2.8%)	(302)	(798)	0.97	(11,296)	(29,877)
Office machine operators, except computer	60,264	61.0%	39,389	62.5%	(20,875)	(34.6%)	(9,400)	(15.6%)	(3,522)	(5,878)	0.92	(13,577)	(22,661)
Telephone operators	77,800	81.0%	37,963	76.0%	(39,837)	(51.2%)	(2,000)	(22.6%)	(480)	(1,520)	0.97	(8,840)	(27,985)
Procurement clerks	38,933	63.5%	30,793	57.0%	(8,140)	(20.9%)	(3,200)	(4.3%)	(1,375)	(1,825)	0.98	(12,964)	(17,213)
Switchboard operators, including answering service	75,588	88.6%	28,562	82.8%	(47,026)	(62.2%)	(18,500)	(19.9%)	(3,190)	(15,310)	0.96	(4,728)	(22,692)
Meter readers, utilities	41,787	17.2%	27,627	15.2%	(14,160)	(33.9%)	(1,500)	(4.4%)	(1,272)	(228)	0.85	(19,915)	(3,568)
Cargo and freight agents	21,430	24.1%	22,253	32.5%	823	3.8%	9,300	10.4%	6,276	3,024	0.99	(14,867)	(7,164)

Office and Administrative Occupations	All Workers, 2000		All Workers, 2014-2016		Employment Change 2000 to 2014-2016		BLS Projected Employment Change, 2016-2026				Frey and Osborne Projected Automation Impact		
	Number	Percent Women	Number	Percent Women	Number	Percent	Number	Percent	Men	Women	Automation Probability	Men	Women
Statistical assistants	31,638	68.5%	17,954	60.5%	(13,684)	(43.3%)	1,100	9.2%	435	665	0.66	(4,681)	(7,169)
New accounts clerks	15,389	83.8%	14,397	72.8%	(992)	(6.4%)	(2,600)	(6.2%)	(708)	(1,892)	0.99	(3,880)	(10,373)
Proofreaders and copy markers	21,836	74.6%	11,769	70.5%	(10,067)	(46.1%)	200	1.7%	59	141	0.84	(2,914)	(6,972)
Gaming cage workers	7,893	72.2%	8,759	68.9%	866	11.0%	300	1.4%	93	207	0.39	(1,061)	(2,355)
Brokerage clerks	9,931	62.8%	7,067	68.8%	(2,864)	(28.8%)	3,000	5.0%	935	2,065	0.98	(2,159)	(4,767)
Totals	19,100,905		18,964,708		(136,197)	(0.7%)	98,800	0.5%	96,939	1,861		(3,713,317)	(10,669,778)

Notes: Numbers employed are for all workers; earnings are for workers who work at least 50 weeks per year, for at least 35 hours per week.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

in the three occupations with the largest job losses since 2000 were above that median: Secretaries and Administrative Assistants had median annual earnings for women of $36,300; Bookkeeping, Accounting, and Auditing Clerks of $37,477, and First-line Supervisors of Office and Administrative Support Workers $44,758. The occupations with the highest expected employment growth according to the BLS, Customer Service Representatives and Receptionists and Information Clerks, both occupations with comparatively high levels of growth since 2000, have earnings for women below that median (of $31,600 and $27,500 respectively; Tables 2A and 4). As shown below (Table 10 in Chapter 4), Secretaries and Administrative Assistants, Customer Service Representatives, Office Clerks, and Receptionists and Information Clerks all saw a decline in real earnings between 2000 and 2014-16 in spite of a growing share of workers with at least a bachelor's degree.

It remains to be seen how far the current wave of technological transformation will continue to change work and prospects in these occupations. Yet, both past and projected declines in these occupations threaten jobs which often have provided basic pathways for women into the middle class (King 1993).

Retail Occupations: Few Signs of Employment Decline but Increasing Precarity

One in eleven U.S. workers work in retail jobs, close to 13 million workers in 2014-16. Occupations in the retail sector include Retail Salespersons, Cashiers, and Stock Clerks and Order Fillers, but also Advertising Agents, Telemarketers, and Models and Product Promoters. Retail is a typical first job for many people. While retail occupations employ many women, they also employ many men; women make up 52 percent of workers (IWPR Future of Work Database). This parity in numbers conceals substantial job segregation, however. Women are much more likely than men to work as Cashiers; men are more likely to work as Stock Clerks and Order Fillers, and Parts Salespersons. And women and men tend to work in different parts of the industry. Women are more likely to work in clothing and cosmetic sales; men are more likely to sell cars, computers, or DYI goods. Working in different segments of the retail sector explains partly why men's median annual earnings for full-time work as a Retail Salesperson are so much higher than women's ($38,000 compared with $26,000; Tables 2a and b); it also means that their job prospects may be affected differently as different segments of the retail sector are affected differently by technological change and changes in consumer preferences.

The majority of occupations in retail have a high risk of technological substitution, according to Frey and Osborne (2013). The two largest retail occupations, Retail Salespersons and Cashiers, and seven smaller retail occupations, have an automation risk higher than 90 percent, according to their study. Potentially, according to this assessment, technology could replace 5.1 million jobs now held by women and 4.2 million jobs now held by men (Table 5). The third largest occupation, First-Line Supervisors of Retail Sales Workers, has a very low risk of technological substitution according to Frey and Osborne (although of course the demand for supervisors will decline if the number of workers to supervise declines).

The retail industry has been the subject of major changes in the past few years, reflecting technological innovation and other factors. Retail productivity nearly doubled from 1987 to 2015 (Mandel 2017). The growth of e-commerce has contributed to a decline in department stores, by 25 percent between 2002 to 2016 (Gebeloff and Russell 2017); and according to Deloitte between 2015 and 2018, the share of in-store spending dropped from 46 to 36 percent of all purchases (Deloitte 2018).

Industry studies also put the retail sector at high risk of automation. The World Economic Forum (2017) identifies eight new technologies that are already at least partially employed in the sector — Internet of Things, Autonomous Vehicles and Drones, AI, Robotics, Digital Traceability, 3D Printing, VR, and Blockchain. These technologies are reducing the need for labor; for instance,

Women and men tend to work in different parts of the retail sector which partly explains why men's median annual earnings for full-time work as a retail salesperson are much higher than women's: $38,000 compared with $26,000.

the Internet of Things allows for automated ordering, autonomous vehicles/drones are starting to be employed in warehouses, AI allows for product customization and also for the greater automation of invoicing and ordering processes (World Economic Forum 2017). Thirty to fifty percent of retail jobs may be at risk (Shavel, Vanderzeil, and Curier, 2017). According to Bain Consulting (Harris et al. 2018), productivity gains from automation in the retail sector between 2015 and 2030 could be as high as 49 percent (depending on the pace of implementation). The same report states "The migration to e-commerce is just automating retail services—replacing an entire suite of human functions from the floor salesperson or cashier with a web-based storefront and a payments-processing app."

Amazon is reportedly considering the opening of 3000 cashless stores by 2021 and opened its first cashless store in Seattle in September 2018 where the costs of purchases are automatically deducted from shoppers' accounts as they leave the store (*Supermarket News* 2018). As a recent analysis of trends in the grocery store sector by McKinsey & Company puts it, Amazon is "asking the right question" because instead of focusing on replacing Cashiers with cashless checkout terminals (still requiring labor, and irritating customers), it is trying to do away completely with the checkout process (Toriello 2017). Cashiers account for approximately 30 percent of labor in the sector, according to McKinsey. Cashiers do not only take money, they also are part of theft control in stores. A *New York Times* investigation highlights emerging approaches to theft control that go beyond the electronic reading of price labels and automatic deduction from customers' accounts by focusing on electronic surveillance and analysis of body language to control theft (*New York Times* 2018). While the function of the cashier would be replaced in this approach, it would require a new function of theft control, responding to electronically generated warnings of suspicious behavior from customers.

Yet, even though the growth of e-commerce has been very rapid, its share of overall employment in the retail sector remains at less than four percent (authors' calculations based on U.S. Bureau of Labor Statistics 2018h). And whatever the technological potential, so far there are few signs that retail employment is falling, except for declines in the Great Recession (Figure 3).

Even though the growth of e-commerce has been very rapid, its share of overall employment in the retail sector remains at less than four percent.

FIGURE
3
Data Do Not Indicate that Retail Employment is Falling

Trends in Retail Sector Employment 2000 to 2018 (in thousands)

Notes: Median annual full-time year-round earnings for women in the largest 20 occupations for all women workers.
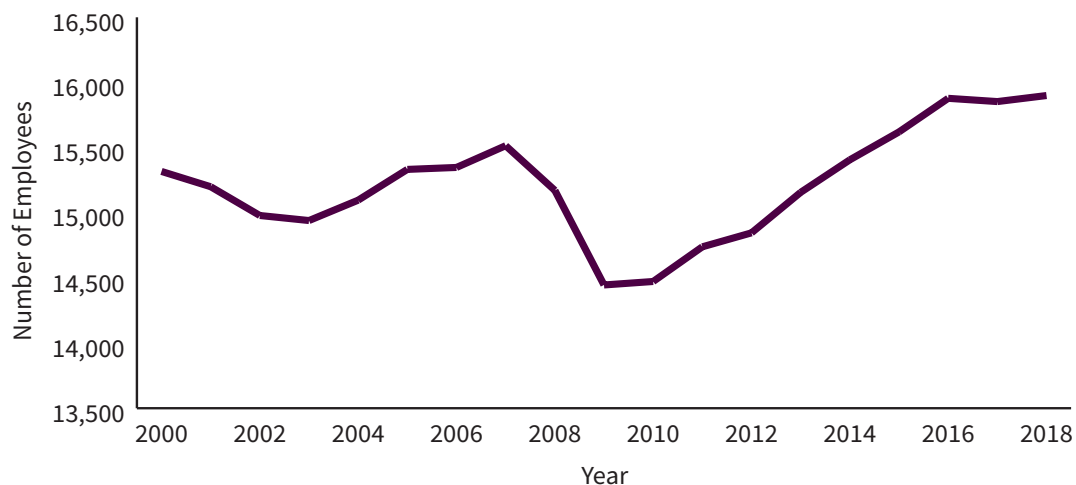
Notes: Data are for September of each year.

Source: IWPR compilation based on BLS Current Employment Statistics survey Employment, Hours, and Earnings from the series CES4200000001.

While there has been a decline in employment between 2000 and 2014-16 in several of the smaller retail occupations which Frey and Osborne's study (2013) puts at high risk of automation, the four largest occupations—Retail Salespersons, Cashiers, and First-line Supervisors of Retail Sales Workers, and Stock Clerks and Order Fillers—experienced substantial growth over the period (Table 5).

The growth in retail employment overall, however, masks a trend towards part-time work (IWPR Future of Work Database, not shown elsewhere). Full-time work for Cashiers declined from 54 to 39 percent for women Cashiers, from 64 to 56 percent for women Retail Salespersons; and from 73 to 64 percent for women Stock Clerks and Order Fillers. Full-time work for male Cashiers is even lower, at 43 percent in 2016, but male Retail Salespersons are much more likely to work full-time than women, even though full-time employment fell among men too (from 78 to 69 percent of workers; IWPR Future of Work Database, data not shown elsewhere). Many workers, moreover, have fluctuating and unpredictable schedules, making it difficult to plan their lives (see Chapter 4 for a more detailed discussion).

Looking ahead, the BLS projects substantial overall growth in employment in retail occupations between 2016 and 2026, even if at a much slower pace than overall projected workforce growth (Table 5). The occupation that is projected

to add the most jobs is Stock Clerk and Order Fillers; BLS projects a decline (although by less than 1 percent of current levels) in the number of Cashiers and several smaller occupations for a loss of 38,404 jobs. Overall BLS expects retail to remain a substantial sector of employment through at least 2026.

In the coming years, as new technologies are introduced in retail, overcoming gender differences will remain a challenge. As discussed above, the retail sector includes many different occupations, with differing opportunities for good earnings and jobs. Full-time year-round earnings for Retail Sales Workers range from $20,000 or less for workers in the bottom 20 percent of the earnings distribution to $60,000 or more for the top 20 percent (IWPR Future of Work Database, data not shown elsewhere). Gender earnings differentials are very substantial for this occupation, and progress towards narrowing them has been slow (in 2000, the gender earnings ratio was 63 percent, compared with 68 percent for 2014-16). Additionally, women are much less likely than men to work full-time year-round, with little change between 2000 and 2014-16; IWPR Future of Work Database, data not shown elsewhere). As workers will need new skills and training to work with new technologies and become more digitally competent, there should also be scope for ensuring that women's share of more responsible positions, from first-line supervisor to higher levels of management, more closely reflects women's share of the workforce. There are some signs of progress. Women's share of First Line Supervisors of Retail Sales Workers, for example, increased from 41.5 to 45.5 percent between 2000 and 2014-16 (Table 5).

In the coming years, as new technologies are introduced in retail, overcoming gender differences will remain a challenge.

Technology is already changing the way work is done in retail, including a growing need to work with computers and digital technology (albeit from a moderate bases; Muro et al. 2017). The work of Zeynep Ton (2014) has shown that there is no one best (or worst) business model for retail, and that retail businesses can be both profitable and use good employment practices. Other case studies highlight such choices in the implementation of retail technology, with one store using the move to labor-saving ordering technologies to cut back labor hours, and another instead redeploying workers to focus on display and customer acquisition and satisfaction (Voss-Dahm 2009). The Gap Store's experiment with scheduling technologies provides another example for the potentially positive impact of employing new technologies in ways that can enhance both employer and worker satisfaction (see Chapter 4 for a more detailed discussion). Technological change provides opportunities to craft better jobs in retail for both women and men; gender segregation and low levels of earnings for many in the sector provide the imperative for taking up those opportunities.

TABLE 5

Retail Occupations and Women's Employment 2000-2026: Different Measures of Potential Job Change

Retail Occupations	All Workers, 2000		All Workers, 2014-2016		Employment Change 2000 to 2014-2016		BLS Projected Employment Change, 2016-2026				Frey and Osborne Projected Automation Impact		
	Number	Percent Women	Number	Percent Women	Number	Percent	Number	Percent	Men	Women	Automation Probability	Men	Women
Retail salespersons	3,205,964	51.8%	3,440,490	50.7%	234,526	7.3%	79,700	1.7%	39,278	40,422	0.92	(1,559,913)	(1,605,337)
Cashiers	2,269,850	76.7%	3,096,980	74.3%	827,130	36.4%	(30,000)	(0.8%)	(7,723)	(22,277)	0.97	(772,598)	(2,228,638)
First-line supervisors of retail sales workers	2,754,392	41.5%	3,079,223	45.5%	324,831	11.8%	57,700	3.8%	31,452	26,248	0.28	(469,978)	(392,204)
Stock clerks and order fillers	1,140,882	36.9%	1,622,128	34.8%	481,246	42.2%	100,900	5.0%	65,737	35,163	0.64	(676,372)	(361,790)
Shipping, receiving, and traffic clerks	628,158	29.8%	609,930	30.3%	(18,228)	(2.9%)	100	0.0%	70	30	0.98	(416,906)	(180,826)
Advertising sales agents	206,822	52.1%	173,126	51.1%	(33,696)	(16.3%)	(5,400)	(3.6%)	(2,642)	(2,758)	0.54	(45,743)	(47,745)
Door-to-door sales workers, news and street vendors, and related workers	172,237	54.8%	145,100	59.2%	(27,137)	(15.8%)	100	0.1%	41	59	0.94	(55,663)	(80,731)
Correspondence clerks and order clerks	172,197	64.8%	135,235	58.4%	(36,962)	(21.5%)	(3,500)	(1.9%)	(1,456)	(2,044)	0.98	(54,888)	(77,014)
Parts salespersons	124,721	10.5%	113,890	12.9%	(10,831)	(8.7%)	12,700	5.0%	11,057	1,643	0.98	(97,174)	(14,438)
Counter and rental clerks	137,604	58.9%	90,793	51.9%	(46,811)	(34.0%)	25,000	5.5%	12,022	12,978	0.97	(42,350)	(45,719)
Telemarketers	213,994	64.3%	78,302	63.3%	(135,692)	(63.4%)	-	0.0%	-	-	0.99	(28,445)	(49,074)
Models, demonstrators, and product promoters	51,079	79.4%	59,156	73.2%	8,077	15.8%	6,200	6.2%	1,663	4,537	0.53	(8,451)	(23,060)
Procurement clerks	38,933	63.5%	30,793	57.0%	(8,140)	(20.9%)	(3,000)	(4.3%)	(1,289)	(1,711)	0.98	(12,964)	(17,213)
	11,116,833		12,675,146		1,558,313	14.0%	240,500	1.9%	148,210	51,868		(4,241,446)	(5,123,790)

Notes: Numbers employed are for all workers. Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

In conclusion, this chapter has highlighted the need for a gender-aware approach to technological change. Occupational segregation, and segregation by race and ethnicity, are prominent features of much employment in the United States. Given current job segregation, women are substantially more likely than men to be in occupations with both the lowest and the highest risk of technological substitution. The analysis of women's and men's largest occupations, and of employment in office and administrative occupations, has highlighted the potential erosion of good middle-skilled jobs for women. Across all occupations, technological substitution is more likely to threaten better paid jobs for women than for men. The discussion of the retail sector shows limited signs of a decline in total employment, yet it points to other disconcerting signs of unequal opportunity, particularly around high levels of part-time work as well as strong gender segregation in the sector.

More positive is women's comparatively high employment in jobs with the lowest likelihood of automation, including in occupations projected to grow such as those in the education and health sectors. Typically, such jobs require at least a bachelor's degree; while women are more likely than men to pursue college level education, substantial differences in educational attainment by race, ethnicity, and age, unless addressed, will limit access to good, growing jobs for many women. This chapter has focused on the impact of technology on the quantity of jobs; the next two chapters focus more on gendered aspects of technological change on the quality of employment.

3 Digitalization, Earnings, and Women as the Designers of the Future

KEY FINDINGS

- Digitalization—work with computers and digital media—has grown in most occupations since 2000, but varies widely across jobs.

- Women overall are more likely than men to work with computers and digital media, but are still significantly underrepresented in the highest-paid tech jobs.

- Earnings for both women and men increase with greater use of computers and digital media, but the returns are significantly higher for men than for women. For each one-point increase in an occupation's digital score women's annual earnings increase $436 on average, compared with $740 for men. This represents a gender gap of 41 percent ($304) in the returns to digital skills.

- It is (still) possible for men to work in jobs that pay well without being digitally literate, but there are many fewer such jobs for women.

- The likelihood of working in jobs with high digitalization varies sharply by gender, race, and ethnicity. Hispanic women are 76 percent less likely to work in such jobs than suggested by their share of the workforce, Black women are 57 percent less likely, and White women are 48 percent less likely. Asian women, by contrast, are 70 percent *more* likely to work in these occupations.

- Although employment in the three largest tech occupations—Computer Scientists and Systems Analysts, Software Developers, and Computer Support Specialists—has grown for both women and men, the share of women has fallen across the past 20 years, while the racial/ethnic diversity of these jobs increased.

- Women's general underrepresentation in high digitalization jobs where the technologies of the future will be designed and implemented reduces women's voices in designing the future.

Women and men differ in their use of computers and digital content at work. Women are underrepresented in the three largest occupations with the highest digitalization scores, making it difficult for them to participate in designing the future of work.

The digital transformation of the economy offers huge potential benefits. Yet, as a recent study on the digital gender divide in OECD countries sets out, access to digital tools and to the benefits of digitalization at work are not gender neutral; women's lack of equal participation in the highest levels of the digital economy limits women's economic advancement at the same time as it reduces economic growth (Borgonovi et al. 2018). In the current labor market nearly all jobs require the use of digital technology in one way or another, and the need to work with computers and digital technologies has increased substantially

since the early 2000s, and is expected to continue to do so (Muro et al. 2017). Digitalization—working with computers and digital media—can have high economic returns for those who are involved in the design and implementation of new technologies. At the same time, as discussed in Chapter 2, advances in Artificial Intelligence and machine learning mean that jobs where computers are a tool for data collection and analysis many be at increasing risk of technological substitution. This chapter approaches digitalization from two different angles: it draws upon data on the digital content of work—the extent to which knowledge of and working with computers is expected in occupations—to examine gender differences in working with computers and digital content, and in the returns such work yields particularly with respect to earnings; and it examines women's participation in the occupations with the highest digital content, the IT and STEM occupations where many of the new technologies are designed.

Women are More Likely than Men to Work with Computers and Digital Media, but Are Significantly Underrepresented in the Highest-Paid Tech Jobs

To examine gender differences in digitalization, the authors use an index of digitalization developed by researchers at the Brookings Institution to track changes in digital content over time within and between occupations (Muro et al. 2017). The index categorizes occupations by drawing on two characteristics from O*Net, a U.S. Department of Labor data set on the content of and qualifications required for occupations.[9] At the low end is using a computer or IPad to record appointments, at the high end is working to design new software applications. Figure 4 shows the distribution of women's and men's work in 5 point increments. It shows that women are more likely than men to work with digital content. Women are particularly more likely to work in occupations that require mid-level digitalization—as Muro et al. (2018) put it, they "now have established a sizeable beachhead in an array of large mid-digital occupational groups," whereas men outnumber women in occupations with both the lowest and highest levels of digitalization.

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9   See Methodological Appendix for a detailed description of the index. To examine changes in the digitalization of occupations, Muro et al. (2017) analyze changes in the characterization of computer-related tasks in occupations in O*Net between 2000-2004, and 2009-2016; O*Net stagger occupational reviews.

FIGURE
4

Women are More Likely than Men to Work with Computers and Digital Content

The Distribution of Workers across Occupations by Digital Content, by Gender, 2014-16
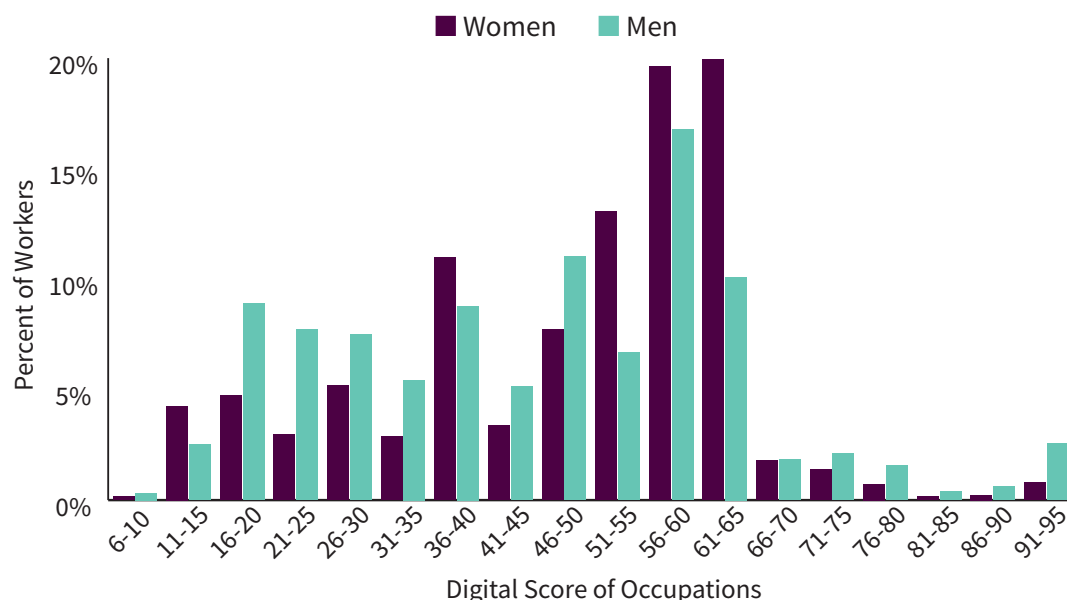
■ Women ■ Men

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Close to 40 percent of women workers work in occupations with a digital score between 56 and 65, but fewer than 30 percent of men do. Muro, Liu, and Whiton (2018) find that women's share of jobs with high digital content increased substantially since 2000, both by women moving into more highly digitalized occupations and through the increased digitalization of the occupations where women typically work. This group includes a large array of occupations, such as Miscellaneous Managers, Elementary and Middle School Teachers and others working in secondary and post-secondary education, Secretaries and Administrative Assistants, Customer Service Representatives, Accountants and Auditors, First-line Supervisors of Office and Administrative Workers, and of Non-retail Sales Workers, Bookkeepers and Information Clerks, and Automotive Service Technicians and Mechanics.

Occupations with the highest digital content are Information Technology and Communications (ITC) occupations such as Software Developers and Electric and Electronic Engineers. Occupations with the lowest digitalization scores include Childcare Workers and Personal Care Aides (predominantly female occupations) and Janitors and Building cleaners, Construction Laborers, and Carpenters (predominantly male occupations). When all women's jobs and men's occupations are considered together, men's jobs outscore women on digitalization.

With the exception of jobs with the highest level of computer use, there is no clear correlation between digital content and the likelihood of automation—each of the groups include some occupations with a high risk of automation as well as some with lower levels of risk, according to the Frey and Osborne (2013) study. The middle group, for example, includes Secretaries and Bookkeepers—with a high risk of automation—as well as Teachers and Supervisors, with a low risk of automation. Childcare Workers, who are not expected to perform much of their work with computers, face one of the lowest automation risks, while Hosts and Hostesses and Counter Attendants in restaurants and other food establishments, also in the low group, are assessed as facing a high risk of automation. Working with computers is only one aspect of new technologies and their potential to supplement or supplant human labor and may not capture much of the risk of the advance of robots and other mechanical devices.

Men Have Greater Earnings Returns on Digitalization than Women

Muro et al. (2017) find a strong positive correlation between digital content and earnings: typically, workers who work more extensively with computers have higher earnings. To estimate whether women and men benefit equally from digitalization, the authors here expand upon their model by analyzing the effects of the digital index on the earnings of women and men separately, controlling for highest level of education.[10] Figure 5 shows a strong correlation between earnings and digitalization for women as well as for men. On average, controlling for education, one digital point adds $436 to women's annual earnings. Yet, women's returns from digitalization are much lower than they are for men. The average value of one point on the digitalization index for men translates into $740 – a gap of 41 percent ($304) in digital returns. Thus, while digital content strongly improves women's earnings, it exacerbates earnings differences between women and men.

The results of the analysis (shown in Figure 5) show not only that women and men have different monetary returns on working with computers and digital media, but also that the trajectory of returns differs by gender. As the need to use computers increases in a job, the relative gains for women fall in jobs with moderate to mid-level digital content (that is, for each increase in the need to use computers in an occupation there is an increase in earnings, but it is less substantial than the previous increase), but then increase more strongly for jobs with the highest level of digitalization (jobs in the IT field). Men, on the other hand, have steeply increasing returns as they move from lower into moderate and mid-level digitalization jobs, but face somewhat slowing returns when they fully specialize in digital fields (albeit- still out-earning women by substantial margins; Figure 5).

> **While digital content strongly improves women's earnings, it exacerbates earnings differences between women and men.**

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10   See Methodological Appendix for a detailed description of the analysis that was performed.

FIGURE
5

Digitalization Raises Earnings, but Less So for Women than Men

The Relationship between Digital Content of a Worker's Occupation and Median Annual Earnings, by Gender, 2014-2016
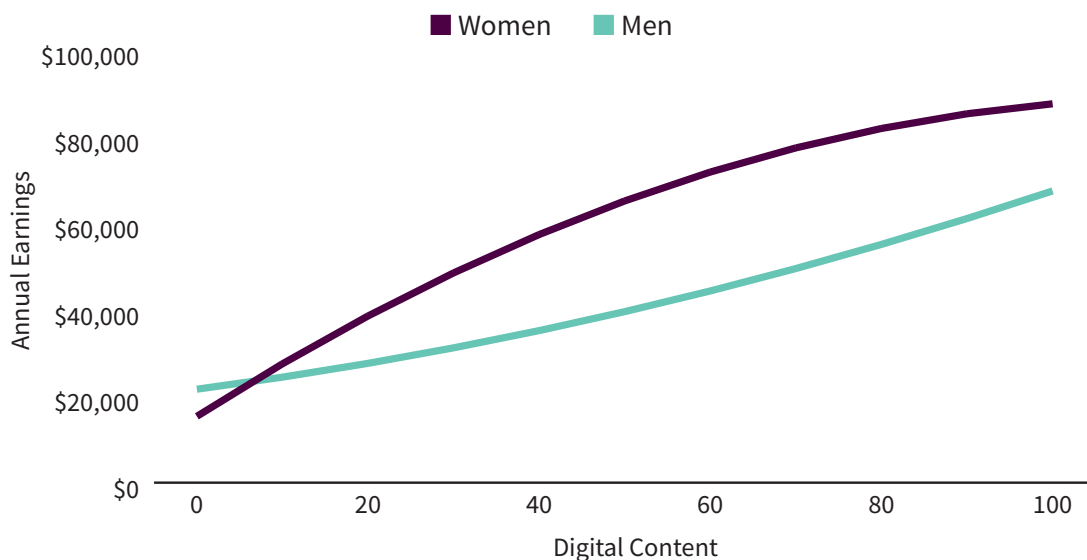
Notes: All occupations. Earnings are for full-time, year-round workers. The index of digitalization has values from 0 (no use or knowledge of computers) to 100 (very high use and knowledge of computers). The relationship shown is from a regression analysis, in which level of education is taken into account.

Source: Authors' regression analysis of 2016 (1-year) data from the American Community Survey from the Integrated Public Use Microdata Series (IPUMS) and digital content scores from Muro et al. (2017). For coefficients see Appendix Table 1.

The gender earnings gap is widest in the occupations that require a mid to high level of digital content (with a digitalization index value between 56 and 65; Figure 5). Working with computers and digital technology in many of these occupations is an essential part of the job but not necessarily one that commands a high premium for computing skills. Computers and software programs are tools of the job, but are not tools for producing new digital applications. This is true for both women and men in these occupations. Hence, whether differences in earnings among women and men in this group are because women's work is comparatively routine and deskilled, or whether women's low earnings reflect lower returns for technological knowledge because much of this work is being predominantly done by women, is an open question.

Earnings on the whole are lower in the occupations with low digital content, most of which are lower or middle skilled occupations, and none of which require a BA degree; but here, too, gender differences are notable. For the large majority of women, low digital content means very low earnings; 89 percent of

women in this low and middle skilled group work in occupations with median earnings of less than $26,000 per year, compared with 49 percent of men. While several of these jobs have median annual earnings of at least $40,000—in occupations such as Carpenters, Pipe layers and Pipefitters, Structural Ironworkers, Brick Layers, and Mining Machine Operators, Postal Mail Carriers, and Dancers and Choreographers—only the latter two employ a substantial number of women (IWPR Future of Work Database, data not shown elsewhere). Thus, for men it is still possible to work in jobs that pay well without being fully computer literate, but this is much less common for women.

Earnings are highest in the jobs with the highest digital content. These are IT and STEM occupations such as Software Developers, Computer and Information managers, Computer Support Specialists, Operations Researchers, and Aerospace Engineers; three in four workers in these jobs are men. Altogether these jobs account for only a small part of the workforce—just 3.6 percent of all workers (1.9 percent of women and 5.2 percent of men), but they are jobs that are projected to grow strongly in the coming decades (IWPR Future of Work Database). Bughin et al. (2018) also estimate that tasks demanding such technical skills currently account for only 11 percent of hours worked, but that demand for such tasks will grow by 55 percent between 2015 and 2030 (and to 16 percent of all hours worked).

Women's Likelihood of Working in Occupations with High Digitalization Varies Sharply by Race and Ethnicity

The likelihood of working in occupations that require extensive computer use varies sharply by race and ethnicity, as well as by gender. Table 6, showing the authors' analysis of the IWPR Future of Work Database, compares the distribution of the workforce by gender, race, and ethnicity in all occupations, in occupations with high digital content, and in occupations with low digital content. Compared to their share of the population, Hispanic women and men are substantially overrepresented in the occupations with the lowest computer use (the lowest paid occupations) and underrepresented in the occupations with the highest digital content (and highest earnings). Hispanic women are over 40 percent more likely to work in a low-digitalization occupation than would be suggested by their share of the total workforce, and they are 76 percent less likely to be in the high digitalization group. Black women are also overrepresented in the low digitalization group, but just by 10 percent, and underrepresented in the high group. White women on the other hand are underrepresented in both the high and the low digitalization group, while Asian women are the only group that is more likely to be in the high digitalization group. Black women are 57 percent less likely to work in high digitalization jobs than is suggested by their share of the workforce, and White women 48 percent, while Asian women are 70 percent more likely (authors' calculations based on

For men it is still possible to work in jobs that pay well without being fully computer literate, but this is much less common for women.

Table 6). Such differences reflect differences in levels of education—Hispanic and Black women are less likely to have at least a Bachelor's degree, a level of education typically required in high digitalization jobs, than White or Asian women. Yet, it also reflects different specializations, socialization, and bias for those with higher levels of education, with Asian women, for example, much less likely than other women to work as teachers.

Hispanic women are 76 percent less likely to be in high digitalization jobs than would be suggested by their shares of the total workforce.

TABLE 6 White Men Represent a Third of All Workers, But Half of Workers in Jobs with High Digitalization

The Composition of the Workforce by Gender, Race and Ethnicity across All Occupations, and Occupations with High and Low Digital Scores

		Employment in the Total Workforce		Occupations with Low Digital Score		Occupations with High Digital Score	
		Number of Workers	Percent	Number of Workers	Percent	Number of Workers	Percent
WHITE	Men	49,828,197	33.8%	7,533,201	32.1%	2,654,954	49.5%
WHITE	Women	44,361,194	30.1%	3,983,540	17.0%	834,505	15.5%
BLACK	Men	7,600,811	5.2%	1,829,300	7.8%	247,881	4.6%
BLACK	Women	8,937,273	6.1%	1,288,552	5.5%	139,589	2.6%
HISPANIC	Men	13,819,337	9.4%	4,786,787	20.4%	283,892	5.3%
HISPANIC	Women	10,558,445	7.2%	2,395,779	10.2%	93,791	1.7%
ASIAN	Men	4,445,287	3.0%	537,641	2.3%	724,596	13.5%
ASIAN	Women	4,130,252	2.8%	544,310	2.3%	255,234	4.8%
OTHER	Men	1,770,420	1.2%	350,643	1.5%	96,936	1.8%
OTHER	Women	1,763,500	1.2%	218,637	0.9%	35,756	0.7%

Notes: Asian includes Pacific Islanders; Whites, Blacks and Asians/Pacific Islanders are non-Hispanic, Hispanics may be of any race. Due to small sample sizes, 'Other' includes Native Americans, persons of two or more races, and anyone else not separately classified. Low digital score defined as 25 or lower, high digital score as 76 or higher.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Despite Gains, Women's Share of the High-Tech Workforce is Falling

In the jobs with the highest digital content, the jobs in which technologies are designed and shaped, men outnumber women in each major racial and ethnic group (Figure 6).

FIGURE 6 **Men Outnumber Women in High Digitalization Jobs in Each Major Racial/Ethnic Group**

Proportion of Workers in Occupations with Digital Scores Higher than 75, by Gender and Race/Ethnicity, 2014-2016

■ Women ■ Men

Group	Women	Men
All	1.9%	5.2%
White	1.9%	5.3%
Black	1.6%	3.3%
Hispanic	0.9%	2.1%
Asian and Pacific Islander	6.2%	16.3%
Other/Multiracial	2.0%	5.5%
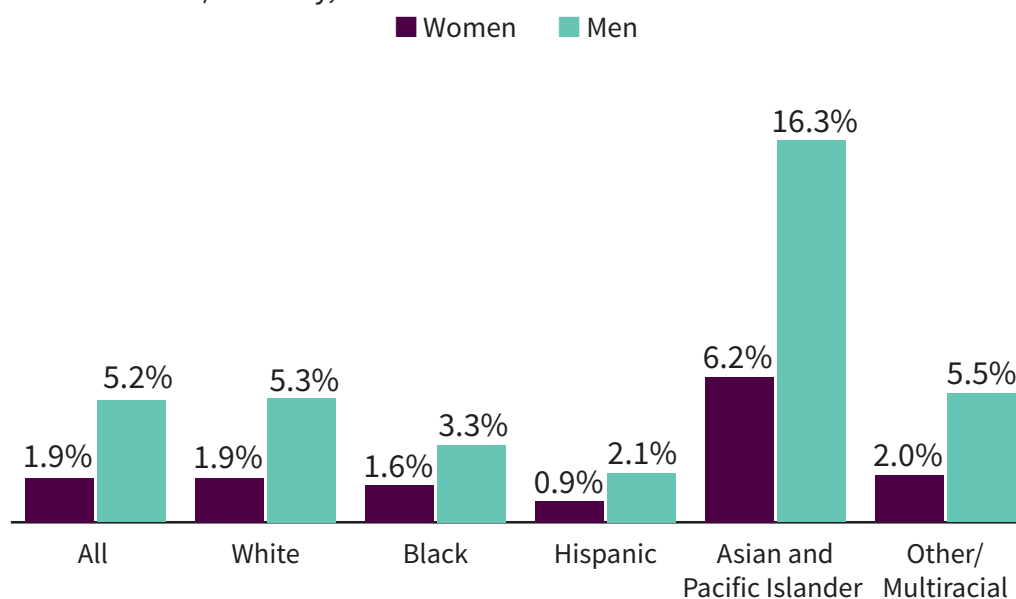
Notes: Whites, Blacks and Asians/Pacific Islanders are non-Hispanic, Hispanics may be of any race. Due to small sample sizes, 'Other' includes Native Americans, persons of two or more races, and anyone else not separately classified.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

The Shares of Women Fell in the Three Largest IT Occupations since 2000

Since 2000, the high-tech workforce has grown dramatically for both women and men, but the number of women workers in these fields grew less than the number of men and the shares of women fell. The number of Computer Scientists and Systems Analysts, for example, the largest high digitalization occupation, increased by 50 percent between 2000 and 2016 (to 1.5 million), the number of software developers by 69 percent (to 1.2 million workers), and the number of computer support workers by 86 percent (to just under half a million workers); at the same time the general workforce grew by around 16 percent (IWPR calculations). The number of women working in these occupations has

also increased substantially. Muro, Liu, and Whiton (2018) suggest that women have made substantial gains in their share of high digital occupations during the last 15 years, and that in several parts of the country, such as Washington, D.C., Sacramento, and New Orleans, they are more than three in ten of these workers; however, in tech hubs such as San Francisco, San Jose, and Seattle, they have made much less of an inroad. Overall, men's participation grew more strongly, and women's shares of workers in the largest three IT occupations fell in spite of an absolute growth in female IT workers, making the field even more male-dominated than it used to be (Figure 7).

FIGURE 7 Women's Share of Employment Fell in Each of the Largest Three IT Occupations since 2000

Women's Share of the Largest Three IT Occupations, 2000 and 2014-2016

■ 2000 ■ 2016
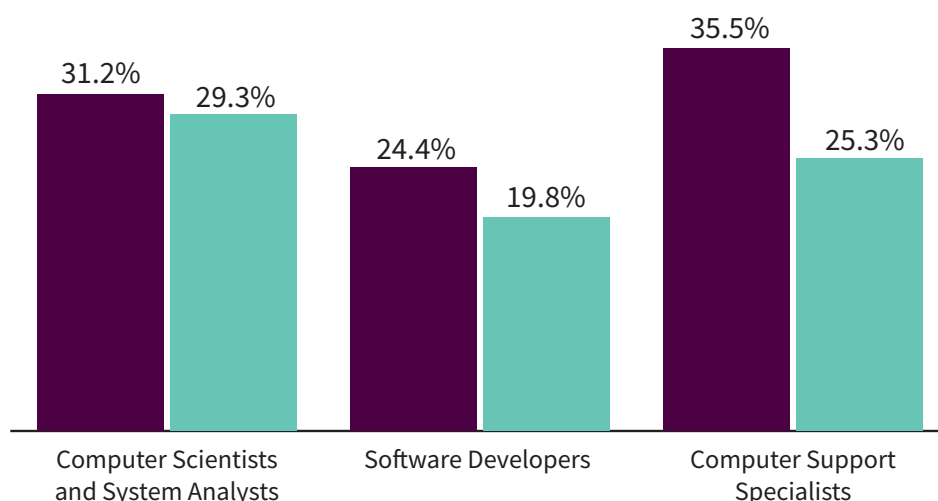
	Computer Scientists and System Analysts	Software Developers	Computer Support Specialists
2000	31.2%	24.4%	35.5%
2016	29.3%	19.8%	25.3%

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Racial/Ethnic Diversity of IT Occupations Increased

While gender diversity has fallen since 2000 in these three occupations, racial and ethnic diversity has increased. In 2000, White workers were almost three quarters of the workforce; by 2016, they were fewer than two thirds (Table 7). The biggest contributing factor is an increase of Asian workers, both women and men, reflecting both immigration and a change in their share of the U.S workforce. The share of Asian women increased from three to five percent of workers in these three occupations, and of Asian men from nine to 16 percent. While they remain substantially underrepresented compared to the total

workforce, the number of Hispanic women in these three occupations more than doubled in absolute terms (albeit from a low base).[11]

		2000	2014-2016
WHITE	Women	21%	13%
	Men	52%	49%
BLACK	Women	3%	3%
	Men	4%	5%
HISPANIC	Women	1%	2%
	Men	3%	6%
ASIAN	Women	3%	5%
	Men	9%	16%
OTHER	Women	2%	0.6%
	Men	1%	2%

TABLE 7 The IT Workforce has Become More Diverse Since 2000

The Composition of Employment in the Largest Three IT Occupations, by Gender, Race and Ethnicity, 2000 and 2016

Notes: Largest three IT occupations are: Computer Scientists and Systems Analysts; Software Developers, and Computer Support Specialists. Asian includes Pacific Islanders; Whites, Blacks and Asians/Pacific Islanders are non-Hispanic, Hispanics may be of any race. Due to small sample sizes, 'Other' includes Native Americans, persons of two or more races, and anyone else not separately classified.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Specializing in tech fields provides high economic returns. Yet, as shown above in Figure 5, these returns remain substantially lower for women than men. Recent research on tech jobs by the U.S. Government Accountability Office (GAO) suggests that one factor contributing to the gender wage gap within the tech field is that men are more likely to work for tech companies, whereas women are more likely to work in tech roles for non-tech companies such as banking or retail. Women are 59 percent of tech professionals and 58 percent of technicians in companies that are not specialized in producing technology, but they are only 30 and 21 percent of workers in these roles in technology firms

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11 The number of Hispanic women working as Computer Scientists and Systems Analysts grew from 14,885 to 34,068; of Software Developers, from 5,737 to 10,309; and of Computer Support Specialists from 7,658 to 15,869.

(GAO 2017). Likewise, Black and Hispanics are more likely to work in tech roles for non-tech than tech companies. Median annual earnings for those who work in tech roles outside of the tech industry in 2015 were 87.6 percent of those who work in the tech sector (GAO 2017).

Forthcoming research by Alegria (2019) highlights how women's experiences and opportunities to thrive in tech differ by race. Her research suggests that White women 'benefit' from perceptions that women have stronger interpersonal skills than men and are seen as (mid) management potential. Such attribution bias, however, seems much less common for Black women, who are much less likely to be encouraged to move into management. The 'women are better managers' bias makes it easier for White women to move into tech without having a specialist IT degree (although once in management, they are perceived to lose their technical credibility and cannot move back into tech roles); at the same time, according to Alegria's research, Black women are asked to provide proof—educational credentials—for each tech position they seek. Analysis of diversity data provided by Bay area tech employers to the U.S. Equal Employment Opportunity Commission suggests, however, that the demographic group that is least likely to be promoted into managerial positions are Asian women and men; the study also confirms that White women in recent years have disproportionately gained executive positions compared to their share of entry level positions (Gee and Peck 2018).

The bias faced by women in tech roles also limits their growth as tech entrepreneurs. Barriers faced by women when seeking support from venture capital funds in the tech fields are well established in research (Malmstrom, Johansson, and Wincent 2018). While the number of women entrepreneurs receiving venture capital funding has increased since 2012, their share of venture funded companies has remained flat, at 17 percent (Teare 2017). Intellectual property rights, through patents, can contribute to business success, not least by improving the likelihood of venture capital funding (Häussler, Harhoff, and Mueller 2012; Graham et al. 2009). While there has been a steady increase in the number of women who successfully apply for patents, either on their own or as part of the team, overall fewer than two in ten patent holders were women as of 2010 (18.8 percent; Milli et al. 2016).

Women's underrepresentation in high tech fields, whether in employment or entrepreneurship, does not have a single cause. Their underrepresentation reflects a number of factors, starting in early childhood, continuing in education, and shaping the ways women and men experience and make decisions at work (see for example Borgonovi et al. 2018, Kahn and Ginther 2017). While workers in high tech jobs are only a small minority of all workers, the workers in these jobs are designing technologies that are shaping our future. Diversity in the workforce is a high priority to prevent a biased and restricted view of the way innovation is prioritized and implemented. As artist

Diversity in the workforce is a high priority to prevent a biased and restricted view of the way innovation is prioritized and implemented.

Stephanie Dinkins asked in a recent *New York Times* discussion about artificial intelligence, "What happens when those writing the rules–in this case we will call it code—might not know, care about, or deliberately consider the needs, desires, or traditions of people their work impacts?" (NYT, October 19, 2018). Finding ways to tackle barriers and encourage greater gender and racial/ethnic diversity in these roles is critical.

In conclusion, digitalization—the use of computers and digital content—is increasing in many occupations. Women are more likely than men to work with computers and working with computers increases their earnings compared to other women, but gender differences in earnings gains from digitalization are profound. Additionally, for women even more so than men, working in jobs with a low need for digitalization means low earnings. Earnings are highest in the jobs requiring the highest use and knowledge of computers, and women are underrepresented in these—even though a growing number of women, including women of color, work in such occupations. Improving women's share of such jobs is a priority because this is the work of designing and shaping technologies of the future. Yet, important as it will be to ensure that women have the education, training, and resources to increase their digitalization-related skills and credentials, on its own this is unlikely to eliminate gender gap in earnings and economic opportunities. There needs to be a complementary strategy of valuing more highly the work that is typically performed by women.

4 | Gig and Platform Work

KEY FINDINGS

- There are few signs that the standard employment relationship is disappearing; the large majority of women and men continue to have open-ended employment arrangements.

- The proportion of women who usually work full-time, an indicator of job quality, has declined substantially in several of the largest occupations for women since 2000, including Cashiers, Customer Service Representatives, Childcare Workers, and Retail Salespersons.

- In the majority of women's largest occupations real wages for full-time workers fell between 2000 and 2016 in spite of a growing share of women with at least BA degrees.

- Women are approximately as likely as men to do gig work—selling products or finding jobs through platforms, agencies, temporary or self-employment—but such work arrangements remain relatively marginal as a share of total employment.

- Finding employment through platforms has opened new opportunities to women. Yet, overall platform employment is highly gender segregated and flexibility in the female-dominated platform segments is more restricted.

- Platform work has opened new opportunities for women entrepreneurs.

Technological and other changes in the economy are leading to an increase in gig work such as temporary contracts, self-employment, part-time work, and work found through digital platforms, but the changes are not as dramatic as many think. The opportunities for women and men in entrepreneurship are increased through platforms, since platforms make it easier to find both customers and suppliers.

Technological transformation can affect not only the number of jobs and the way work is performed but also the quality of employment, potentially changing the relationship between workers and employers, how workers find work, whether they have access to employment benefits, and whether they are self-employed or directly employed by a single employer. The substitution of jobs by technology may reduce the demand for workers overall, or for workers with certain skills sets, and may lead to more workers competing for fewer jobs and/or reducing hours in those jobs, potentially leading to an increase in part-time work, temporary contracts, and self-employment, all forms of employment that are less likely to provide employment benefits. There is a great deal of concern about the future of work increasingly being composed of non-standard employment, including work obtained through platforms such as Uber, Lyft, Task Rabbit, and Care.com; yet for some workers, such new ways of finding and selling work may also open new opportunities.

The Standard Employment Relationship Remains the Norm, but Part-Time Work in Some Jobs Has Increased

The vast majority of workers continue to work full-time, year-round (BLS 2018). With the exception of a small decline among those who work full-time, year-round among Cashiers (a decline of 1.1 percentage points since 2000 to just 31 percent), full-time, year-round work has stayed at the same level or grown in all other large occupations for women. Full-time workers are much more likely than others to have access to employment benefits such as health insurance, pension contributions, and paid time off (U.S.

Bureau of Labor Statistics 2018g). Among the largest occupations, however, the share of women who work full-time, year-round varies substantially, from fewer than half of all women who work as Cashiers, Maids and Housekeeping Cleaners, and Nursing, Psychiatric and Home Health Aides, to more than 80 percent among Accountants and Auditors, Registered Nurses, Social Workers, and First Line Supervisors (data not shown). Additionally, many of these occupations have seen a decline in the number of women workers who usually work full-time (even if they are not working year-round), including a decline of almost 15 percentage points for Cashiers, nine percentage points for Customer Service Representatives, eight percentage points for Child Care Workers, and 7.5 percentage points for Retail Salespersons (data not shown). These are all occupations that already had above average levels of part-time work. Thus, the data suggest a falling quality of work and an increase in the polarization between those who work full-time, year-round and those who do not.

Shifts in employment practices in the last two decades have made hours of work much less predictable as employers attempted to minimize labor costs by adjusting paid working hours as closely as possible to changes in demand (Lambert 2008). Particularly, women and men in low-paid service jobs in retail, hospitality, and caregiving often have little control over the numbers and scheduling of working hours. A nationally representative survey of young workers (ages 26 – 31) found that 41 percent of workers had just a week or less notice of their schedule, and three quarters experienced fluctuations in the hours they worked from month to month (Lambert, Fugiel, and Henry 2014). For those who are paid hourly this means that earnings may change from pay period to pay period, making it difficult to plan for rent, tuition, and other responsibilities. Many of these young adults are also parents, making combining work and family particularly challenging when earnings and schedules are unstable. (See Chapter 5 for more discussion of work and family issues.)

Women's Earnings Have Fallen in the Majority of the Largest Occupations Despite Higher Levels of Education

Analysis of the largest common occupations for women highlights the stagnation and decline in worker's median earnings since 2000. As discussed in Chapter 2, many of women's largest occupations have high risks of technological substitution and have declined or grown at a slower pace than overall employment. Table 8 below shows the change in median earnings in the largest occupations for women for the largest racial and ethnic groups; median annual earnings fell in 12 of these 20 occupations. This is despite the fact that with just one exception (White women Social Workers), the share of women with at least a bachelor's degree increased since 2000. In the occupations that are at particularly high risk of technological substitution—Secretaries and

> **The data suggest a falling quality of work and increase in the polarization between those who work full-time and those who do not.**

Administrative Assistants, Cashiers, Retail Salespersons, and Receptionists and Information Clerks—a substantial increase in educational attainment is accompanied by a decline in real earnings.

There are several factors that likely contribute to the drop in women's earnings even when the share of women with a BA or higher in each occupation increased. Bivens and Shierholz (2018) argue that the decline in workers' wages is due largely to the erosion of their bargaining power relative to their employers.' This loss of bargaining power reflects a number of factors including the "steady erosion of union coverage," which would allow workers to collectively bargain for better wages and benefits had it not declined. The share of the workforce that belongs to a labor union has fallen to just 10.5 percent while the real wages of workers have stagnated or fallen (BLS 2019, DeSilver 2018).

Workers' bargaining power is also reduced when unemployment is high and employers can pick and choose among workers. During the Great Recession (2007-2009) and for years afterward unemployment rates were extremely high; as discussed, in occupations such as bank tellers, the recession led to the permanent substitution of many workers, with demand for these roles not increasing during the recovery. In 2010 the annual average unemployment rate for all workers was almost 10 percent (9.6 percent) and it didn't fall below five percent until 2016 when it fell to 4.9 percent (BLS 2019). The data in Table 8, therefore, also likely reflect the tendency for employers to increase the education and experience requirements of jobs when hiring during a slack labor market (Modestino, Shoag, and Balance 2018). This will push workers to increase their educational attainment while workers' relative lack of power keeps wages from growing.

Finally, workers are continually upgrading their skills, educational attainment, and credentials as they become more aware not only of the benefits of having these credentials but also of the costs of not having them. Many workers are aware that those with postsecondary education are more likely to be employed, less likely to be unemployed, and have higher earnings and better benefits (Pew Research Center 2016). At the same time, there has been a great deal of concern about the impact of automation and other technologies on employment as well as about a "skills gap" where employers have job openings but can't find workers who are qualified. While the idea of a skills gap is questionable when wages haven't grown, workers act on the information they have and seek to improve their credentials and future earnings and job security.[12]

> **Workers are continually upgrading their skills, educational attainment, and credentials as they become more aware not only of the benefits of having these credentials but also of the costs of not having them.**

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12   As noted above, some research indicates that employers increase the educational and experience requirements of jobs when labor supply is plentiful and reduce them again when the labor market is tight. Modestino, Shoag, and Balance (2019) found no evidence that the actual content of jobs changed or that these higher education and skill requirements were needed.

TABLE 8 — Despite Increased Education, Women's Earnings Fell in Many of their Largest Occupations

Change in Women's Bachelor's Degrees and Median Annual Earnings, 2000 to 2014-2016

	Percentage Point Growth in the Share of Women with a Bachelor's Degree or More, 2000 to 2014-2016			2000 to 2016 Change in Women's Median Full-time Year-round Earnings
	White Women	Black Women	Hispanic Women	
Secretaries and Administrative Assistants	9.1	10.7	8.2	($32)
Registered Nurses	9.2	12.3	10.6	$6,265
Elementary and Middle School Teachers	0.6	0.7	4.1	$1,070
Cashiers	3.7	1.6	2.0	($1,240)
Nursing, Psychiatric, and Home Health Aides	3.3	2.7	2.4	($1,450)
First-Line Supervisor of Retail Sales Workers	8.3	6.7	5.7	$638
Customer Service Representatives	7.4	3.9	4.7	($3,335)
Retail Salespersons	6.9	4.0	3.2	($1,948)
Managers, nec (including Postmasters)	15.7	15.7	11.5	$8,678
Waiters and Waitresses	6.0	4.1	2.1	($703)
Maids and Housekeeping Cleaners	1.7	1.7	1.3	($703)
Accountants and Auditors	12.0	11.9	14.2	$6,102
Childcare Workers	8.4	5.5	5.4	$735
Personal Care Aides	4.5	3.8	3.1	($1,045)
Office Clerks, General	8.3	10.2	6.4	($618)
Bookkeeping, Accounting, and Auditing Clerks	6.3	6.1	4.9	$2,542
Receptionists and Information Clerks	6.1	7.3	4.7	($448)
Chefs and Cooks	4.3	2.4	1.4	($961)
Teacher Assistants	9.6	11.2	10.9	$310
Social Workers	(1.1)	3.0	2.6	($309)

Note: White and Black women are non-Hispanic while Hispanic women may be of any race. Women from other racial groups (Asian/Pacific Islander, Native American, Other Race and Multiracial) are not shown separately due to small sample sizes. Full-time is defined as 35 or more hours per week, year-round as at least 50 weeks per year. Nec stands for Not Elsewhere Classified.

Source: IWPR Future of Work Database; for methodology and sources see Methodological Appendix.

Conflicting Perceptions of the Extent of Gig Work

Official Labor Market Data Finds No Evidence of a Growth in Gig Work

The 2017 Contingent Worker Survey (U.S. Bureau of Labor Statistics 2018a) was fielded by the BLS to examine trends in gig work—broadly defined as contingent and various other forms of alternative work arrangements—since the last such survey was conducted in 2005. The BLS survey found only 3.8 percent of workers fitting their broadest definition of contingent or temporary work (including any worker, whether self-employed or independent contractor, employed through temporary help service agencies, or directly employed, who believe that their job will last a year or less; U.S. Bureau of Labor Statistics 2018a). This was a lower share of the workforce than in 2005.

Likewise, BLS found little evidence of an overall increase in the share of workers who are self-employed or independent contractors, who work through temp agencies, or who work in on-call arrangements; together these workers account for just 10.1 percent of the workforce. The first, and the largest category, is independent contractors and freelance workers who by themselves make up 6.9 percent of the workforce (women are 36 percent of all independent contractors). While these alternative work arrangements make up a small part of the workforce, altogether they employ some 5.9 million women (U.S. Bureau of Labor Statistics 2018a).

The BLS data contradict common perceptions of what may be happening with the employment relationship. One recent survey, for example, found over half (57 percent) of respondents to be concerned about an increase in temporary work (Pew Research Center 2016). As Abraham et al. (2018) point out, the popular concern and perception of growth in on-demand work, together with a general perception that standard full-time employment relationships are in decline, echo similar concerns raised in the 1980s, 1990s, and 2000s; and, as then, are hard to substantiate in official labor market data.

Public Perceptions of Employment Insecurity May Reflect Broader Changes in the Employment Relationship

Other studies suggest that the BLS methodology may be missing a substantial number of workers. Based on extensive survey data, for example, Gallup suggests that 29 percent of workers—32 percent of men and 26 percent of women—are covered by one of the four work arrangements identified as contingent by BLS (Gallup 2018). BLS limited its recent survey to nontraditional arrangements only among those workers for whom it is their primary source of earnings; those using such forms as a supplementary source of earnings were excluded. Additional research indicates that many workers with traditional work arrangements for their primary job also work in these more precarious

For many workers, earnings in their primary jobs are so low that the income earned from alternative forms of work is essential to their financial well-being.

and alternative forms of employment as a second job to supplement their incomes (Bernhardt 2018, Mishel 2018, and Smith 2016). For many workers, earnings in their primary jobs are so low that the income earned from these alternative forms of work are essential to their financial well-being. As Bernhardt (2018) notes, workers, whether they are in traditional work arrangements or not, are not seeing their wages grow, they lack workplace benefits, and many do not have access to sufficient hours of work.

The puzzling lack of conformity between public perceptions and official data and scholarly research may be due to the process that has been described as the fissuring of employment relationships (Weil 2014). While workers continue to be employed on an assumed permanent basis, the quality of employment has declined for workers performing lower skilled work, particularly in the service sector, as corporations have focused primarily on their main value-adding businesses, and have subcontracted work related to cleaning, cooking, maintenance, and administration to other companies. In these contracts, labor costs are one of the main factors of competition, leading to a general decline in terms and conditions for many workers operating in the market for low-skilled work (Weil 2014).

While Small as a Share of the Workforce, a Substantial Number of Workers Do Not Have Stable Work Arrangements

Even though these workers are only a small proportion of the total workforce, in 2017 there were an estimated 5.585 million contingent workers, and 47.3 percent of them were women (slightly higher than women's share of total employment in the same year, at 46.6 percent). The majority of these workers (55 percent) would prefer a permanent job; contingent workers are also substantially more likely to work part-time than all workers (40.8 compared with 17.4 percent) and they are much less likely to have access to employer provided health care insurance (25.1 compared with 49.8 percent) or employer provided pension plans (18.4 compared with 43.4 percent, U.S. Bureau of Labor Statistics 2018a).[13]

Women, who are most often the primary care provider in families with children, make up 47 percent of on-call workers and 48 percent of temporary help agency workers. On-call work and unpredictable scheduling can make it difficult for parents to arrange for childcare. Unpredictable schedules also mean volatility in income streams and the ability to plan financially. Further, workers in many of these alternative work arrangements do not enjoy the same rights and protections that traditional employees have under the unemployment insurance system, the workers compensation system, the Fair Labor Standards Act, and other laws and regulations (Abraham et al. 2018).

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13   Data are not published by gender.

Men and Women Have Different Experiences Finding Work through Digital Platforms

This divergence between public perceptions and labor market data includes the number of workers who work through electronic platforms that enable workers to connect with clients who need rides, help with chores and other common tasks, or family care.

The BLS Contingent Worker Survey also estimates the number of 'electronically enabled workers' who find paid work through electronic platforms, and includes workers who find and deliver products via the internet (such as people designing software or websites through platforms such as Mechanical Turk, or renting apartments) and people who use platforms to find work that they perform in person through platform companies such as Uber, Lyft, Care.com, or TaskRabbit. The BLS finds that only a small number of workers, 1.6 million, currently perform 'electronically mediated employment' as their main source of earnings. Women make up 46 percent of workers using digital platforms (Current Population Survey staff 2018).

As discussed, the BLS survey includes only those workers who perform this type of work as their primary job, and thus the findings may underestimate the actual extent of platform-mediated work. Yet, these low estimates are supported by other studies. Farrell and Greig (2016, 2017), based on data from 240,000 individuals who received income through platforms between 2012 and 2016, concluded that 0.9 percent of adults (just less than 1 in 100 workers) participated monthly in platform-related work, and that altogether just one in 20 (4.9 percent) adults ever used platforms to find income-earning activities. Farrell and Greig (2016, 2017) also found a steep decline in earnings gained from platform work during that period, concluding that as the formal economy improved after the Great Recession, many workers instead chose more conventional employment. Mishel (2018) also argues that most platform workers use platform work as a secondary form of earnings, and that, once the number of hours worked are analyzed, platform work accounts for only a very small share of all hours worked in the economy; he estimates that Uber drivers directly account for only 0.07 percent of total full-time equivalent employment, and that platform workers altogether account for just 0.1 percent (one in 1,000 workers).

Platform Work—Ridesharing, For Example—Offers New Opportunities to Women

Women and men are approximately equally likely to work through platforms (Pew 2016; U.S. Bureau of Labor Statistics 2018a). The flexibility offered by platform work may be particularly appreciated by women and men with caregiving commitments and may offer new opportunities to women (although

Women and men are approximately equally likely to work through digital platforms.

there are potential disadvantages that arise from working as an independent contractor). Ride sharing platforms, for example, allow drivers the flexibility to decide when and where to work. One analysis, based on data from almost 200,000 Uber drivers, suggests that "while the Uber relationship may have other drawbacks, Uber drivers benefit significantly from real-time flexibility, earning more than twice the surplus they would in less flexible arrangements." (Chen, Chevalier, Rossi, and Oehlsen 2017). That flexibility, particularly around childcare, is rated highly by women in a six-country survey of Uber drivers (IFC 2018). Also rated highly is access to work as drivers in the first place: the occupation of 'taxi and limousine drivers' is clearly 'nontraditional' for women, with women in the United States making up just 12 percent of all drivers (U.S. Census Bureau 2017) but 27 percent of Uber drivers (Cook et al. 2018).

The greater ease of access to driving, however, has not closed the gap in earnings. Women Uber drivers in the United States make 7 percent less per hour than men (Chen et al. 2017); this gap is partly due to when women drive, but a bigger factor is women's lower retention in the industry (and the fact that they drive fewer miles per hour, which may be related to lower retention and less familiarity, of course). A systematic analysis of gender differences in reasons for leaving the ridesharing industry is unavailable; however, as with other male-dominated fields, it is likely that factors such as sexual harassment and hostile work environment (in this case from clients) play a disproportionate role for women's decisions to exit the occupation.

Platform Work is Starkly Gender Segregated, and Flexibility Tends to be Restricted in Female-Dominated Platform Work

While ridesharing is male-dominated, women are much more likely than men to access care and domestic work through platforms such as Care.com, TaskRabbit, or Amazon Home Services (and there are more people accessing care and domestic work through platforms than access ridesharing; Pew 2016). While platforms are the medium for selling and buying work in all of these spheres, ridesharing and domestic and care work differ quite substantially in terms of the flexibility and quality of work their platforms, and consequent jobs, provide to workers (Ticona, Mateescu, and Rosenblat 2018). As Ticona et al. (2018) explain, in (predominately male) on-demand models such as ridesharing through Uber, the company mediates the entire labor exchange process, from hiring and dispatching to payment. While workers are rated, and the interaction includes their name and photo, such information is not part of the initial selection of the ride. In contrast, in platforms such as Care.com (where work is primarily performed by women), the person who is offering the service is encouraged to market herself aggressively, increasing the scope for discrimination and online harassment. Services differentiate themselves by the extent of background checks they perform (Forbes 2015). As Ticona et al. (2018)

Women in the United States make up just 12 percent of all 'taxi and limousine drivers,' but 27 percent of Uber drivers.

suggest, the need for an online presence and active social media marketing in such jobs can disadvantage many of those who traditionally provide such services. Childcare and particularly elder care workers include many who are older (and less likely to be as familiar with social media) as well as many immigrant workers with English as their second language (Hartmann et al. 2018).

The Ticona et al. (2018) study also documents the fact that the care sector of the platform economy does little to provide workers with flexibility in the case of emergencies or unforeseen events. Whereas Uber drivers may lose their earnings if they have to stop driving on short notice for any reason, canceling scheduled care-related services can come at a much higher price because of cancellation and no-show fees charged by many platforms (Ticona et al. 2018).

Platform Work Offers New Opportunities for Women's Entrepreneurship

Platform work has the potential to expand the marketplace in which women, and men, can offer their products and services. Women are approximately as likely to sell their work via platforms as men, according to the Contingent Worker Survey (U.S. Bureau of Labor Statistics 2018). Platforms such as Etsy—with nearly $441 million in annual revenues in 2017—allow women to work remotely, and to directly offer their creations to clients globally. Etsy provides a marketplace for 'makers'—very often craftspeople. Close to nine in ten sellers on Etsy are women. For the large majority, producing and selling on Etsy is supplementary to their main source of income but for three in ten it is their main source of business (Etsy 2015). While working on Etsy does not overcome the need for finance, or potential gender bias when women try to seek support for growing their businesses, it allows them to access a much larger potential customer base than traditional retail and wholesale would allow a small supplier, which many Etsy makers are.

Whatever the size and future growth projections for employment through platforms, platform work potentially can provide greater flexibility of the timing and/or place of employment than traditional work arrangements. Some workers may find this flexibility and opportunity to grow a business attractive in an era when health insurance can be purchased at reasonable cost on the health care exchanges. This idea is a key component of Obamacare and voluntary part-time employment has increased since its implementation (Baker and Bucknor 2017). There are also many savings and investment products available that can substitute for employer-provided pensions. Of course, the loss of an employer contribution to both health care and retirement security is an important lack. And while some working in the gig economy have substantial skills and can command high hourly prices, others can find only low-paid work with insecure schedules and unstable total earnings.

While some working in the gig economy have substantial skills and can command high hourly prices, others can find only low-paid work with insecure schedules and unstable total earnings.

In conclusion, there is a mismatch between public perceptions and empirical estimates of the extent of change in the employment relationship, with data collected by the U. S. Bureau of labor Statistics finding much less gig work, contingent employment, self-employment or temporary work, platform-mediated employment, or the sale of products and services through platforms—as the primary job of the worker—than expected by many commentators. Other factors, such as the fissuring of the economy, and the growth of part-time and irregular work in a subset of occupations, may contribute to societal impressions of greater employment insecurity. That said, even though estimates of the share of contingent employment are still small, a substantial number of workers perform such work, involving approximately as many women as men. It is also possible that, if this era of technological change results in more job displacement than the BLS now expects, more workers will turn to platform employment as their main source of income. While platform work may come with few benefits and little flexibility in some fields, it can also offer new opportunities for women in fields where they are underrepresented, such as in ridesharing and entrepreneurship.

5 The Future of Work and Family

KEY FINDINGS

- The need for paid and unpaid elder care is rising as the population ages, and as the share of Americans with Alzheimer's disease and related dementias is expected to almost triple, from 5 to 14 million. These trends affect women more than men because women perform the majority of both paid and unpaid care work.

- Personal Care Aides, the occupation with the largest BLS-projected job growth, has median annual earnings of less than $22,000 for full-time, year-round work.

- Investments in new care-related technologies, such as nursing and elder care robots, are growing. Other devices, such as in-home monitoring devices, are increasingly being used. But robots to provide elder or child care remain marginal in mainstream caregiving.

- More than one in five women in low-paid service jobs work part-time because of child care and family care responsibilities, often with little control over their schedules. Scheduling technology can provide greater control over hours of work to those balancing work and family caregiving.

Automation and technological change will likely affect the dynamic of work and family obligations, for both paid and unpaid caregivers. Changes in how families provide care to children and aging parents, and changes in how work is actually done, can help alleviate the conflict between work and family obligations for many workers. At the same time, those employed as paid family caregivers may face new risks.

Both Paid and Unpaid Care Work is Expected to Grow Substantially, Presenting Added Challenges for Women

Caring for children, for the elderly, and adults and children with physical or mental disabilities are major factors in structuring how women and men interact with the labor market. Even though more men are spending time with their children, contributing to housework, and caring for elderly relatives, this work is still largely women's work (Parker and Wang 2013). In the coming decades, the aging of the population is likely to sharply increase the need for care (Mather 2015). A recent study by the Center for Disease Control estimates that the number of Americans with Alzheimer's disease and related dementias will triple between 2015 and 2060, from 1.6 to 3.3 percent of the population, or from around 5 to close to 14 million people (Matthew et al. 2018). And while Alzheimer's and dementia impact all population groups, the incidence rate is particularly high among African Americans.

Looking after one's children and/or adult relatives in need of care takes time; it also typically comes with fairly rigid schedules and less control over when and where paid work can be done. The unequal division of care work between women and men is a major factor behind the gender wage gap. Care work means that women have less time for paid work. Rose and Hartmann (2018) show that once women's lower time in paid work is taken into account, over a 15-year period, women earned only 49 percent of what men did during the same period. While technological change and innovation

> **While technological change and innovation have affected domestic and family care work over the years, technology has not reduced the time needed to care for children or adults.**

have affected domestic and family care work over the years,[14] technology has not reduced the time needed to care for children or adults, and the time spent on childcare by women has remained remarkably stable during the last five decades (Pew 2013).

Personal Care Aides is the Fastest Growing Occupation

In the last two decades there has been a dramatic increase in the number of workers—most of whom are women—who are employed as care workers. Growth has been particularly rapid for Personal Care Aides who typically provide care in the home of a client. Between 2000 and 2014-16 the number of workers in this occupation grew from under 300,000 to more than 1.3 million, and this is also the occupation for which the BLS projects the highest number of new jobs (Table 9). The BLS projects an additional 777,600 jobs, a projected growth of 39 percent from 2016 levels. Projected job growth in the number of Personal Care Aides alone far exceeds projected job growth for all workers in office and administrative and in retail occupations. The BLS further projects over 600,000 additional jobs for Nursing, Psychiatric, and Home Health Aides who largely perform work in nursing care facilities. While Frey and Osborne (2013) do not assess these occupations as having high risk of automation, nevertheless their assessment (an automation risk of 74 percent for Personal

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14   Technological change also raised standards of cleanliness, reducing the extent of labor saving (see for example Mokyr 2000; Schwartz Cowan 1985).

TABLE 9   Care Work Occupations and Women's Employment 2000-2026: Different Measures of Potential Job Change

Care Work Occupations	All Workers, 2000		All Workers, 2014-2016 (ACS)		Employment Change 2000 to 2014-2016		BLS Projected Employment Change, 2016-2026				Frey and Osborne Projected Automation Impact		
	Number	Percent Women	Number	Percent Women	Number	Percent	Number	Percent	Men*	Women*	Automation Probability	Men*	Women*
Nursing, psychiatric, and home health aides	1,660,927	87.5%	2,054,357	87.5%	393,430	24%	613,100	24.0%	76,669	536,431	0.40	(96,677)	(616,542)
Personal care aides	281,198	87.6%	1,372,357	83.3%	1,091,159	388%	777,600	38.6%	129,859	647,741	0.74	(93,091)	(401,901)
Childcare Workers	1,257,410	95.3%	1,263,731	93.7%	6,321	1%	84,300	6.9%	5,284	78,989	0.08	(6,654)	(99,499)
	3,199,535		4,690,445		1,484,589	46%	1,475,000	31.4%	206,528	1,184,172		(189,768)	(1,018,444)

Source: IWPR Future of Work Database; for methodology and sources see Methodology Appendix.

Care Aides, and of 40 percent for Nursing, Psychiatric, and Home Health Aides) suggests substantial scope for new technology to substitute for some of this type of care work (see discussion below).

Childcare Workers, unlike Personal Care Aides or Nursing, Psychiatric, and Home Health Aides, are assessed as having a very low risk of automation, of just eight percent, by Frey and Osborne (2013). The BLS projects much less growth for childcare than for the other two care occupations, of just seven percent over the next decade (Table 9), in line with the rate of growth projected for the total workforce. By contrast, in their economic growth scenarios Manyika et al. (2017b) put Childcare Workers into a high growth category for the United States because they assume that social and economic factors will lead to a further growth in women's labor force participation, growth that is unlikely to happen without further expansion in and subsidies for child and elder care.

Low Pay and Poor Job Quality in Many Care Jobs Threaten the Economic Security of Women Workers, Particularly Women of Color and Immigrants

Job quality for many in this growing workforce is low (Shaw et al. 2016). In 2016, median annual earnings for women who worked full-time year-round as Childcare Workers were only $20,299, $21,314 for Personal Care Aides, and $25,100 for Nursing, Psychiatric, and Home Health Aides (the latter need to have graduated from high school and have postsecondary certification). Part-time work is common, and, as is typical, fails to convey important fringe benefits, such as employer contributions to health insurance and pensions: close to half of all Personal Care Workers (47 percent), four in ten Childcare Workers (41 percent), and a third of Nursing, Psychiatric, and Home Health Aides (33 percent, IWPR Future of Work Database). Even though levels of educational attainment increased significantly in this workforce since 2000, real earnings have fallen slightly (Hartmann et al. 2018; see also discussion in Chapter 4 above). This poor job quality, falling wages, and lack of fringe benefits have negative implications for the economic well-being of paid caregivers, particularly women of color, including Black and Hispanic immigrants, who are particularly likely to work in these occupations.

Robots May Supplement, but Not Replace, the Need for Human Care

What role can, and should, technology play to reduce the burden of unpaid care, improve work-family balance, and increase the quality of paid care? According to the study of the probability of automation by Frey and Osborne (2013), the potential for technological replacement of care work for Personal Care Workers is comparatively high, at 74 percent. Interestingly, they assess the probability of technological substitution of Childcare Workers as much lower, at just eight percent; it is not quite clear what would make the care for the elderly or for people with disabilities qualitatively so different from care for children. To date, the evidence of a technological transformation of care work is still very limited. New uses of robots, which can be defined as any powered machine that assists with mobility such as an electric wheel chair (Brucksch and Schultz 2018) to provide physical or social care are still marginal in the elder and child care spectrum; yet against the background of aging populations in many high-income countries, this is expected to change in the coming decades (Di Nuovo et al. 2018, Foster 2018). Japan, the country with the highest ratio of people aged 65 and older to the general population and large projected care work shortages, is investing heavily in nursing and elder care robots (The Guardian Newspaper 2018). New robot technologies are targeted both at easing the emotional and physical aspects of care—facilitating lifting as much as helping those with physical disabilities be more mobile and independent (Brucksch and Schultz 2018, Headquarters for Japan's Economic Revitalization 2015). And while the use of robots to provide social interaction and emotional care is still very limited, there is an expectation that new generations of machine learning and artificial intelligence will increase the potential impact of robots here, too (Olaronke, Ojerinde, and Ikono 2017).

Most of the discussion of care robots focuses on elder care; there has been much less discussion of robots for child care (Hosseini and Goher 2017). A recent advertising blog on robots proclaims, "Childcare robots are also providing ways for parents to better monitor their kids in their absence. Many families have different schedules and it becomes difficult to look after children when both parents are working. This problem is especially difficult to deal with when small children are involved."[15] Whatever the technical potential, leaving children, particularly small ones, with only robot care while parents are at work or on an errand, is unlikely to transform standards of responsible child care in the near future (or substitute for basic tasks, such as changing diapers). The discussion of AI in relation to child care is primarily concerned with supplementing rather than substituting for human care through applications that make it easier to maintain and share information about a child between parents and child care providers (see, for example, BusinessWire 2018) or

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15   Yell Robot, <https://yellrobot.com/childcare-robots/>

by enhancing children's learning (see for example Fridin 2014, Timms 2016). Development of robotic care has been particularly focused on children, elderly adults, and adults with learning disabilities (see for example Moorthy and Pugazhenthi 2017 or Silvera-Tawil and Roberts-Yates 2018).

Robots and other technical innovations may provide physical assistance with lifting and walking, dispense medication, and provide basic social interactions, while new ITC facilities make it easier for families, or medical staff, to monitor clients remotely, and thus potentially reduce the need for a personal care worker to be present. So far, there is little sign of replacing basic functions such as bathing, feeding, or changing diapers, and even if some functions can be replaced by technology in the future, the continued aging of the population is likely to ensure high demand for human employment. While in the distant future the use of robots may become commonplace both in the home and in classrooms and institutions, in the foreseeable future costs as much as skepticism among humans are limiting their dissemination (Conti, Di Nuovo, Buono and Di Nuovo, 2018, Olaronke, Ojerinde, and Ikono 2017).

To date, the use of computers and digital media in personal care work is low, and, unlike the large majority of occupations, computer-related tasks did not increase in the occupation between 2000 and 2016 (Muro et al. 2017). Technological innovation, however, can play a role in improving the quality of care work, for both care workers and clients, by integrating personal care aides more fully into healthcare teams. At the same time, digital technologies can be used to provide training to workers, and pilot programs for personal care aides are under way in several areas across the country. Developments in telehealth and remote monitoring have the potential to generate substantial cost savings by making it easier for individuals to age in place or reduce nursing home stays (Jacobs 2018; Rantz et al. 2015). Tracking technology and health sensors can increase the confidence and capacity of personal care workers to supplement medical care in home-based settings (Landau et al. 2010). Integrating Personal and Nursing Care Workers more fully into care teams through digital media, and using digital media to increase their skills as care workers, can improve health outcomes and reduce the costs of Medicare, savings that could be reinvested in improving the quality of care work. Osterman (2017) has outlined the potential benefits of increasing the role of home-based care workers. As he writes, "Home care aides see their clients every day for hours. No one is in a better position to help with the challenges of chronic conditions than they." Yet, as Osterman also highlights, raising the role of domestic care workers, improving their job quality, and realizing such savings, also faces huge obstacles, not least from the prejudice and low expectations of other medical staff.

Technological innovation can play a role in improving the quality of care work, for both care workers and clients.

Technology Can Provide More Control over When and Where Work is Done for Workers and Caregivers

Many women are confronted with a mismatch between the organization of paid and unpaid work. Their options for finding solutions to this mismatch vary considerably by their professional status and the work they do. Women in professional occupations may have more flexibility to work remotely or work from home than women in many service occupations. Women in low-paid service jobs in retail, hospitality, and caregiving in particular often have little control over the numbers and scheduling of working hours. More than four in ten workers in low-wage predominantly female occupations work part-time, more than twice the level of part-time work among all workers; more than one-fifth work part-time because they have child care and family care responsibilities, and almost the same numbers say that they would prefer a full-time to their part-time job (Shaw et al. 2016).

As we discussed in Chapter 4, many employers have changed scheduling practices and increased uncertainty over working hours and schedules for many workers in the lower wage service sector. The lack of certainty over scheduling can create havoc for anyone with child care responsibilities (Vogtman and Shulman 2016). As Kossek and Lautsch (2017) point out, "Part-time work permitting control over work volume/workload hurts lower level employees the most (due to involuntary income and benefit loss)." And, as Gerstel and Clawson (2018) add to this debate, the impact of instability and unpredictable hours reverberates beyond the individual worker to their families, and broader environment. Indeed, New America Foundation and Bloomberg organized *Shift: The Commission on Work, Workers and Technology* to brainstorm about the future of work and improve policymakers' and community stakeholders' engagement with the pending technological disruptions. In their report, one group suggested that if the future of work does indeed move toward less employment security and more gig work, families may revert to 'traditional' formations, with one partner having to fully focus on finding work, while the other would fully focus on the house and the family (New America Foundation and Bloomberg 2017).

There has long been a body of case studies showing both the potential and the returns on employers of giving employees a greater say in the scheduling of their work. The Sloan Foundation's When Work Works awards regularly highlighted examples from organizations with complex scheduling needs—such as 2008 winner Arizona Spine and Joint Hospital, where, just by using a calendar, pen, and paper to let employees pick and choose their preferred working hours, invariably the schedule was covered (Families and Work Institute, 2008). Innovation in scheduling technologies has made it much easier and cheaper to prepare schedules; it also makes it much easier to provide employees with input on when they work, and to improve the predictability

> **Many employers have increased uncertainty over working hours and schedules in the lower wage service sector. The lack of certainty over scheduling can create havoc for anyone with child care responsibilities.**

of their working hours. A recent intervention at Gap Stores shows striking economic returns; median sales increased by 7 percent in stores where hourly employees had been given greater control and certainty over their working hours (Williams et al. 2018). As part of the intervention, staff could use a 'Shift Manager' app to swap hours without the need for managers to be involved, and managers could post the availability of additional shifts as needed.

Remote Work is Increasingly Common, but Not for All Workers

Developments in communications technologies mean that remote working is much more possible (and one recent survey finds telecommuting options at the top of working arrangement wishes of working parents; Weiler Reynolds 2015). Yet while there has been a sharp increase in the number of companies that allow (at least some of) their employees to regularly work from home for at least part of the time—from 33 percent in 2012 to 40 percent in 2016 (Matos, Galinsky, and Bond 2017)—this survey highlights that home-based working is not available to most workers in most companies.

While control over where and when they work is a highly sought after benefit for many parents who work in professional and managerial jobs, it can often come at a price, either of work overload (see for example Lupu and Empson 2015; Kossek, Thompson, and Lautsch 2015) or of being faced with stigma and adverse career consequences for making use of flexible working options (Chung 2018, Williams, Blair-Loy, and Berdahl 2013).

Platforms Expand Caregiving Options for Those Who Can Afford the Costs

Platforms such as Care.com which focus on child and elder care are specifically designed to make it easier to match paid caregivers with those needing care services. Care.com, which was founded in 2006 primarily as an individual service, in 2016 also began to offer its services to companies as part of their benefits package. Case studies suggest that employers can easily recuperate the costs of providing employees with benefits such as back-up care through the Care.com network by making it possible for employees to continue to do at least some work when they have a care crisis; and employees value aspects of time saving and perceived quality assurance membership in such a network entails (as well as any financial benefits from discounts of course; IFC 2017). Some parents, of course, also use ridesharing services to address the 'pick children up from school and take to activity' time crunch, and thus can relieve time pressures (see for example Pinsker 2018). For those who are able to afford these services, platforms can make the tasks of caregiving more manageable.

As discussed in Chapter 4, for those who provide their services through platforms the experience can be more mixed, possibly providing greater

While control over where and when they work is a highly sought after benefit for many parents who work in professional and managerial jobs, it can often encourage overwork or induce stigma for using flexible work options.

flexibility and control over the timing of work but at the costs of having to work without benefits, often low earnings, and insecurity over the amount of work. Moreover, the introduction of social media into a field where personal referrals were paramount has made it more difficult for older and immigrant women to compete, despite their years of experience and skill.

Technological Innovation Can Improve Gender Equality

Leading companies acknowledge that they need to do better on diversity, particularly gender diversity, and believe that in order to successfully recruit, retain, and develop women, providing greater flexibility is key. Indeed, work life policies were at the top of the list of companies' human resource strategies when the World Economic Forum interviewed senior executives about their preparations for the Fourth Industrial Revolution (World Economic Forum 2016). Technological innovations have the potential to make it easier for women and men to be both good caregivers and successful employees. As important if not more so will be the need to address social expectations about who does what work, particularly when it comes to men and caregiving. Social policies, such as paid family leave and subsidized care, also make it easier for workers to combine unpaid care and paid employment.

Successful strategies for increasing gender diversity also need to acknowledge that women and men often face different time constraints when it comes to retraining and workforce development.

There is general agreement that technological change in coming years will require many workers to reinvent themselves and their skills in order to keep up with changes in technology. Companies such as AT&T, Starbucks, and Walmart have started to provide their workers with free or subsidized access to online learning tools. Such initiatives are not only important because they make upskilling affordable; they also help workers identify what skills to acquire. Yet, typically such solutions rely on workers pursuing training on their own time. Because women typically are the main caregivers in their families, finding the time to retrain themselves may be particularly difficult. This is particularly so for single mothers. Single mothers are often highly motivated to pursue education to improve their economic position; yet between child care and paid employment, many find it impossible to complete their studies. Fewer than one in twelve single mothers (eight percent) enrolled in college graduate with a degree within six years, and more than half (55 percent) leave school without earning any college credential, not even a certificate (Reichlin Cruse et al. 2018). Providing paid time at work for reskilling, ensuring that information about desired skills and approved training providers are easily available, and making sure that expectations for retraining and upskilling have time lines that are feasible for those with care responsibilities, can make it easier for women and men with caregiving responsibilities to keep up with the new economy.

Technological innovations have the potential to make it easier for women and men to be both good caregivers and successful employees.

In conclusion, in the near future, the need for care, especially elder care, is expected to grow substantially. Women are the large majority of paid and unpaid family caregivers, and this development will affect women more than men. So far there are few signs that technological innovation will significantly reduce the time needed for care work; but technology can make it easier for paid and unpaid care workers by reducing the physical hazards of care work, making communication and monitoring easier, improving control and choice of when and where work is done, and reducing the time it takes to organize care. Many of the innovations that are needed to ensure that care work is less punishing for paid and unpaid caregivers, however, are not primarily technological but will be linked to broader social policies that reflect commitment to improve job quality and gender equality.

Because women typically are the main caregivers in their families, finding the time to retrain themselves may be particularly difficult.

6 CONCLUSION

Shaping the Future of Work with Gender-Aware Policies

Predictions about the future of work and the quantity of job change vary widely but there is broad agreement that technological change will have a substantial impact on the way work is performed in many occupations. Many types of technological innovation are proceeding at a very rapid pace, but their speed of implementation in the world of work is essentially unknown. While this technological innovation has enormous potential to improve the quality of work and life, it is also likely to cause substantial disruption to many occupations when and if fully implemented. Even if there is no agreement among observers on the pacing and precise extent of job change, there is agreement that technological change will require substantial retraining and upskilling for many workers in the coming decades. Change is likely to be particularly profound for workers in middle and lower skilled occupations where new technologies are more likely to displace than complement human labor.

Given that women and men often do different types of work, and given women's greater responsibilities for unpaid work, these changes have different implications for women and men, and policies to address technological change need to be designed in a gender-aware manner. The data in this report demonstrate the critical importance of considering gender in discussions of likely employment changes. Women, of all major racial and ethnic groups, are more likely than men to work in the occupations with the highest risk of automation. Gender differences are not only about the number of jobs at risk, but also about the type of job opportunities. Whereas men are predicted to lose jobs to automation in the lower-paid occupations, women's potential job losses due to automation are anticipated to span the lowest, moderately, and most highly paid jobs where they typically work. Jobs in office administration, for example, which pay in the middle range for large female occupations, are expected to decline substantially over 10–15 years, continuing a downward trend that started before the Great Recession. These middle-skilled office and administrative occupations offer bridges into the middle class; for Hispanic women Secretaries and Administrative Assistants is the highest paid among their ten largest occupations.

These changes make college level education ever more important. Women have made large strides in achieving higher levels of education during the last few decades and, particularly among younger women, outnumber men among college graduates and advanced degree holders. Women are well represented among some of the jobs requiring high levels of education with the lowest likelihood of technological substitution, such as Teachers and Nurses. Yet, the majority of adults are not college graduates, and the likelihood of having higher levels of education varies sharply by race and ethnicity. In the coming years, the share of women seeking further education is likely to continue to increase, and many of them will have children or other care responsibilities. Holistic policy approaches that combine work with retraining or child care and income supports with college enrollment will become even more important in the coming years as technological change increases the need for reskilling and higher levels of education.

Whether at high or low risk of automation, the way work is performed is already changing, and in most jobs the use of computers and digital content has grown. For both women and men, working in jobs that require higher levels of computer knowledge and skills means higher earnings. While there are still some occupations with decent earnings that do not involve much digitalization, such occupations typically employ few women: for women, much more than for men, lack of digital literacy means low earnings. At the same time, working with computers and digital media does not eliminate the gender wage gap: returns on digitalization of work are nearly double for men.

Women are more likely than men to work with computer and digital media but remain substantially underrepresented in the highest paid tech jobs, the jobs that require the highest knowledge and use of computers and digital media and that produce the technology of the future. Encouragingly, the number of women in such jobs has increased, particularly for women of color; time trends, however, also show that overall these occupations are becoming even more male-dominated because men's employment in high tech fields has grown faster than women's. This report reminds us of women's historical role in the development of computing; working with computers and digital media is a much more integral part of most women's work, than it is of most men's. Many women are already digitally literate—the challenge is to help them move into fields where their digital skills can be developed and returns on those skills are higher and more secure than in the fields where women are now concentrated.

While the report reviews and finds little evidence of an economy-wide trend towards more temporary and less secure employment arrangements, there is a clear increase in part-time and irregular employment in several occupations, including in caregiving occupations that employ many women. The report highlights the fact that women are just as likely to be involved as men in using digital platforms to work or sell goods and services. Such work can open new

Many women are already digitally literate—the challenge is to help them move into fields where their digital skills can be developed and returns on those skills are higher.

business opportunities. Yet, the type of work performed through platforms is highly gendered, and conditions of employment tend to be worse for women than men. Platform-mediated care work, in particular, often requires considerable social media presence, and hence, digital and social media literacy, which many of the women who traditionally do this work may not have because of their age and/or because they may not have fluency in English. The greater emphasis on social media presence also makes these workers, mainly women, easier targets for discrimination and online harassment. Transitions to platform jobs, while potentially providing greater flexibility for workers with care responsibilities, intensify the need for portable benefits that can help paid care workers cope with the lack of employer-provided benefits and improve their income security.

> **The need for gender-aware public policies is particularly profound because of the increase in the need for care work, in families and in the marketplace, as a result of the aging of society.**

The need for gender-aware public policies is particularly profound because of the increase in the need for care work, in families and in the marketplace, as a result of the aging of society. These tandem trends—technological and demographic change—suggest the need to accelerate progress in improving the allocation of care within the household and the pay and quality of care jobs outside the household, while increasing women's access to current male-dominated jobs in the technology sector and other well-paid jobs, enabling women to enjoy a fair share of the benefits of technological change. After each major technological wave in the past, women have increased their paid work; and even though there is still a small gap in women's and men's share of the paid workforce, differences between women's and men's economic contributions to their families and to the economy have fallen substantially. Changes in the division of unpaid work between women and men have been less substantial. Even though men are doing more care work, the large marjority of care work is still performed by women, and care work, whether paid or unpaid, remains largely a female domain. Women's continued roles as primary caregivers within families mean that expanding work and family supports to promote equity as employment opportunities and the work-family interface change with technology is particularly important to women. These supports will be critical both to improving the quality of the rapidly growing number of paid jobs in caregiving and to promoting equal access to digitized and technical jobs requiring intensive training.

There is general agreement that in the absence of intentional policies to ensure that the implementation of automation and other technological changes in the workplace is controlled, that the benefits are shared broadly, and that all workers have access to education and job training to prepare them for the new world of work, economic inequality will increase, and likely gender and racial/ethnic inequality as well. The growing low-wage care sector, in which many women work, can generate better quality jobs with appropriate investments. Technology can be used to improve working conditions by using

devices to assist workers in lifting and moving clients, for example. Wages in these jobs can be raised, and care outcomes can be improved, by using digital tools to train workers and by more fully integrating personal care workers into professional care teams. Because there are so many potential economic benefits to the spread of automation, artificial intelligence, and digitalization in the workplace—increased efficiency and productivity, especially in mundane and repetitive jobs, while freeing up human labor to focus on more interesting and beneficial pursuits—it is critical that employers and policymakers focus on reducing inequalities, so that access to the opportunities provided by technological change are widely available.

A number of policy and program interventions can help to ensure a future of work that maximizes opportunities and minimizes risks:

Improving skills development:

- Expand access to affordable postsecondary education and training, along with wraparound supports, for adult students seeking retraining.

- Enhance skill development, including digital literacy, for care workers; increase investments in the child and elder care infrastructure, and promote the development of technological solutions to improve the quality of care work.

- Increase access to on-the-job training to allow more workers to develop the skills that can prepare them to remain in the workforce and advance to new jobs as more job tasks become automated.

- Prepare for expected jobs losses in female-dominated jobs, such as office administration; expand supports for displaced workers; and help displaced women workers identify and move into growing well-paid fields to address expected job loss.

Creating new opportunities in the high-tech world:

- Accelerate efforts among employers, job training programs, and postsecondary institutions to expand the representation of women and communities of color in the high-tech occupations that are redesigning the future.

- Improve the earnings of women so that they earn the same rewards for digital work as men.

- Support women's digital entrepreneurship and provide tools and supports to help them expand their businesses.

- Promote women's advancement to leadership positions and tackle gender and racial bias—algorithmic and otherwise—in recruitment and promotions.

Improving job and income security and job quality:

- Provide opportunities for workers to participate in design and implementation of technological changes at their workplaces.

- Expand access to paid leave, child care, and other job quality benefits in the United States and make sure benefits are portable and available to gig workers.

- Invest in smart technological solutions to reduce care burdens and work-family conflict and promote policies that facilitate a more equal division of care work between women and men.

- Encourage the development of new technologies that work with people; design technologies that complement people's work and allow them to focus on the more variable and challenging parts of their jobs.

Automation will create unprecedented opportunity to dramatically speed progress toward gender, racial, and ethnic equality. Intentional efforts to apply knowledge and technology to tackle inequality, along with efforts to improve efficiency and productivity, are essential to building a future of work that expands opportunity across the labor market.

Methodological Appendix

Research that has estimated the impact of technological change on work and workers has produced divergent narratives about whether jobs are likely to increase or decline but few look at men and women separately. This report seeks to bring a gender lens to this research and assess the risks and benefits that automation, artificial intelligence, and digitalization pose for working women and men building on past research. To do this, IWPR developed two separate databases: one to estimate the potential impact of automation and other technology on women's employment and earnings in the future, and one to allow us to look at changes in women's employment and earnings since 2000. Together these data bases are known as the IWPR Future of Work Database.

To assess the impact of digitalization on women's and men's earnings, we use regression analysis.

Occupational Projections Database

The occupational projections database allows IWPR to build on prior research that estimates the impact of automation and other technology on employment and apply these estimates to the jobs of women and men separately. This database combines data on the demographic characteristics of workers in detailed occupations, information on their employment and earnings, and data on the digitalization of detailed occupations following Muro et al. (2017), and probabilities for automation based on Frey and Osborne (2013). All data are for workers who were employed in the occupation at the time of the survey.

To build this database IWPR began with data from the Occupational Information Network (O*NET) which is under the sponsorship of the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA). This database contains detailed occupational characteristics for 974 detailed occupations which are classified based on the 2010 Standard Occupational Classification (SOC). For each detailed occupation, The O*NET database includes variables on the digital content of detailed occupations. Following Muro et al. (2017), we used the variables Knowledge of Computers and Electronics and Work Activity—Interacting with Computers. Because these variables are rated on two separate scales—the importance of each to the occupation is measured on a scale of 1 to 5 while the level required in the occupation is measured on a scale of 0 to 7—O*NET provides this formula for standardizing the two scales:

S = ((O - L) / (H - L)) * 100

where S is the standardized score, O is the original rating score on one of the three scales, L is the lowest possible score on the rating scale used, and H is the highest possible score on the rating scale used.

Using this standardized score and the formula shown below provided by Muro et al. (2017), we constructed digital scores for each detailed occupation.

$$\text{Digital Score} = \frac{\sqrt{K_{level} \times K_{importance}} + \sqrt{WA_{level} \times WA_{importance}}}{2}$$

Where K is Knowledge and WA is Work Activity.

Once digitalization scores were calculated for each occupation, the O*NET occupations were matched to the detailed 2016 to 2026 occupational projections from the Bureau of Labor Statistics (BLS) using the SOC codes. This matching required that some occupations be further collapsed to match the level of aggregation in the BLS data. For example, the O*NET occupations 'Accountants' with SOC code 13-2011.01 was combined with 'Auditors' with SOC code 13-2011.02 to match the BLS occupation 'Accountants and Auditors' with SOC code 13-2011. Once all O*NET and BLS occupations were matched, we had a total of 761 detailed occupations.

These occupations were then matched with detailed occupations (the OCC variable) from the American Community Survey as provided by the Integrated Public Use Microdata Series (IPUMS) at the Minnesota Population Center. The American Community Survey (ACS) provides information on the demographics of workers in each occupation as well as earnings, the extent of full-time, year-round employment, and share of workers employed in the public sector. Using this detailed information for workers in these occupations, however, required that we further combine some occupations to match the level of aggregation of the ACS. This left us with a total of 463 detailed occupations. All analyses using the ACS combined 3 years of data (2014-2016) to ensure adequate sample sizes.

Historical Database

The historical database was designed to allow us to look at changes in women's employment and earnings between 2000 and 2016. Over this 16-year period levels of digitalization and the use of automation and artificial intelligence increased (Muro et al 2017). This database allows us to assess whether there have also been changes in women's occupational distribution, employment, earnings, or education. To do this, the ACS was used. Because the occupational classification system changed between 2000 and 2016, the IPUMS provides an occ2010 variable that reclassifies all detailed occupations according to the 2010 occupational classification system. Thus, occupations in 2000, 2005-2007, and

2014-16, the years in this database, are consistent and can be compared over time.

Data for 2000 are data from the Decennial Census while the data for 2005-2007 and 2014-2016 combine three years of data to ensure that sample sizes are large enough to analyze at the level of detailed occupations with breakdowns by sex, race, and ethnicity. This database contains data to examine change over time in women's and men's occupations, employment, earnings, and education by race and ethnicity where occupations are large enough and integrated enough to support this level of disaggregation.

The IWPR Future of Work Database

Each of the databases described above contains data for adult workers aged 18 and older. The reader should also note that the occupation variable differs slightly in each database. The occupational projections database uses an occupational categorization scheme that more closely matches the categorization scheme in the Bureau of Labor Statistics and O*NET databases (occ) while the historical database uses the occupation variable that is harmonized over time (occ2010). Data in both databases are only for those women and men employed in the occupation at the time of the survey used (or the 2000 Census).

Regression Analyses

Muro et al. (2017) use a basic regression model to estimate the returns on increasing digitalization of occupations controlling for education, and they found that a one-point increase in an occupation's digitalization scores (score ranges from 0 to 100) was associated with a $292.80 wage premium. Their research did not look at the impact separately for men and women, however. Building on their work, regression analysis was used to consider the returns on digital skills separately for men and women. To examine differences in the returns on digital skill for men and women rather than for all workers in the occupation, the authors used the individual worker as the unit of analysis, rather than the occupation as done by Muro et al. (2017).

This model takes the form:

1) $y = \beta 0 + \beta_1 \chi_1 + \beta_2 \chi_2 + \beta_3 + \beta_2 \chi_2 * \beta_3 \chi_3^2$

Where y is the median annual wage, β_1 is a dummy variable for education (<high school, high school, some college, Bachelor's or more), χ_2 is a dummy variable for sex, χ_3 is the digitalization score (0 - 100). Because our original regression suggested that the results might be curvilinear, we also add an interaction of sex with digitalization squared to capture how increased digital skills differ by sex.

The coefficients are shown in Appendix Table 1.

APPENDIX TABLE 1	Estimates of the Impact of Digitalization on Median Annual Wages			
	Model 1	**Standard Errors**	**Model 2**	**Standard Errors**
EDUCATION				
High School	3535.07	202.48	3020.50	203.24
Some College	6368.38	210.55	5764.39	211.70
Bachelor's Degree or Higher	38335.25	214.58	37772.68	215.42
SEX				
Female	-7922.48	278.42	6276.04	537.52
Digital Score	740.99	3.77	1270.08	14.57
SEX BY DIGITAL INTERACTION				
Female	-304.34	5.42	-1011.050	23.934
Digital Score Squared	-	-	-5.472	0.146
INTERACTION BETWEEN SEX AND DIGITAL SCORE SQUARED				
Female	-	-	7.467	0.253

Notes: All occupations. Earnings are for full-time, year-round workers. The index of digitalization has values from 0 (no use or knowledge of computers) to 100 (very high use and knowledge of computers).

Source: Authors' regression analysis of 2016 (1-year) data from the American Community Survey from the Integrated Public Use Microdata Series (IPUMS) and digital content scores from Muro et al (2017) as calculated in the IWPR Future of Work Database.

To examine the relationship between median annual wages and the probability of automation scores as calculated by Frey and Osborne (2013) separately for women and men to better understand if and how this relationship changed based on sex, a simple bivariate regression model regressing median annual wages on the probability of automation scores per occupation was used.

This model takes the form:
2) $y = \beta 0 + \beta_1 x_1$

Where y is the median annual wage and β_1 is the probability of automation score.

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