CHAPTER 2

TECHNOLOGY-DRIVEN TASK REPLACEMENT AND THE FUTURE OF EMPLOYMENT

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ABSTRACT

In this chapter, the authors offer a critical appraisal of predictions of a jobless future due do rapid technological change, as well as provide evidence on whether the rate of occupational change has been increasing. The authors critique the "task replacement" methodology that underlies the most powerful and specific predictions about the impact of technology on employment in particular occupations. There are a number of reasons why assuming a correspondence between task replacement and employment declines is not warranted. The authors also raise questions about how rapidly the development, acceptance, and diffusion of labor-displacing technologies is likely to occur. In the empirical portion of the chapter, the authors compare the current rate of employment disruption with those observed in earlier periods. This analysis is based on an analysis of occupation data in the US covering the period 1870–2015. Using an index of dissimilarity as the metric, the authors find that the rate of occupational change from 1870 to 2015 does not provide evidence of a sharp uptick in the rate of occupational shifts in the information age. Instead, the rate of occupation shifts has been declining slowly throughout the second half of the twentieth century. Thus, the issues and results discussed here suggest that imminent massive employment displacement is not a foregone conclusion.

Keywords: Automation; robots; job displacement; future of work; jobless future; digitalization

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1. INTRODUCTION

A great deal of attention has been devoted to the specter of a "jobless future." Carl Frey and Michael Osborne's (2017) prediction that 47 percent of jobs in the US (and 2 billion jobs internationally) are vulnerable to automation spawned many headlines, and a small industry of follow-up studies. While Frey and Osborne's work has been particularly influential, a wide spectrum of other authors have also grappled with the future of work and its impact on society (e.g., Brynjolfsson & McAffee, 2011, 2014; Ford, 2015; Mindell, 2015), as have a number of prominent white-paper reports (Executive Office of the President, 2016; OECD, 2016).

The predictions of a jobless future have reached far beyond the websites of labor market specialists. Yuval Harari (2017), following Ray Kurzweill (2005), has perhaps gone the furthest, suggesting that technology is allowing humans to try to "upgrade themselves into gods." Others are taking the jobless future as a starting point in designing the university of the future (Aoun, 2017) and the healthcare system of tomorrow (Darzi, 2018).

Perhaps most notably, prominent leaders such as Richard Branson and Elon Musk and a number of authors and opinion writers have taken the jobless future as a central rationale for a universal basic income (Cohn & Taylor, 2016; Lowrey, 2018; Signorelli, 2017, Weller, 2017). The idea here is that if only a small fraction of society is employed, there must be a mechanism other than wages for enabling members of society to purchase the goods and services being produced by robots and to share in the prosperity the sophisticated machines are capable of producing. In the short term, more conservative commentators (e.g., Cohn & Taylor, 2016) have suggested that the specter of automation represents a compelling case for keeping wages low and benefits few, lest employers have a greater incentive to hasten their adoption of robotic technologies.

Perhaps as a result of powerful headlines, historical examples, the rapid diffusion of cellphones, or a combination of factors, the American public has accepted many of the key tenants of the automated future scenario. Polls indicate that large majorities of survey respondents believe we in the midst of a profound wave of technological change; that new technologies are inevitable and irresistible, and that significant economic displacement is likely (Facilityexecutive.com, 2017; Pew Research Center, 2017).[1]

There is of course a debate about the extent and speed of job displacement, but in our view this debate remains unsatisfactory. Critics of the "jobless future" (e.g., Bessen, 2015; Mishel & Bivens, 2017; Palvi & Vemuri, 2016; Trilling; 2017) stress the empirical fact that large-scale job displacement has not yet occurred, but the theoretical and methodological underpinnings of the job-loss predictions have not been systematically examined. We set this objective for ourselves, along with the presentation of some empirical results that raise questions about whether an automated future is imminent.[2]

The "automated society" thesis rests on four propositions:

1. Computers and other technologies are advancing swiftly and at an accelerating pace.
2. Technological advances as a rule replace tasks performed by people.

3. We are rapidly approaching a tipping point where technology will dramatically reduce the need for human labor.
4. The labor market and other institutions will require fundamental restructuring in order to enable citizens to access the benefits of new technologies.

In this chapter, we reexamine the first, second, and third of these propositions. Technology does not always replace tasks, since many technologies are designed to work with, rather than instead of, people. And the relationship between technological advancement and employment is far from a one-to-one substitution. Many technologies expand human capabilities and generate new types of employment as corollary developments. And sometimes even labor-saving technologies end up producing more work. We outline a number of mechanisms, both proximate and diffuse, that map out some of the ways that technologies add to the demand for workers.

This chapter begins with a discussion of the "task-replacement framework," which provides the principle empirical support for predictions of a jobless future. This section is followed by an examination of some of the assumptions that underlie this approach. We then outline a variety of reasons that labor-saving technologies do not consistently reduce the amount of paid labor.

The empirical core of the chapter is an analysis of the rate of occupational change spanning the period 1870–2015. This analysis is designed to shed light on whether technological change is speeding up or slowing down. The evidence suggests that the rate of occupational change has declined since the 1970s, thus raising questions about whether the pace of occupational change is indeed accelerating. The conclusion suggests that there are good reasons to question the premise that paid employment is on the verge of extinction.

2. THE TASK-REPLACEMENT FRAMEWORK

Several studies have endeavored to explore whether there are tradeoffs between the number of robots and the number of jobs. For example, Daron Acemoglu and Pascual Restrepo (2018) find that the introduction of robots in American commuting (metropolitan) areas reduces employment and wages, particularly for men in blue-collar occupations. The effects are concentrated in automobile manufacturing and other industries such as metal and chemical production.

Drawing on German data, Wolfgang Dauth (2017) finds that the negative effects of robots in manufacturing employment are fully offset by increases in non-manufacturing employment. They also report that "robot exposed" industrial workers did not lose their jobs, although there were negative effects on wages. This research raises the question of whether these results are dependent on institutional arrangements or perhaps macro-economic conditions.

A deeper concern, however, is that robots represent only one type of technology. Employment is potentially affected by non-robotic computers, the Internet, and mobile communication technology as well as technological advances in health care and many other fields. A broader analysis of technology and employment thus endeavors to examine the effects of technology across the full range of occupations, rather than limiting the focus to robots per se.

The most comprehensive approach to the connection between technology and employment is what we call the "task-replacement" framework. When Oxford researchers Frey and Osbourne estimated the fraction of the labor force "at risk" of losing a job, the debate over the future of work became much more focused. In other words, Frey and Osbourne developed a methodology that could attach a number to the automated future that was easily captured in a headline.

Frey and Osborne's article, first published online in 2013, estimates the effect of recent technological advances on the future of employment. They (p. 38) find that

> […] 47 percent of total US employment is in the high risk category, meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two.

They (p. 42) also note "… that computerisation will mainly substitute for low-skill and low-wage jobs in the near future."

Frey and Osborne's task-substitution method is perhaps the most common approach taken by forecasters. This analysis begins with data from the Department of Labor's O*Net surveys on the nature of the tasks performed by incumbents in occupations and proceeds by rating how susceptible each task is to replacement by robots, artificial intelligence, and other technologies. Tasks are rated on nine dimensions, which are in turn grouped into three categories: perception and manipulation, social intelligence, and creative intelligence. Having assigned a probability distribution of automation for each occupation, simple multiplication (or weighting), sometimes hedged with confidence intervals and generous time parameters, yields the fraction of the labor force at different levels of risk of displacement.

Frey and Osborne try to avoid making specific predictions about the number of jobs that are likely to be displaced by straddling the issue of technological inevitability. On the one hand, they suggest that they are merely estimating what is likely to be technologically feasible. On the other hand, they suggest that jobs which are at "high risk" of automation are in fact likely to be automated soon. "We make no attempt to estimate the number of jobs that will actually be automated …" (Frey & Osborne, 2017, p. 268), but they immediately proceed to suggest that jobs in the "high risk" category could be expected to be automated "relatively soon, perhaps in the next decade or two."

A number of studies have followed Frey and Osborne in using this approach to estimate the approximate number of jobs likely to be displaced (McKinsey Global Institute, 2017; Pajarinen & Rouvinen, 2014). A recent example suggests that 30 percent of the work in the British National Health System could be automated using existing technology (Darzi, 2018). Not only is the number high for the labor market as a whole, but in most analyzes jobs with relatively low educational requirements are particularly vulnerable. It is fascinating to see how central occupations are to this debate. It is also odd that very few sociologists are involved in these debates, especially given the long-standing prominence of occupation in the sociological toolkit.

The logic of this approach is powerful: if machines substitute for human labor, over time, jobs will be lost, and perhaps in considerable numbers. After all, machinery has certain advantages over a paid labor force: machines do not need coffee breaks (although they can break and need repairs); they do not ask for increased wages or improved working conditions; they can perform at speeds and consistency that are difficult if not impossible for human labor to compete with. In addition to powerful logic, prominent historical examples support this framework. Tractors replaced human (and animal) labor on farms; trains, cars, and buses replaced horse-drawn transportation; telephone operators have been replaced by computerized telephone switching systems.

3. UNSTATED ASSUMPTIONS OF THE TASK-REPLACEMENT PERSPECTIVE

The task-replacement approach typically takes the arrangement of tasks into jobs as given, yet there are a number of reasons to examine this connection more closely, not the least of which is that the introduction of new technologies can result in the shift in how work is organized into tasks.

Jobs represent a particular configuration of tasks; sometimes these are arranged into full-time positions, and at other times tasks are organized into part-time jobs. In recent years, the "gig economy" has linked compensation to the performance of individual tasks. In this context, employment becomes a matter of collecting enough single tasks rather than securing a position with a salary and benefits. In this way, communication platforms that facilitate creating connections between these tasks may be contributing to the refinement of tasks into smaller and smaller slices (Sundararajan, 2016).

Some organizational psychologists and management analysts have recommended increasing the variety of tasks in a given job in order to reduce boredom and increase employee engagement (Barrick, Thurgood, Smith, & Courtright, 2015; Christian, Garza, & Slaugher, 2011). This approach to job design could also reduce the vulnerability of any particular position to automation. In other words, if one task were automated, jobs with a broader portfolio of tasks would be less susceptible to replacement than those which emphasized a single repetitive task.

The notion of individual tasks should also be given careful consideration. Task replacement assumes that certain repetitive tasks are susceptible to automation, yet the design of particular tasks is often the result of careful analysis and intentional design. Adam Smith famously divided the production of a pin into 18 separate tasks. Smith viewed the process of dividing processes into tasks as central to the advancement of productivity. Frederick Winslow Taylor extended this logic as this basis for his approach to scientific management.

While it is easy to take tasks as given or even natural, we can sometimes see the process evolve before our eyes. Take the case of phone trees, the effort to automate responses to customer inquiries made via the telephone. The process of automation requires taking a conversation between people and dividing into a variety of distinct tracts. For example, those inquiring about business hours are directed to press (or say) one; those seeking to make a new purchase are to press (or say) two; those with service problems, press three (or say), and so forth.

This process can be alienating to customers for a variety of reasons. Personal conversations typically being with a greeting which is absent in the automated context.[3] A customer's issue may not easily fit into the categories provided. A customer may not choose the category that matches his or her issue. And the process creates a set of cognitive challenges to the customer, thus shifting some of the work of obtaining an appropriate response from the company to the customer.[4] Over time, however, customers may become accustomed to automated telephone scripts, at which time the exchange may come to seem more or less natural.

Thus the nature of jobs, the identification and configuration of tasks, and the relationship of technology to these tasks are all socially constructed. These issues are typically not given close scrutiny in studies that seek to quantify the number of jobs likely to be lost or "at risk" due to automation.

Conceptually, this line of critique views work as embedded in cultural and technological interfaces at the micro-level and organizational-technology ecologies at a more macro-level. Empirically, it points on the one hand to finer-tuned analyzes of technology work on the one hand as well as new approaches to using occupational data.

4. TASK COMPLEMENTARITY VERSUS TASK REPLACEMENT

The general public may take it as a given that adding a machine means subtracting a worker, but this conclusion is far from given. Indeed, a long line of commentators have argued that we should strive for complementarity between machines and workers rather than focusing on the substitution of the former for the latter.

John Markoff (2015) suggests that the polarity between complementarity and substitution has been a point of contention among technologists for decades. One school of thought saw the objective of computers as supplementing or augmenting human capabilities, while the other pursued the goal of computers acting independently or autonomously. He summarizes these two approaches as representing intelligence augmentation (IA) on the one hand and artificial intelligence (AI) on the other. The former led to the development of the world wide web, which is designed to facilitate human acquisition of information, while the latter has led to the application of a range of devices, including personal assistants such as Apple's Siri and Amazon's Echo.

Examples of the tension between the IA and AI approaches are examined in detail by David Mindell (2015) in his book *Our Robots, Ourselves*. He notes that the designers of the Apollo lunar missions confronted the question of whether space missions should be manned or unmanned, and, if humans are present, where decision making would be located. Should astronauts have control of the spacecraft, enabling them to act as pilots, or should any adjustments to the flight plan be made in the mission control center, essentially making astronauts into passengers? Mindell maintains that more technology does not (and should not) necessarily mean a diminished role for humans. Indeed, advances in the clarity of vision and the speed of communication can increase people's control of remotely operated vehicles.

While space-bound astronauts represent at most a handful of workers, a similar set of issues presents itself in the context of commercial aviation. Mindell's discussion of a system called a "head's up display" (HUD) shows how sophisticated navigation systems can complement rather than replace the work of airplane pilots.

With HUD technology, pilots view a glass screen where a recommended flight path is superimposed in green lights. The HUD approach resembles the type of "augmented reality" human–virtual interaction that underlies Google Glass. The screen is positioned at eye level so that pilots can simultaneously look out the forward window. The regular sight lines of the pilot are not diverted to a virtual display; rather, the information generated by an autopilot system is displayed so that it supplements what the pilot can see on her own. The pilot's job is to line up an icon of the plane on a green circle on the glass display that represents the "optimal" path toward a smooth landing. This task does not remove pilots from the task of guiding the plane to a safe and smooth landing but rather is designed in such a way as to use both human pilots and machines to best effect. Pilots report that this system engages them and allows them to practice and perfect their landing skills rather than leaving them as disengaged observers of their planes who rely on auto-pilot landing technology. HUD technology has been in use dating back to the 1970s in commercial aviation and even longer in military contexts, with improvements over time occurring in both the underlying simulation information and in the quality of the visual interface.

The question of complementarity versus substitution is active in the case of self-driving vehicles. A number of currently available sensor-assisted systems are designed to reduce accidental crashes and drifting between lanes. This technology, however, does not replace drivers who are still in control and responsible for the safe operation of the vehicle. The question of control becomes more complex when "level 3" autonomy of cars enables drivers to divert their attention from the task of driving until they are alerted to respond to an emergency situation.[5] But only when vehicles are designed with no controls – no brakes or steering wheels – that large employment displacement becomes possible.[6] Cruise-control, where drivers relinquish control for extended periods of time, may approximate self-driving, but drivers remain needed in this type of system in case of emergencies.

5. WHY LABOR-SAVING DEVICES DO NOT ALWAYS REDUCE EMPLOYMENT

Our principal objection to the dire employment predictions developed by Frey and Osborne and others is that labor-saving devices (LSDs) do not always save labor.[7]

While many recognize that technology can create as well as destroy jobs, it is usually assumed that job creation is a separate issue that occurs elsewhere in the economy, separate and distinct from the introduction of a labor-saving technology. The processes summarized here relate more directly to the LSDs themselves. This paradoxical outcome may occur for at least six distinct reasons.

First, new techniques often sharply *reduce the cost* of an activity and consequently expand the volume demanded. The resulting situation is not simply the replacement of human labor but instead a substantially expanded industry. One such example is the introduction of the Xerox copying machine, which increased the volume of documents copied in offices. The time spent copying documents (and filing them, and searching through them, and deciding which to discard, etc.) increased despite the fact that the labor involved in producing any individual copy was substantially reduced. This technology, followed by the widespread distribution of low-cost printers linked to personal computers, has thus far thwarted predictions for a paperless office (Sellen & Harper, 2003). The volume of paper used in offices has increased sharply since 1970, although in the last few years we may be turning a corner on this trend. In a similar way, email substantially reduced the time needed to write a letter, which resulted in far more notes being written, and many person-days consumed by scanning, deleting, organizing and responding to emails.

In a second set of cases, LSDs enable substantial *improvements in quality* that absorb more time and effort. Ruth Schwartz Cowan (1985) carefully researched example of this type is the introduction of the kitchen stove in the nineteenth century. By cooking on stoves rather than on an open hearth, housewives were able to dramatically increase the range and quality of meals prepared for their families, yet this advance did not reduce the amount of time needed to cook dinner. A more contemporary example might be word processing, which sharply lowered the cost of revising documents, thus increasing their quality, yet very likely increasing the amount of time and labor spent to produce them.

Third, quantitative improvements in technology often result in a qualitative transformation of the product or service, thus *expanding the realm of the possible*. Bullet-speed trains (not to mention airplanes) not only replace horsepower but provide transportation service at speed and level of comfort that was impossible with horses. While such distinctions may be difficult to draw in practice, there is clearly a point at which LSDs do not simply replace the effort previously employed by human labor but increase the nature and scope of the activity. Consequently, making a list of jobs that are likely to be replaced by LSDs does not provide a complete assessment of the impact of technological change.

A fourth way that LSDs can expand the volume of work is indirectly via the *creation of new industries*. An early example would be the introduction of the automobile, which increased the speed and reduced the cost of travel so greatly that entirely new industries were created, including tourism. Thus, in calculating the employment impact of the automobile, the lost employment of blacksmiths and other jobs directly connected with horse-drawn transportation, would be most visible, but a full calculus would place the tourist industry among many others on the positive side of the balance sheet.

In a more contemporary example, the case of drone aircraft suggests some unanticipated impacts of automated vehicles on employment. One might expect that remote-operated airplanes would reduce staffing levels by removing the need for a pilot. The unoccupied plane, however, is just one component of a complex system. In the military context, at present, the US deploys squadrons of four drone craft, which require a support staff of roughly 50 at the crafts' landing site. Another 50 are located in the US to analyze the voluminous data generated. And of course the drone requires an operator, so drones may well increase overall staffing needs.

Far more important than the staffing levels for individual vehicles is the vastly expanded missions for drones. In the military context, drones are used for extended surveillance and occasional missile strikes. In other words, drones are used for missions that extend rather than replace those of traditional military fighter and bomber aircraft. Indeed, surveillance can be extended in many directions – to monitor potential attacks on our own bases, to track the flow of enemy troops and weapons, and to track the movement of people and drugs across borders.

The general principle here is that new technologies often sharply reduce the cost of activities and consequently expand the domain of potential uses. Drones are being deployed by farmers to monitor miles of crops in the US for disease and yield, by insurance companies seeking to assess damage to roofs after storms, and by public safety officials to monitor beaches against the risk of shark attacks, among many potential uses. Each of these uses will likely generate jobs for the manufacture and maintenance of aircraft, the remote operation of these vehicles, and analysis of the vast amounts of video and other data these craft will produce once a system for regulating drone use is in place.

In another example of this principle, the increase in data-processing power brought about by personal computers creates the computer gaming industry, which now rivals the film industry in revenue (Babb, Terry, & Dana, 2013). While over 200,000 people are employed in the video game industry, the growth of employment in this area would have to be offset by losses in jobs associated with non-computerized toys.[8]

A fifth consideration is that *old and new techniques often overlap, sometimes for decades*. New technologies are introduced into an existing ecology of related systems, techniques, rules, and customs. Not only do old and new techniques often overlap, but the short-run effects of the LSDs may be directly opposite to their long-term effect. For example, while the introduction of credit cards led many to expect the advent of a cashless economy (Harper & Batiz-Lazo, 2013; Robat, 2011), the subsequent emergence of ATMs helped to extend the life of cash for at least several decades. One may think of ATMs as a transitional technology that extended the life expectancy of an old technology (paper money). The number of bank tellers actually grew most rapidly during the period when ATMs machines were arriving on the scene (employment almost doubled between 1970 – when ATMs were just beginning to be introduced – and 1980).[9] The deregulation of banking led to the proliferation of branch banks (Bird, 1990), and thus bank tellers' jobs increased along with ATMs. Employment in this field remained 40 percent higher in 2010 than when this innovation became widespread in the early 1970s.

Since 2010, the adoption of mobile banking and check-scanning technologies pose a new generation of challenges to employment at brick and mortar banks.

The case of ATM machines suggests that there are often unexpected twists and turns as technologies develop and are implemented. More specifically, technological systems often create the ecological context for subsequent developments in complex and unexpected ways, all of which may bedevil forecasts regarding employment trends in specific fields.

Finally, a full understanding of technological change requires *an appreciation of bottlenecks*. Technologies that overcome bottlenecks in a production system can have very large effects on productivity and employment. On the other hand, technological innovations often underperform expectations because they reveal bottlenecks in the system that were not previously identified. In the case of ATM machines, the bottleneck in communication between cash dispensers and bank computers was overcome during the 1990s, resulting in an essentially new market segment, the installation of large numbers of ATMs in retail outlets. Here again, a new technology has impacts far beyond the replacement of the initial set of employees.

6. TIMING AND SEQUENCING

Let us now consider the matter of timing and sequencing. If the development, acceptance, and diffusion of a wide range of technologies does come to pass in a way that substantially impacts employment, there is still the question of how rapidly this occurs. We would like to suggest that the most likely sequence of events will result in a slow-down in the rate of change as well as creating opportunities for major social adjustments. It is difficult to discern a scenario whereby 47 percent of jobs are displaced all at once, that is, such a short period of time that social adjustments are difficult if not impossible. The essential idea here is that initial rounds of major job losses will slow down the economy, thus slowing the pace of subsequent technological innovations while simultaneously creating the political opportunity for institutional responses.

Let us consider the possibility that, in the next 10 years, major employment shifts occur in retail sales and transportation. This scenario assumes that half or more of cashiers, sales clerks, truck drivers, taxi drivers, and bus drivers face job losses due to online shopping, touch-screen ordering, and self-driving vehicles. This set of changes would cause painful disruptions in the lives of many American workers and their families. In the US, roughly 4.5 million individuals are employed in retail sales, 3.5 million are cashiers, another 3.5 million drive trucks, with perhaps another million drive busses and taxis. The complete automation of these jobs would thus impact as many as 12 million workers.[10] This would represent an employment loss that would be much larger than the increase in unemployment experienced during the Great Recession of 2008–2010, which impacted roughly 7.5 million jobs.[11] Similar developments experienced by major international trading partners might well compound the problem.

There would likely be a number of consequences of the rapid loss of 12 million jobs. First, the economy would sink into a recession, which would result in the decline in business investment, thus slowing the automation of subsequent jobs. In other words, a huge initial wave of job losses would substantially slow down the development and adoption of subsequent employment-reducing technologies. Policy responses – such as aggressive macro-economic policy, job retraining, expanded safety net and investment in needed social services – might be introduced to try to stem the job losses or to cope with their effect.

It is hard to envision a scenario where 47 percent of the labor force loses employment all at once. Even if this all transpires quickly, some sectors will be hit first, and massive initial job loses will both slow the rate of investment in and adoption of subsequent labor-saving technologies, and will instead focus attention on major policy interventions.

7. THE RATE OF OCCUPATIONAL CHANGE, 1870–2015

This discussion of timing leads us to the empirical section of the chapter. A key premise of the automation thesis is that this time is different, specifically that more technologies are being developed than ever before, that they are being adopted more quickly than ever, and that their impact on the job market is more far-reaching than in earlier periods. One can easily point to evidence that is consistent with the "speedup" hypothesis. It is the case that the number of patents approved in the US has climbed sharply since the early 1980s, and some common examples suggest that new technologies penetrate the market more quickly than in earlier decades (McGrath, 2013; U. S. Patent and Trademark Office, 2017). But the implication – that new types of work are coming and going faster than ever – has yet to be tested.

We conducted a study of the rate of occupational change cover the period 1870–2015 to ascertain whether the "speedup" hypothesis is consistent with the data. This project analyzes US decennial census data from 1870 through 2000 and annual CPS and American Community Survey data in more recent years. The method involves using the index of dissimilarity (Jacobs, 1993) to ascertain the extent of the shift in the occupational structure in a decade. This statistic measures the extent of occupational shifts that would be required simply by the changing nature of the available jobs. This indicator represents the minimum amount of occupational movement driven by changes in the occupational structure. This approach provides one measure per decade of the rate of occupational change (until the 2000, after which data are compared across five-year intervals).

Data are drawn from published US census volumes and from the Public Use Micro Samples (Ruggles et al., 2018). These constitute samples of decennial US census respondents. Occupational information is available from a sample of respondents who typically completed the "long form" of the census.

The main methodological challenge is that the list of occupations changes every decade. For example, comparing the occupations in existence in 1920 with those in 1930 assumes the availability of a consistent set of occupations for these two time periods.

Simply using a standard set of occupations (say, the 1950 classification system) solves the problem of comparability (to a certain degree) but over time the comparable statistics become less valid, that is, less reflective of the underlying changes in jobs. The other problem is that the underlying data from 1890 or 1900 were not necessarily collected in a way that is fully consistent with the 1950 classifications. The best strategy is to work at more than one level of occupational aggregation, and to shoot for consistency over shorter time spans (followed by interpolation).

This problem is similar to the challenge of examining the gender segregation of occupations and college majors (Jacobs, 1989, 1995). In both cases, the evidence suggests that movement at different levels of aggregation tend to follow one another. In other words, if there has been a significant change in gender segregation across a limited set of aggregated categories, a similar trend is typically evident when more detailed categories are employed. In this way, using a variety of complementary measures of time trends provides a check on the consistency of the findings.

The findings presented in Fig. 1 are based on eleven broad occupational categories that are consistent over the course of the twentieth century. The results indicate that the rate of occupational shifts peaked during the Second World War and declined slowly but steadily in the second-half of the twentieth century. This highly aggregated measure no doubt misses much of the occupational shifts that have occurred during this time period. As noted above, the principal virtue of this approach is that it provides a consistent baseline for comparisons over time.

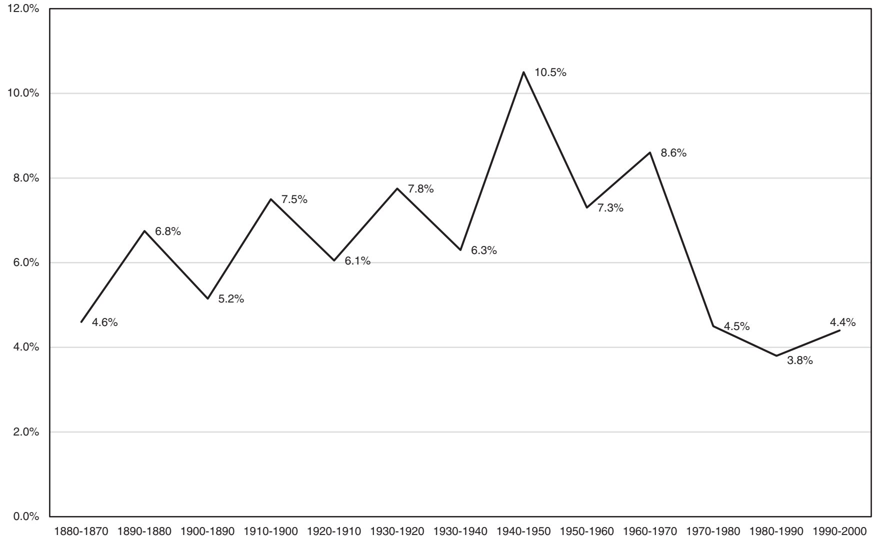

Fig. 1. Trends in Rate of Occupational Shifts, 1870–2000 (11 Major Occupational Groups).

A second analysis utilizes the detailed occupational data based on the 1950 census (see Fig. 2). Both earlier and subsequent census data were recorded in order to be consistent with the coding scheme used in 1950. The results in Fig. 2 mirror those presented in Fig. 1. The trend line for the rate of occupational change has been declining for most of the twentieth century, and particularly during the period since the end of the Second World War.

Fig. 2 includes two trend lines: one includes agricultural occupations while the second excludes them. Agriculture was a major sector of employment during the end of the nineteenth century. We excluded agriculture in order to ascertain whether the high rates of the occupational shifts during the earlier periods of industrialization were simply a matter of shifts out of farming. The data suggest that there were periods in which movement out of agriculture was quite significant, particularly around the period of 1900 and during the 1950s. In both of these time periods, the curve including agriculture falls significantly above the line, which excludes agriculture. Nonetheless, the longer-term picture clearly indicates no evidence of a sharp uptick in the rate of occupational shifts in the computer era.

The period since 2000 is examined in more detail in Fig. 3. Three different coding systems are employed: 1950, 1990, and 2010. The latter two systems include more detailed classifications related to computer employment, and are more detailed in general. As a result, the curves using the more recent coding systems have slightly higher rates of occupational shifts than are captured by the 1950 coding system. Yet the time trend that emerges from each of these measures is remarkably consistent. The graph presented in Fig. 3 consists of three parallel

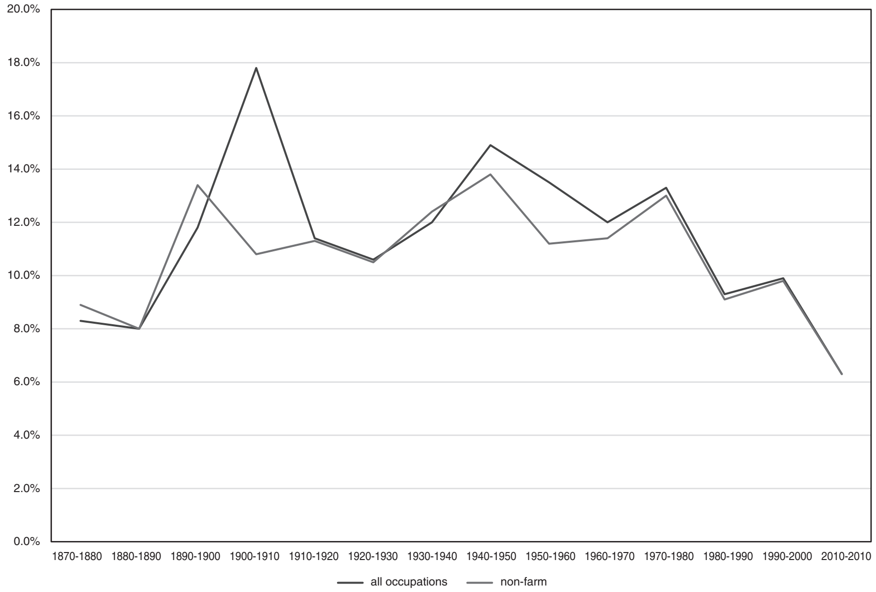

Fig. 2. Rate of Occupational Change, 1870–2010, 1950 Detailed Occupational Codes.

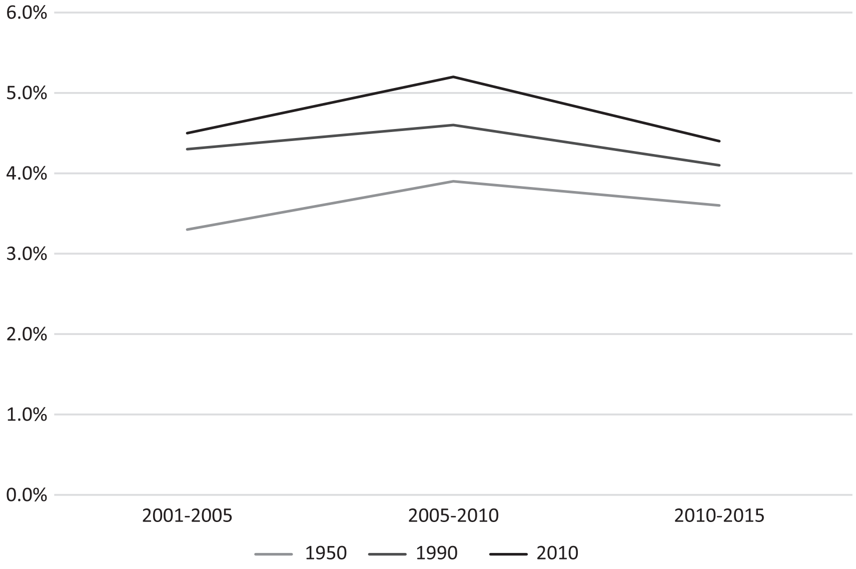

Fig. 3. Rate of Occupational Change, 2001–2015.

lines. This echoes the findings obtained in other settings using occupational and college data at varying degrees of aggregation (Jacobs, 1989, 1995).

Substantively, the picture that emerges shows no evidence of a sharp upward trend in occupational mobility rates. There was a slight uptick in the second of the three five-year periods examined but this was followed by a slight downward trend in the most recent five-year period. There is simply no evidence that the wave of occupational transformation predicted has yet begun.

This analysis is consistent with the findings of a report by Atkinson and Wu (2017). Both studies find that the rate of technological change has been slower in recent decades than during earlier years of the twentieth century. This finding suggests that the problem may be that change has been too slow, not too fast, and is broadly consistent with the sluggish data on productivity growth in recent decades (Conference Board, 2014; Gordon, 2016).

8. CONCLUSION

This chapter set out systematically examines the theoretical underpinnings of a "jobless future," as well as provides evidence to examine the rate of occupational change in the American economy over the last century. We began by critically looking at the task-replacement framework, an approach that seeks to quanify the amount of jobs at risk for automation. While this is the most comprehensive approach to date for examining the connection between technology and employment, there are unstated assumptions that underlie this approach and its corresponding prediction of a jobless future due to automation. The nature of jobs, the configuration of tasks, and the relationship of these tasks to technology are all socially constructed. Studies that seek to quanitfy the number of jobs "at risk" due to automation fails to take into acount that work is embedded in cultural and technological relationships. Adding one machine does not always mean firing one worker. In other words, the relationship between technology and employment is not reducible to a summary of tasks that can be automated. While LSDs and other technological advancements sometimes dramatically reduce employment in specific fields, these changes sometimes increase employment and often alter the *nature* of work, rather than make it obselete. We also raise the issue of how rapidly such development, acceptance, and diffiusion of technologies could occur. Initial rounds of major job losses would slow down the economy and cause painful disruptions in the lives of these workers, which would then both slow the pace of subsequent technological innovations as well as create the political opportunity for institiutional respones.

Indeed, this issue of timing led us to the empirical contribution of this chapter. Using an index of dissimilarity, we find that the rate of occupational change from 1870 to 2015 does not provide evidence of a sharp uptick in the rate of occupational shifts in the information age. Instead, the rate of occupational shifts has been declining slowly throughout the second half of the twentieth century.

Thus, the issues and results discussed here suggest that imminent massive employment displacement is not a foregone conclusion. Yet the suggestion that jobs will remain part of our social and economic landscape going forward does not imply that all is well in the labor market. There are many towns and even regions where jobs remain scarce. There are many low-wage and part-time jobs that are not sufficient to support individuals and their families. The rise of the gig economy raises many concerns about the further erosion of hard-won protections built into full-time employment positions. In other words, there are many things that could be and should be improved in the US labor market.

As we see it, there are two alternative goals based on two competing visions of the future of employment. One view is that well-paying jobs doing meaningful work should be the goal of employment policy. The other suggests that we should begin to prepare for a transition to a post-employment economy. The analysis presented here suggests that it is too soon to confidently predict the demise of work, and thus the goal of providing more job opportunities with better pay and working conditions, complemented by a generous safety net, should remain front and center in dicussions of the future of work.

NOTES

1. It should also be noted that most respondents feel that this will affect other people: most say that their own position is not susceptible to these trends.
2. There are many other important issues facing the US labor market, including inequality, precarious employment, the decline in manufacturing jobs and disparities by race, ethnicity, and gender (e.g., Autor, Dorn, & Hanson, 2015; Autor, Katz, & Kearney, 2006; Gilbert, 2018; Kalleberg, 2009, 2011). The focus here on the specter of a jobless future is not meant to diminish the importance of these issues.
3. The "greeting task" has become a separate job in stores such as Walmart, although greeters can also sometimes double as security guards (Buss, 2016). Touch-screen ordering in fast-food restaurants has led some restaurants to add the job of "greeter," who can help

customers who are having trouble with the screens and clean the dining area (as well as wipe down the touch screens themselves) (Krystal, 2017).

4. Some technologies save labor primarily by shifting work from paid staff to unpaid customers. This process is among the topics discussed by Craig Lambert (2016) in his book *Shadow Work*.

5. This intermediary context, when autonomous systems handle most but not all driving tasks, raise the "handoff problem." Faced with a crisis, drivers can feel disoriented and confused, and their increasing reliance on automated routines may leave them poorly prepared to handle a real emergency. In the aviation context, Mindell cites this type of "handoff problem" as the cause of the crash of Air France flight 447 over the mid-Atlantic in 2009.

6. In some cases, an 80 percent replacement of tasks by machines might result in a substantial reduction in employment, but in other cases the effects can be quite different. For example, 80 percent improvements in language translation software might well increase the number of translators employed if reduced cost and increased speed increased the demand for translation services. There are also some important zero-one cases, like self-driving cars, where there will either be little or no employment impact until vehicles become completely autonomous.

7. Another line of critique of the "task-replacement" framework notes that the creation and destruction of jobs can be orthogonal to the automation of particular tasks. Jobs can disappear not because particular tasks are automated but because the context for that work is disrupted. For example, career opportunities in journalism have declined not because robots are undertaking investigative reporting but rather because the business model of newspapers has been challenged by the Internet. In other words, task substitution in some cases may understate the number of jobs at risk from technology as well as overstating it in others. The point is that the relationship between technology and employment is not reducible to a summary of tasks.

8. The Entertainment Software Association (2017) reported over $30 billion in total revenue in 2016, compared with $38 billion in box office revenue for films (and $67 billion in total film-industry revenue).

9. The number of bank tellers rose from 254,000 in 1970 to 502,000 in 1980, a level of employment that dipped after the 2008 recession but rebounded by 2016. Bank teller employment thus far exceeds the level present at the introduction of ATM machines (U. S. Bureau of Labor Statistics, 2016 and other years).

10. This scenario needs to recognize the fact that there are many other jobs in the impacted industries. For example, while there are roughly 3.5 million truck drivers, the trucking industry employs nearly 9 million people. If we assume 50 percent job losses in these fields and take into account the loss of other jobs in the same industries, the economic impact would exceed the size of the Great Recession.

11. In 2010, the US unemployment rate peaked at 9.6 percent, an increase of 5 percent from the low point registered in 2006. Given a labor force of roughly 150 million, this represented an increase in unemployment of 7.5 million workers.

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