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Abstract

Debates about the future of work frequently reference past instances of transformative innovation to preface analysis of how automation and artificial intelligence could reshape society and the economy. However, technological shifts in history are rarely considered in depth or used to improve predictions and planning for the coming decades. In this paper we show that a deeper understanding of history can expand knowledge of possibilities and pitfalls for employment in the future. We open by demonstrating that evidence from historical events has been used to inform responses to present-day challenges. We argue that history provides the only way to analyze the long-term impacts of technological change, and that the scale of the First Industrial Revolution may make it the only precedent for emerging transformations. Next, we present an overview of the current debates around the potential effects of impending labor-replacing innovation. We then summarize existing historical research on the causes and consequences of technological change and identify areas in which salient historical findings are overlooked. We close by proposing further research into past technological shocks that can enhance our understanding of work and employment in an automated future.

JEL-Codes: J230, J640, J810, N310, N330, N710, N730, O310, O330.

Keywords: technological change, innovation, automation, future of work, technological unemployment, labor displacement.

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Introduction

Technological change is frequently discussed as one of the major challenges of the 21st century. A wave of books in the 2010s depicted idyllic and catastrophic visions of an automated future (Brynjolfsson and McAfee 2014, Ford 2015, Baldwin 2019), and the threat of driverless vehicles causing large-scale job destruction has attracted particular attention (Mohan and Vaishnav 2022). However, the impacts of past innovations on work and labor markets have received only superficial analysis in contemporary discussions. In this paper we argue that deeper investigations of history can make important contributions to debates on the future of work.

The plan of the paper is as follows. Section 1 articulates a general case for how history can provide useful knowledge. We give examples of historical research informing discussions about present-day concerns: during the 2007–09 Global Financial Crisis and the COVID-19 pandemic the public and policymakers looked to history to understand events and inform responses. We present several ways in which debates on the future of work would similarly benefit from a historical perspective.

In Section 2 we review major points in the current debates on the future of work. The discussion is led by economists, technologists, and policymakers, and centers around analysis of which jobs are most at risk of labor displacement, the potential for employment polarization, and whether new technologies will entrench inequalities on multiple dimensions. These debates invoke simplistic histories of the British Industrial Revolution, but rarely engage substantively with past experiences of technological change. While they do implicitly acknowledge the value of history, these anecdotes of previous technological shocks artificially narrow our understanding of the potential impacts of automation and distort expectations for the future.

In Section 3 we review scholarship from economic, social, and technological history on the impacts of innovation on work and labor markets, focusing on examples from Europe and the United States. We highlight research in the following areas: innovation incentives and adoption; resistance to technology; historical instances of technological unemployment; the distributional consequences of new technology; and changes to work organization, job content, and job quality. Past examples of technological change illustrate the extent to which the impacts of technology can be shaped or mediated by individual and institutional choices.

In Section 4 we describe key areas in which the gap between historical knowledge and current debates has led to a narrow perspective on the set of possible trajectories for the future of work. We show that the potential for resistance to technological change, the risk of

technological unemployment, and the uncertain future path of innovation are readily visible in existing scholarship of the history of technological change. We go on to highlight areas in which further historical research could contribute additional insights to future of work debates.

Section 1: History as Useful Knowledge

When we use evidence to analyze choices or make predictions we are informed by the past, whether recent or distant. The more recent past is often assumed to be a better source of evidence for policymaking. It has the benefit of proximity, which gives researchers an expectation that many unobserved variables remain constant between the case study and the present problem. However, there are situations in which the more distant past can provide a more applicable analog. The features of some current problems may only have parallels that occurred far earlier in time: for example, earlier events may be more appropriate comparators because of their scale. Large changes happen rarely, and comparisons with recent but smaller social, economic, or political shifts or events may be inaccurate.

History provides a far wider range of examples and evidence for study than is available in the recent past. If studies of technological change are limited to the last few decades, researchers will have comparatively few examples to investigate and limited variation in the important contextual variables that shape the eventual impacts of an innovation, as we discuss in Section 3. There have been many disruptive technologies in the past, and they have occurred in a variety of settings. Awareness of social, political, and cultural influences on the course and effects of innovation, and of differences between technological waves and their implications, is more acute in history than contemporary research on economics and technology (Freeman and Louçã 2001, Allen 2017).

The methodological diversity of historical research enables a broader perspective on the impacts of technological change than analysis which relies exclusively on approaches from economics. Many aspects of the development, adoption, and consequences of innovation are not easily quantified or modeled mathematically. These aspects are nonetheless significant: some of the most vital questions of 21st century innovation can only be explored by a diverse mix of approaches. Methodological pluralism in history enables analysis of social or political resistance to inventions and non-economic factors that influence the direction of technological change and the adoption of new techniques. Qualitative elements of work that may change dramatically with innovation, such as effort demands and control over the work process, can

also be explored with historical evidence.[1] The mixture of descriptive and quantitative approaches used in history enables a rich and wide-ranging view of the course and effects of technological transformations.

While historical research provides a deep understanding of qualitative aspects of life, it can also be used to construct quantitative accounts for selected periods and dimensions. Recent increases in computing power, together with the new availability of large datasets from the 19th century and later, are enabling scholars to generate a more comprehensive view of long-run economic and social dynamics than had been possible before. Two examples are illustrative: Thomas Piketty's *Capital in the 21st Century* (2014) analyzed long-run administrative data to overturn long-held views on the relationship between development and inequality. In *Streets of Gold* (2022) Ran Abramitzky and Leah Boustan use millions of data points to revisit narratives on immigration and social mobility in the United States. These initiatives reflect a sea change in the study of history. They herald a future in which the past can yield increasingly powerful insights into social science processes, by linking contextual and qualitative information with large datasets. In turn, they may produce a future in which historical evidence is routinely consulted.

Historical research also exploits the depth of information in non-digitized sources to complement large datasets. Archival evidence was a key element of Claudia Goldin's Nobel Prize-winning studies of women's career paths, labor force participation, and the gender earnings gap (Goldin 1990, Goldin 2021, Kungliga Vetenskapsakademien 2023).

Policymaking can be constructively informed by historical scholarship. In two major catastrophes of the last two decades, the Global Financial Crisis (GFC) of 2007–09 and the coronavirus (COVID-19) pandemic, the public, policymakers, and researchers looked to history and historical knowledge to understand the unfolding crisis.

During and after the GFC, economists and economic historians used historical evidence, especially from the Great Depression, to understand which policy responses to financial crises and contractions may be more or less effective, the constraints of currency blocs, and the transmission mechanisms of financial distress to the real economy. Research on the duration of the Great Depression and the constraints of fixed exchange rates under the gold standard was important during public and policy discussions of the slow recovery from the GFC and the ensuing Eurocrisis (Eichengreen 2015, Küsters 2022). The GFC also stimulated research on booms and financial crises, using comparative perspectives (Schularick and Taylor 2012, Calomiris and Haber 2014, Dimsdale and Hotson 2014, Turner 2014, Bordo, Redish et al. 2015, Quinn and Turner 2020) and detailed analysis of individual events (Accominotti 2019).

[1] Some recent contributions from labor research and economics are discussed in Section III below and Berg et al (2023).

Research on the causes of financial crises, their effects, and policy responses with historical perspectives has continued into the 2020s (Albers 2020, Bent 2020, Lennard 2020, Kenny, Lennard et al. 2021, Rockoff 2021).

Insights from economic history directly shaped policymaking: then-US President Barack Obama stated that the Great Depression expertise of Christina Romer and Ben Bernanke was an important reason for appointing the former to be Chair of the Council of Economic Advisors and re-nominating the latter as Chair of the Federal Reserve. Bernanke himself has recently argued that history is essential to understand monetary policymaking (Bernanke 2022), and his work on the Depression (Bernanke 1983) was cited by the Nobel committee when it awarded him the 2022 economics prize (Kungliga Vetenskapsakademien 2022).

Similarly, the COVID-19 pandemic produced a sharp increase in public and scholarly interest in the 1918 influenza pandemic and other historical pandemics, including the Black Death. Faced with supposedly "unprecedented" events, there was a scramble *for* precedents: Google search trends show an explosion in searches for "Spanish flu" and "Black Death" in the first half of 2020.[2] Reflecting this growing popular and scholarly interest, pre-existing research was given much greater prominence, and the COVID-19 crisis stimulated new studies. Scholars have sought to understand the effects of past pandemics on employment, inequality, education, innovation, and other social and economic indicators, and have used these findings to inform public debates and policy (Guimbeau, Menon et al. 2020, Arthi and Parman 2021, Basco, Domènech et al. 2021, Mamelund and Dimka 2021, Alfani 2022, Beach, Clay et al. 2022, Franke 2022, Jedwab, Johnson et al. 2022). The crisis led to the creation of new research centers on pandemics, some of which incorporate historical studies, and more funding for research on past disease outbreaks.

In sharp contrast to the two crises discussed above, the emerging debate on the future of work has seen much less detailed discussion of historical precedents. This is not from a lack of general interest: most of the popular books on automation and the future of work include a brief section on economic history to provide context for recent developments. However, these chapters are almost invariably superficial. The absence of deep historical analysis from the future of work debates is a missed opportunity, as past instances of technological change can illuminate the future of work in unique ways. While there are differences between 21st century automation and past innovations, three salient characteristics make historical experiences relevant.

The first is scale: the First Industrial Revolution (c. 1750–1850) may have been characterized by widespread labor displacement that has been unmatched since. If this was the case, then it

[2] Similarly, searches for terms related to the 1929 financial crisis and the Great Depression spiked in late 2008.

could be the best parallel to what technologists claim will be a wave of labor-displacing innovation in the coming decades. The scale of disruption to the labor market is likely an important factor determining how smoothly workers and economies can adapt to new technology.

Matching the scale and effects of past and present innovations is essential to make reasonable predictions for the future of work. An inaccurate comparison, no matter how good the underlying data, will produce a poor projection. By way of analogy, even if an economist in 1750 had access to excellent data from the then-recent past and econometric tools equivalent to those available in the 2020s, he would not have been able to predict the dramatic transformations of the following century. Contemporary research constrained to data from the last half-century, which has seen less transformative innovation (Bloom, Jones et al. 2020, Park, Leahey et al. 2023), may draw misleading lessons for the future of work. In Schumpeterian language, while the gales of creative destruction have been perennial over the last two centuries, some storms have greater force.

Second, and relatedly, there is a fundamental similarity between the innovations of the First Industrial Revolution and the goals of current automation. Both are intended to be labor displacing. The major technologies of 1750–1850, in broad terms, replaced human and animal muscle and dexterity with inanimate power and implements. Textile machines supplanted the arms and legs of weavers and the hands of spinners. Sewing and riveting machines replaced the hand-sewing work of bootmakers. Steam engines took the place of human strength and draught animals to drive machinery and move goods over water and rails. Technologies of the Second Industrial Revolution (c. 1850–1940) improved on these inanimate methods in physical production, and the Third Industrial Revolution or ICT Revolution (since c. 1970) introduced early digital technologies that primarily augmented and did not replace labor. The potential impacts of the automation revolution or "Fourth" Industrial Revolution are most similar to the First Industrial Revolution: technologists are aiming to replace human cognition in the workplace, superseding the human brain's capacity for pattern recognition and routine decision-making.[3]

Finally, the full effects of technological change on the labor market and workers can only be captured over the long run, which requires historical analysis. Historical experiences include entire cycles of labor replacing technology for study, whereas the effects of recent innovations are incomplete and complicated by interactions with global trade and offshoring. Analyzing the life cycles of both workers and technological shocks requires a long-term perspective. This is necessarily true of the intergenerational impacts of the shocks. Analysis and comparison of historical changes in technology over the long run can enable more informed decision-making

[3] Some researchers have questioned whether automation technologies will achieve this goal (e.g. Cetrulo & Nuvolari 2019, and, more forcefully, Munn 2022).

by firms, workers, and governments about how to approach the risks of technological unemployment, the potential for job-changing innovation, and how to secure the opportunities of inventions that replace human labor.

Section 2: The Current Debates on the Future of Work

At present, debates on the future of work are dominated by economists, technological futurists, and policymakers. Most discussions start with estimates of how many jobs are at risk of automation. Estimates are high. The much-circulated paper by Frey and Osborne (2017) found that up to 47% of jobs in the United States were potentially automatable. While this seminal article presented higher estimates than later studies, follow-up papers still provide concerning projections (Arntz, Gregory et al. 2016, Chang and Huynh 2016, Manyika, Lund et al. 2017). These emerging views stand in sharp contrast to the sanguine outlook economists once held about the impact of technological change on labor displacement.

Beyond the potential scale of the labor market shock, the discussion considers three further concerns. The first of these is whether the emergence of artificial intelligence (AI) is different from past waves of innovation and may lead to permanent technological unemployment. The second addresses the distributional effects of labor displacement and reinstatement. A third concern, that has received less discussion in public debates but for which there is a growing body of academic research, is the effect of these new technologies on job quality.

2.1: Permanent Technological Unemployment and Distributional Effects

A central question of the future of work debate is whether new technologies will permanently replace human labor. Anxiety about permanent technological unemployment is perennial: Aristotle wrote about it, as did Karl Marx, Jean-Baptiste Say, David Ricardo, and John Maynard Keynes (Bix 2000).

Prior to the era of modern economic growth, concern that new technologies would displace labor often created political barriers to their adoption (Frey 2019). However, over the last two hundred years, in aggregate, more new jobs have been created than lost. This did not mean that transitions were painless: some workers faced periods of unemployment, a decline in the value of their human capital, and technological shocks may have entrenched geographic or intergenerational disadvantages.

The emergence of AI has revived real concern that new technology may cause permanent technological unemployment, which most participants in the debate claim has not been

considered a threat since the early 19th century.[4] The central contention is that AI will outcompete human labor on every front, and that the new work created by new technology will also be performed by machines (Pratt 2015, Susskind 2020). It is worth noting how very recent this revival of the old concern has been. It is only in the last decade that it has received serious consideration by scholars, and despite the new interest in this area, most economists continue to avoid the well-established Keynesian terminology. Instead of discussing technological unemployment, they refer to "labor displacement" (Acemoglu and Restrepo 2019), or the "equilibrium impacts of technological progress" (Goos 2018). Despite the neutral language, economists are increasingly concerned: in a recent poll of leading economists, 35–40% agreed that artificial intelligence will increase long-term unemployment (Autor 2022).

The second concern is that the adoption of new technologies may entrench inequality. This consideration is linked to the short-term labor displacing impacts of technology. Autor (2022) frames changing perspectives in recent decades as the product of three models that economists have used to understand how the adoption of new technology impacts labor market outcomes. We follow his typology here and discuss how each model implies a different set of distributional effects driven by the adoption of new technology, and each has produced a paradigmatic set of expectations about the labor market impacts of innovation.

The first model, Skills Biased Technological Change (SBTC), is the canonical "race between technology and education". It casts the distributional impacts of the adoption of new technologies as the result of supply and demand. When the supply of highly-educated workers increases, their wage premiums will not decrease if the demand for their skills keeps pace or exceeds the additional supply (Tinbergen 1974, Goldin and Katz 2008). The model allows that highly skilled workers may be securing a skill premium. However, it does not imply that the real wages of low skilled workers will decline. Therefore, while the adoption of new technologies may be driving an increase in inequality, this is the result of increasing skill premiums. The model focuses on the impact that new technologies have in terms of skill premiums and does not explore job creation or job loss resulting from changes in the demand for skills.

In the paradigm informed by SBTC models, innovation increases the wage premium for highly skilled labor. Early SBTC models were based on the countervailing forces of supply and demand: new technologies have a skills bias and increase demand for highly skilled workers. This increased demand, if it is not offset by increasing supply, then drives a wage premium for skill (Tinbergen 1974, Goldin and Katz 2008). In *The Race Between Education and Technology*, Goldin and Katz show that despite a large increase in the number and proportion of highly skilled workers in the United States over the last century, wage premiums persist.

[4] In fact, there was substantial public concern about permanent technological unemployment at various times in the late 19th and 20th centuries, most notably in the 1930s (Commons 1926, Bix 2000).

Sustained demand for highly skilled workers is driven by the ongoing technological innovations powering modern economic growth (Goldin and Katz 2008).

The second model, Routine Biased Technological Change (RBTC) or the "Task Polarization Model" identifies the impact of innovation at the task level. Introduced in the early 2000s and built on the scaffolding of the SBTC model, RBTC takes as its starting point that the adoption of new technologies impacts tasks within occupations (Autor, Levy et al. 2003). This model allows for differential impacts of technological change within an industry or an occupation: some workers are more exposed to labor-replacing innovation, and more routine tasks are more likely to be replaced. Empirical papers often find a hollowing out of the occupational structure and polarization of incomes resulting from the adoption of new technologies (Goos and Manning 2007).

The third and most recent model is one of labor displacement and reinstatement (Acemoglu and Restrepo 2019). In this model, the impacts of shifting demand for labor are considered both in terms of skills premiums or penalties and job loss and job creation. Autor et al (2022) show that new jobs created in recent decades are frequently poorly paid, have bad working conditions, and lack a safety net. Moreover, 50–70% of the increases in wage inequalities between 1980–2016 can be attributed to the polarizing impacts of new technologies (Acemoglu and Restrepo 2022).

The academic research on technological unemployment (more commonly called labor displacement) and wage polarization is commonly cited in policy discussions (OECD 2019). At present, these focus on retraining workers. The MIT Work of the Future group states "[o]ur policy focus is on education and training for adults, particularly those whose work is more vulnerable to automation". This approach may be the legacy of the decades of work done within the SBTC paradigm, but the MIT researchers acknowledge that it has seen relatively little success and policy makers are exploring new ideas. The authors also acknowledge that more research is needed to understand how to serve workers displaced by new technologies (Autor, Mindell et al. 2020). There are some new discussions about labor regulation and mechanisms to incorporate worker voice in how new technologies are used (Autor, Mindell et al. 2023, OECD 2023), but these have received much less attention than skills training.

There is a small body of research on the effects of contemporary automation and algorithmic management on job content and quality (Smids, Nyholm et al. 2020, Antón, Fernández-Macías et al. 2023, Berg, Green et al. 2023). Despite the important contributions of this incipient literature, it remains largely peripheral to the books and policy papers that lead the public and policy discussions about automation. Next, we turn to those agenda-setting works and the policy debate about the future of work.

2.2: History in the Contemporary Debate

Many recent books addressing the automation revolution include a historical chapter (Brynjolfsson and McAfee 2014, Ford 2015, Baldwin 2019, Bootle 2019, Susskind 2020, Aghion, Antonin et al. 2021), but this is often merely a framing device. Usually placed immediately after the introduction, these chapters present a brief, simplified summary of global economic history over the last 2000 years. The consistent message is that poverty was the norm and there was little growth for thousands of years. In the late 1700s a series of inventions dramatically changed the British economy and society, and eventually spread to the rest of the world. Prices for manufactured goods dropped, and consumers everywhere enjoyed a wider variety of cheaper products. Some workers lost their jobs, but creative destruction also generated new employment opportunities, and by the mid-19th century most people had benefited substantially from industrialization. The discussion generally ends on this optimistic note, without considering the adaptation process or lasting impacts of these shocks on workers, families, or places. It bases expectations of the future on a misunderstanding of the past: there may be some disruption, but innovation will proceed and improve wellbeing across the globe. A few of the recent books on the future of work do acknowledge short-term "frictions" introduced by job destruction (e.g. Baldwin 2019), but evidence of deleterious long-run impacts from past technological change (Section 3.3 below) is generally overlooked. On the other hand, that historical experiences—even if highly simplified—are referenced so frequently underlines our argument above that the past is a natural reference point in the face of potentially dramatic change or crisis.

In policy documents the history of innovation and labor displacement is mentioned only in passing. The UK Future of Work Commission Report (2017) at first strongly endorses the value of understanding history to suggest possibilities for the future: "The best guide to what might happen in the future, and the role of policy in shaping it, is almost always the past." However, it condenses technological and economic history since the 17th century into three short paragraphs.

The OECD's 2019 Employment Outlook analyzes the future of work by considering the characteristics of AI, and classifying potential AI innovations as augmenting or replacing labor. There is little discussion of history and nearly all of the report only analyzes recent developments. It claims that while technology may displace some current workers, "a substantial contraction of employment is unlikely". In part, this claim is based on the assertion that "[h]istorically, the net effects of major technological revolutions on employment have been positive" (OECD 2019). The OECD's most recent (2023) Employment Outlook focuses on the realized and possible impacts of artificial intelligence, motivated by concerns about ChatGPT. While the report takes a somewhat more cautious tone and acknowledges growing concern about labor-replacing and job quality effects, its perspective is even more short-

termist than the 2019 report, focusing almost entirely on developments since the COVID-19 pandemic.

Similarly, the ILO's Global Future of Work Commission Report (2019) and the white papers produced by the World Economic Forum's Preparing for the Future of Work Project and related programs make little reference to the historical experience (2016, 2018a, 2020a, 2020b, 2020c, 2023). Despite repeatedly framing the future as a "Fourth Industrial Revolution", the authors take little note of predecessors. Even a WEF white paper that projects different possible scenarios for the future of work does not consider past innovation paths or their implications (2018b).

The Institute for the Future of Work's recent (2022) report initiating the Pissarides Review notes uneven rates technological adoption between firms and unequal impacts of technology on job quality. The report alludes to historical parallels and the presence of "winners" and "losers" in past waves of innovation, but does not provide further depth. As discussed below, these points could be strengthened with reference to historical episodes of innovation.

Some contributions to the policy debate from academia have taken a slightly broader perspective and, perhaps as a partial result, present a more cautious view of the future. The 2019 MIT Work of the Future report, as is common, begins with history. One short section provides a reasonably balanced high-level survey of the long-run benefits and negative impacts of technology. The policy prescriptions, however, do not incorporate evidence or perspectives from past instances of dramatic innovation.

The message from these reports is broadly the same as that described in the public-facing books discussed above. When history is mentioned at all in these discussions, it is used to suggest that technology may cause some disruption in the short-run, but it will not produce significant unemployment. Experiences of the past are not used to inform policy recommendations.

Section 3: Technology and Work in History

Incorporating existing research on historical experiences of technological change can contribute to a better understanding of impacts on work and labor markets. In this section we synthesize findings in five areas that are relevant for future of work debates.

Topic 3.1: Innovation

Schumpeter (1942) cemented the importance of innovation in technological change and the process of creative destruction. Economic historians have made significant progress, especially in recent years, in understanding the long run dynamics of innovation. Researchers

have provided evidence for the importance of scientific knowledge, networks of information, human capital formation and education, factor prices, and market size. Historical studies have also illustrated the difficulty of predicting which technologies will dominate, and explained the long persistence of older techniques (Edgerton 2007).

Perhaps the most influential arguments discuss the relative prices of capital, land, and labor. The work of Hicks (1932), Habakkuk (1962) and most recently Allen (2009) has argued that inventors seek to economize on the most expensive factor of production. In the United States in the 19th century, this produced skilled-labor-saving innovation that used natural resources extensively by comparison with British practices (Habakkuk 1962, Temin 1966, Ames and Rosenberg 1968, James and Skinner 1985, Broadberry 1997). The production of knowledge on induced innovation has led directly to significant public discussions and attempts to base policy on economic history research (e.g. the British government's claim in 2021 that it would create a "high-wage" economy, BBC 2021).

Researchers have shown that networks of producing and sharing knowledge are a contributor to innovation (Mokyr 2002), as are the skills or human capital of both potential inventors (Squicciarini and Voigtländer 2015) and technology adopters (Hornung 2014, Kelly, Mokyr et al. 2014, de la Croix, Doepke et al. 20178)

The institutional shift in economic history has contributed to our understanding of the best conditions for innovation. Beginning with North & Weingast (1989), economic historians and economists have argued that formal and informal institutions enable (or inhibit) and shape the directions of innovative activity (e.g. Acemoglu et al. 2005, Cantoni & Yuchtman 2014, Cox 2017).

Following from interest in institutions, scholars have begun to investigate the role of culture. While this area remains more debated than that of institutions, a number of papers have argued that culture is important for growth, either directly (Becker and Woessmann 2009) or through institutions (Temin 1997, Belloc, Drago et al. 2016).

In addition to research on the drivers of innovation, historical studies provide a different perspective on technological adoption. A number of studies have shown how innovations that later appear demonstrably superior are not always rapidly or uniformly adopted. Two examples are the variety of power sources and designs available to early automobiles (Wells 2007) before the internal combustion engine became dominant, and the competition between railroads and canals for long-distance transportation in the 1820s and 1830s (Goodrich 1961). These cases show that there were multiple technological paths available at many points in history (Edgerton 2007, Acemoglu and Johnson 2023a), as there are now.

Similarly, historical examples of innovation show that technological diffusion is an extended process, and not purely because firms were locked-in. Sailing ships continued in use long into the age of steam (Harley 1972, Harley 1973), and water power was a major source of energy for American manufacturing up to the end of the 19th century (Hunter 1979, Hunter 1985, Hunter and Bryant 1991). Seemingly obsolete technologies can continue in use for many decades, with implications for available jobs, work organization, and job locations. These points are occasionally, but rarely, mentioned in future of work discussions (OECD 2019).

There are a number of causal mechanisms driving growth through innovation (Koyama and Rubin 2022). While the structures for generating and sharing new ideas have changed with the rise of corporate R&D and government research funding (Reich 1985, Usselman 2002), economic, social, political, and cultural forces continue to shape the rate and direction of technological development and diffusion. History has provided a firmer basis for understanding the conditions that are conducive to innovative activity, the incentives that encourage inventors to develop technology in different directions, and the uncertain path of technological development.

Topic 3.2: Social and Political Responses to Technology

Historical cycles of technological change demonstrate that the adoption of new technology is not simply a matter of inventors developing ideas and entrepreneurs deciding whether and how to use new techniques. Instead, the process is frequently mediated by politics, and sometimes violence. The most famous example is machine breaking during the First Industrial Revolution, and Luddites make a cameo appearance in most popular books about the future of work. However, they were neither the only nor the first instance of direct action against job-replacing innovation.

We can begin from a frequently-cited anecdote: William Lee developed the first stocking frame for knitting in 1589 and applied to the British crown for a patent. Queen Elizabeth I is reputed to have said "Thou aimest high, Master Lee. Consider thou what the invention could do to my poor subjects. It would assuredly bring to them ruin by depriving them of employment, thus making them beggars". The hosiers' guilds had lobbied the Queen to block Lee's innovation as they were concerned it would displace their labor (Frey 2019).

Technological resistance has been much more widespread and sophisticated than this example. Some researchers have argued that guilds systematically opposed the introduction of new labor-replacing or deskilling technologies (Mokyr 1992, Frey 2019). Others have argued that the guilds supported new technologies which reinforced their existing position in the market, and resisted those which undermined it (Epstein 1998).

As well as the Luddites in the 19th century, workers destroyed spinning jennies during the 1770s (Aspin 1964), and the "Captain Swing" riots saw the destruction of threshing machines, mostly in Southern England, around 1830 (Hobsbawm and Rudé 1969). This resistance to innovation was ultimately unsuccessful, but localized machine-breaking may have delayed or limited technological adoption in some areas, which contributed to later decline and deindustrialization (Mann 1971). Indeed, the stocking frame example is but one instance in which resistance to technological change was so strong that innovations were prohibited outright (Frey 2019). Whether the state responded to popular resistance with repression or conciliation also played a role in enabling or limiting technological adoption (Horn 2005), which may have had long-run consequences for development.

One of the most significant contributions in this area is by Nuvolari (2002). He argued persuasively that machine-breaking in the First Industrial Revolution was primarily intended to *direct* technological adoption away from deskilling technologies that demanded factory discipline, and not simply to prevent innovation outright. Other studies have examined how machine-breaking may have been related to the adoption of labor-replacing technology (Caprettini and Voth 2020).

Incorporating this history demonstrates that resistance to technological change can be a rational response for workers whose earnings are threatened by innovation, and may aim to shape, rather than simply block, technological transitions. Machine-breaking, mediated by politics and state coercive capacity, may have affected differing rates of technological adoption but as we will discuss in Section 4, this question merits further study. The history of resistance to technology also underlines that the impacts of innovation are not a fixed outcome determined purely by the features of an innovation, but can be altered by human decisions.

Topic 3.3: Technological Unemployment in History

There has been a long-running debate about whether labor displacement took place during the Industrial Revolution. Some scholars refer to technological unemployment that devastated workers (Frey 2019), while others doubt whether substantial and sustained job destruction occurred at all (Mokyr, Vickers et al. 2015). In addition to the scarcity of comprehensive occupational information for now-rich countries before the mid-19th century, researchers have always faced the difficulty of disentangling technological unemployment from other sources of changes in labor demand (Bix 2000). A few new papers are quantifying the extent of past labor displacement.

The canonical episode of technological transformation, as discussed above and mentioned in contemporary debates, is the First Industrial Revolution. Historians have debated whether

there was job loss in this period, as well as its scale and extent, for more than 100 years. These discussions have usually been part of debates about how British living standards changed during industrialization. One of the earliest prominent "optimists", J. H. Clapham, described the "loss of domestic spinning" in certain regions, but did not dwell on any long-term consequences as he claimed, unevidenced, that it was replaced by other rural by-employments and the effects were only severe for some "widows and others who had lived by spinning" (Clapham 1926). This assertion is part of a tradition of minimizing the elimination of female-dominated occupations (Humphries and Schneider 2021), from which gender historians have been the main dissidents (Pinchbeck 1930, Valenze 1995). In their series on British laborers, the pessimists Barbara and J. L. Hammond pointed to descriptive evidence of unemployment and highlighted that what appears as "temporary" job loss in hindsight could nonetheless have been injurious to workers. They also emphasized the importance of regionally concentrated unemployment (Hammond and Hammond 1920). T. S. Ashton noted technological unemployment *en passant* in his general history of the Industrial Revolution (Ashton 1948), but it did not merit a mention in his 1949 article on the standard of living.

In a later round of the living standards debate Max Hartwell conceded that there were "pockets of underemployment" and "technological underemployment" after Eric Hobsbawm emphasized this point in their exchanges (Hobsbawm 1957, Hartwell 1961, Hobsbawm 1963). Nonetheless, Hartwell downplayed the importance of job loss. Later contributions from Jeff Williamson and Peter Lindert dismissed unemployment as a significant drag on living standards in their key contributions (Williamson 1980, Lindert and Williamson 1983), while focusing—as many late 20th century writers in this area have—on male unemployment.

Although job loss appeared at various times in these debates across many decades, the difficulty of measuring unemployment during the 18th and 19th centuries limited its salience. Indeed, the lack of national statistics for unemployment has left it out of the most recent research that assesses changes in living standards using composite indicators of wellbeing (Gallardo-Albarrán and de Jong 2021). Following the limited quantitative evidence on job destruction during the First Industrial Revolution, recent popular books on the future of work suggest that technological change has always generated enough new jobs to replace those destroyed by innovation in the medium term (Brynjolfsson and McAfee 2014).

The recent digitization of census records and administrative data has allowed researchers to directly quantify some instances of technological unemployment and capture its effects on workers. Feigenbaum & Gross (2020) have shown that the automation of telephone switching in the US during the early 20th century, which replaced manual operators, pushed incumbents out of the labor market or into lower-paying jobs. Two other recent papers explore the outcomes of mechanization on employment in the United Kingdom. A study of the impact of mechanization on the British bootmaking industry in the 19th century finds that approximately

150,000 jobs were lost as the industry mechanized and 142,000 jobs were created. However, incumbents did not move from the old jobs into the new (Vipond 2022). Industrial innovations also eliminated the widespread occupation of hand spinning, which had employed up to 10% of the British population in 1770. There was scant labor reinstatement and the resulting job loss persisted at least into the 1830s (Schneider 2023).

Two other papers take a less direct approach. The first draws on the Hand and Machine Labor Study (1894), which compared the relative productivity of manual and mechanized labor across a range of US industries. The paper finds that mechanization led to both job loss and job creation (Atack, Margo et al. 2019). A second paper matches US patent data with extensive administrative data, and finds that industries exposed to technological innovation experienced declining wages and a decrease in the number of jobs (Kogan, Papanikolaou et al. 2021).

While several papers find that new jobs were generated to replace those lost to new labor-saving technologies, access to these new employment opportunities was stratified by gender, age, education, and geographical location. Incumbents whose skills were rendered obsolete by new technologies may have had limited opportunity to move into newly created jobs.

Topic 3.4: Distributional Effects

The three paradigms discussed in Section 2.1 have all been applied to economic history. An early paper using the SBTC model, by Claudia Goldin and Lawrence Katz (1998), argues that while the innovations of the First Industrial Revolution may have been de-skilling, this was not the case from 1909 to 1929 in the US. Instead, the adoption of new technologies over this period was correlated with higher pay. More recent papers arguing that the adoption of new technology is associated primarily with an increase in pay for highly skilled workers include Bessen (2011), which used micro-data to assess the skill levels of weavers in the 19th century US and concluded that the automation of tasks was linked with higher levels of skill. Van Lottum and Van Zanden (2014) found skill complementarity in the 18th century shipping industry, and Ridolfi, Salvo, and Weisdorf (2022) use French industrial census data from the 19th century and conclude that areas with more steam engines had more and better-paid jobs.

Other historical papers have found impacts that fit a routine-biased technical change model. Chin et al. (2006), using an extensive individual-level dataset of wages for seamen, found that the transition between sail and steam created both a deskilling effect, as able-bodied seamen were replaced with unskilled workers, and a skills-biased effect, through the new demand for engineers. The average wage for workers on steam ships was 40% higher than workers on sailing ships. In addition to higher income inequality, the authors also found labor displacing impacts as employment of able-bodied seamen and sailmakers fell. Another paper leveraged historical employer–employee panel data and found that the introduction of steam technology

had both deskilling and skill-demanding impacts (Hynninen, Ojala et al. 2013). The distributional impacts of the RBTC paradigm are less benign than those in SBTC-type models, by construction: the new technologies increase inequality not only through rising skill premia, but also as the result of low-skilled workers receiving lower pay or being displaced entirely from the production process.

The most recent paradigm, labor displacement and reinstatement, has also been applied to historical instances of innovation. Papers have found that the adoption of new technologies has been correlated with both declining wages and fewer employment opportunities for impacted incumbents (Atack, Margo et al. 2019, Feigenbaum and Gross 2020, Kogan, Papanikolaou et al. 2021). It is notable that many economic history papers that aim to quantify technological unemployment also explore the distributional impacts. Relatedly, Humphries & Schneider (2021) argue that because the destruction of hand spinning during the British Industrial Revolution drove hundreds of thousands of women from paid work, it led to the development of the male breadwinner family model.

While economic historians have begun to investigate the diverse impacts of technology on employment over the medium term, the individual consequences of job loss and the intergenerational impacts require further investigation.

Topic 3.5: The Organization, Content, and Quality of Work

The task-based breakthrough in modeling the impacts of innovation (Autor, Levy et al. 2003) and potential future effects (Frey and Osborne 2017) draws attention to the effects of technology on the content and organization of work. The most important and studied example of changes in the organization of work in historical contexts is the establishment of factory production during industrialization. Another important area of research has been in the changing task composition of labor, which emerged as a subsidiary element of debates about the direction of technological change in the 19th century United States (noted in 3.1 above). These two strands have implications for the quality of jobs, which has seen growing interest in contemporary studies, including by researchers interested in the future of work. One limitation of existing historical research on the organization and quality of work is that economic historians have taken little interest working conditions and the content of jobs, while labor historians have rarely used a systematic, comparative approach.

The rise of factory production led to a fundamental shift in the organization of work through the development of centralized work premises. While some large construction projects in the pre-industrial age had fixed, central work locations, the permanence and division of labor in factories set them apart from these earlier projects (Pollard 1965). Centralization was essential to exploit inanimate power sources, but it also enabled work discipline and was accompanied by shifts in job quality.

The classic downside of factory work by comparison with home-based labor was a sacrifice of employee control. This was usually accompanied by other changes such as longer working hours, lower occupational safety, and more exhausting labor, all in exchange for higher and more stable wages. Even so, employer control was the foundation of the disamenities of factory work (Marglin 1974, Schneider 2022). The tradeoffs of factory labor have been discussed by researchers for decades (e.g. McKendrick 1961, Pollard 1965, Thompson 1967, Rule 1981) albeit without a systematic approach. The recent development of job quality measurement (Clark 2005, Cazes, Hijzen et al. 2015, Warhurst 2017) and its application in history (Schneider 2022) enables a clearer analysis of how technology has changed work tasks, practices, organization, and job quality. Differences in work systems between firms and locations again suggest that human decisions as well as technology shape work organization and quality (e.g. Cohen 1990, Lazonick 1990). In this spirit, longue durée social history can make important contributions to understanding the forces that have changed the organization of work (Lucassen 2021).

A second strand of related literature considers changes in the task content of work. A classic formulation comes from the American gun-making industry in the 19th century: induced innovation, responding to expensive skilled labor, led to the invention of deskilling technology, which replaced skilled employees with semiskilled workers and advanced machinery (Ames and Rosenberg 1968, Hounshell 1984, James and Skinner 1985). This deskilling made work more repetitive. Its descendant is the division of labor in an assembly line factory, which followed the Smithian principle whereby workers focusing on fewer tasks would be more productive (Hounshell 1984). The assembly line system also added dimensions such as the ready supply of parts and tools to reduce walking time on the factory floor. To increase productivity, workers were forced to be more like machines, similar to present-day work practices in Amazon fulfillment centers (Yeginsu 2018). In the 20th century a number of studies explored the effect of increasing routinization and contemporary automation on the mental health of autoworkers, generally finding negative results (Walker and Guest 1952, Kornhauser and Reid 1965).

There is significant space for further studies in this area, especially using systematic and comparative approaches, but the existing studies show that First and Second Industrial Revolution technologies increased labor discipline, at least partly compensated by higher and more stable wages, and skill-replacing technology made some of this low-control work more repetitive. Routinization has also been associated with poor mental health since at least the mid-20th century. Parallels with aspects of recent technological change (as in the fulfillment center example) suggests that there is value in more detailed analysis of this process in the past.

Section 4: Including History in the Debate

Having discussed the current debates on the future of work in Section 2 and reviewed the literature on past instances of technological change in Section 3, we now summarize areas in which historical research could contribute to a richer and more comprehensive understanding of the possibilities and pitfalls of technological change. At present, most economics research and policy planning for this subject does not integrate history. The public-facing narrative in the books discussed in Section 2.2 presents a thin version of the past that shapes expectations of the future. Integrating historical analysis of the causes and consequences of innovation would improve academic and policy discussions. We discuss four areas in which debates on the future of work would be improved by existing research on the history of technological change (4.1). We then (4.2) survey how new research on past instances of innovation could further enhance our understanding of possible futures of work.

4.1: A Broader View

Firstly, as discussed in Section 3.2, historical evidence shows that there has been considerable social resistance to labor-replacing technologies. In addition to the examples above, the containerization of shipping threatened jobs for longshoremen by the 1970s, but strong unions in some countries resisted layoffs for decades (Turnbull and Wass 1994, Levinson 2016). This issue extends beyond the challenge of automation: a rapid net zero transition implies job loss in some industries (Scheer, Schwarz et al. 2022). A recent ILO report on the employment impacts of climate change adaptation argues that transition and mitigation measures will, on net, generate employment opportunities that offset lost jobs (Maitre, Behrendt et al. 2018). However, a survey in twenty countries that together account for 72% of global CO2 emissions finds that support for climate change policies hinges in part on their perceived impact on the respondents' household (Dechezleprêtre, Fabre et al. 2022). Writers on the future of work and the green energy transition have not sufficiently allowed for the possibility of widespread, and even effective, resistance to technological change. The same questions haunt the recent emergence of generative AI, including ChatGPT (Acemoglu and Johnson 2023b). Despite this, few economists have looked towards past examples of transformative innovation and their reception.[5] To project possibilities for the future of automation, researchers and policymakers need to consider the politics of resistance to job-replacing and job-changing innovation.

Secondly, and *contra* Mokyr et al. (2015), there is evidence that past innovations have caused large-scale and long-term job loss with scarring effects on workers and their families. While in aggregate and over the very long run technology has created at least as many jobs as it has destroyed, there have been significant instances of job-replacing innovation. As shown by the

[5] Baldwin (2019) takes the threat of political resistance to innovation far more seriously than most books in this area.

papers cited in 3.3 and 3.4 above, examples such as hand spinners and telephone operators from the 18th century to the 20th century indicate that technological unemployment can be a long-term negative shock to individuals and communities. There is also a growing body of literature that shows how recent trade shocks and deindustrialization, for example, have entrenched spatial disadvantage (Acemoglu, Autor et al. 2016, Blanchflower 2019). While some economists are beginning to express concern about technological unemployment (Autor 2022, Brynjolfsson 2023), most future of work discussions have rarely considered historical examples of job destruction and the long-run impacts on individuals and regions. Beyond the immediate costs to workers and their families, new technologies may have unequal impacts on employment opportunities and earnings by gender, ethnic background, and location. The effects on social structures, norms, and opportunities in response to technological shocks can only be assessed over the long run, but these broader questions have not been addressed by the present-day debates on automation.

Thirdly, historical scholarship cautions against a deterministic view of the adoption and diffusion of new technologies (see 3.1). Which innovations eventually dominate may take decades to determine, and seemingly obsolete technologies can persist for a similar timeframe. Both of these points have important implications for the future of work. Some automation technologies that appear successfully initially may attract investment in complementary human capital that rapidly depreciates because of the success of following or competitor innovations. Tuition and time spent on coding bootcamps in the 2010s, for example, may be rendered redundant by generative AI. At the same time, pre-AI technologies in services and in production techniques that use little physical automation may continue in use for much of this century, with implications for labor demand. While some authors are appealing for attention to these points (Brynjolfsson 2023) and integrating them into the construction of incentive structures which will drive outcomes, they remain largely overlooked.

4.2: Historical Research Frontiers

The strengths of historical analysis of technology explained in Section 1, namely the ability to conduct long run studies, a diversity of examples for comparison, and methodological pluralism, enable many valuable directions of research to inform the future of work. Here we propose six tracks.

Firstly, a long-run view can offer insight into the evolution of inequality driven by ongoing waves of technological change and consider intergenerational impacts. Only some participants in the current debates have recently accepted labor displacement as a potential consequence of innovation. However, the generational implications have not been explored, and can only be investigated by studying the effects of past innovations over the long run. There is new evidence (3.3, 3.4) that access to new opportunities may be driven by class, race, age, and geographical location, meaning that cycles of technological change entrench

inequalities across generations. There is, as yet, no research which focuses on the long-run effects of this inequality.

While new studies in economic geography have established the path dependency of the creation of new work and its implications for regional development, the sources of path dependency have yet to be fully explored. The origins of spatial inequality could be observed over the long-term, which may yield insights that a more short-term view could miss. Historical analysis also incorporates the social and cultural underpinnings of long-run deprivation, which may intersect with technological change (Humphries and Thomas 2023).

There has been surprisingly little in-depth research on technological unemployment. As noted in Topic 3.3 above, historians have discussed job loss resulting from innovation during the First Industrial Revolution in general terms for more than a century. However, the lack of quantitative evidence until recent years has led to a common belief that technology never produced substantial, long-run unemployment (Mokyr 2002, Mokyr, Vickers et al. 2015, Future of Work Commission, Watson et al. 2017). Moreover, the definition of "technological unemployment" varies: some papers suggest it only occurs when there is an aggregate change in the unemployment rate (Ridolfi, Salvo et al. 2022), while others use it when there is job loss that may be offset by new jobs for other workers (Vipond 2022). While there is much uncertainty about the prevalence of technology replacing workers in the past, recent research suggests that this an important avenue for further study.

History can provide more insight into the political economy of creative destruction and how resistance to innovation has impacted technological adoption and growth. While there is substantial evidence of resistance, as shown in 3.2, its effects on the rate, and particularly the direction, of innovation and adoption have received less attention. Frey (2019) and Voth & Caprettini (2020) have begun to examine this question, but there is ample room to explore further. As we have emphasized, the political economy of technology has been neglected in the modern debate: most futurists and economists assume that innovation will continue to create as many jobs as it destroys, avoiding the problem of permanent technological unemployment. When the implications are discussed, it is by futurists, who are often debating the merits of Universal Basic Income or Universal Basic Services in a world without work (Coote and Percy 2020, Susskind 2020). Ignoring potential distributional consequences and resulting resistance enables futurists to avoid addressing the tradeoffs of technology, how to compensate losers from innovation, and the possibility that citizens may resist new inventions at work, at the ballot box, or in the streets.

At a more granular level, there is little systematic research that analyzes the shopfloor or cubicle-level impact of technology across examples of innovation and over time. Some papers mentioned above in 3.5 examine single instances of technological change, but task-level analysis and job quality measurement enable detailed comparative investigation of working

conditions and work content. The contemporary studies discussed in Section 2.2 necessarily lack a long-run perspective and few provide comparative analysis between different scales of innovation.

Finally, the rise of global history in recent decades provides the opportunity for researchers to consider the international dimensions of technological dynamism, which are not commonly incorporated into contemporary studies. Innovations are likely to have differing effects in different contexts and dynamic impacts across countries. As yet, most research on the future of work only analyzes impacts in single countries, which compounds the limitations of a short-term view. Such studies could pursue the implications of premature deindustrialization in a more detailed way (Rodrik 2016).

Conclusion

The public and policymakers look to history to understand major contemporary challenges. The value of historical perspectives was demonstrated in two recent crises, the Global Financial Crisis and the COVID-19 pandemic. Faced with tremendous—but not, as has commonly been stated, unprecedented—catastrophes, the public, policymakers, and scholars have drawn on the past to comprehend the implications of current events and plot possible routes out of the crisis.

Debates on the future of work focus on two issues: whether automation will cause permanent technological unemployment, and how the labor market impacts of the widespread adoption of AI will be distributed. Job quality has also begun to receive attention in academic and some policy circles. Popular books on the topic often open with a brief, stylized history of technological change which paints an overly straightforward and optimistic picture of the impacts of technology. While implicitly acknowledging the value of history, this simplified narrative distorts understandings of the past and, therefore, expectations of the future. Policy research and recommendations incorporate still less engagement with past examples of innovation.

Existing research on technological shocks in historical contexts is well placed to make contributions to the debate on the future of work in the areas discussed in Sections 3 and 4. Scholars have investigated key factors that shape the rate and direction of innovative activity, resistance to technological change, the risk of technological unemployment, the distributional impacts of innovation, and how technology can alter the organization, content, and quality of work.

The neglect of past experiences of technological change in the contemporary debate has perpetuated misapprehensions about the possible effects of innovation. Many writers and

reports have suggested that new techniques rapidly displace old (World Economic Forum 2016, 2020c), that technological unemployment is an imagined risk (Mokyr, Vickers et al. 2015, Future of Work Commission, Watson et al. 2017), and have focused narrowly on skill-based policies to adapt the workforce for the future (World Economic Forum 2016). Few commentators have discussed effective resistance to technology, implying that innovations will be broadly accepted. While some contributions acknowledge economic and social disruption in historical episodes, such disturbance is generally described as transitory. Some scholars are now reconsidering these views, which highlights how omitting historical experience may have impoverished debates up to recent years.

There are various ways in which history is well-placed to inform debates about the future of work. They all rely upon a sufficiently detailed knowledge of the past to select appropriate comparators and comprehend key differences between past and present. Evidence from history can enable a broader and richer understanding of the potential labor market impacts of the Fourth Industrial Revolution. It can allow for an intergenerational analysis of the impact of labor market outcomes, consider the potential for long-term scarring, and assess the effects of social and political resistance to new technologies. Historical studies can also measure the extent of technological unemployment, investigate how technology has changed the organization, content, and quality of jobs, and explore the global effects of technological shocks. Such studies may be particularly valuable because the projected cognition-replacing technologies of the Fourth Industrial Revolution will, if futurists are to be believed, have labor displacing implications more similar to the macroinventions that replaced human muscle and dexterity during the First Industrial Revolution than to the microinventions that are the focus of most contemporary research.

We have shown here why and how researchers, policymakers, and citizens concerned about the future of work can benefit from looking to past instances of innovation. We hope that colleagues across the many sectors and academic fields interested in the future of work will join in collaborations that use history to understand the possibilities of an automated future.

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