Has Technology Destroyed Jobs?
A Systematic and Narrative Review of Historical Labor Displacement

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Abstract

Concerns about job-replacing technology are a recurring companion to waves of invention (Bix 2000) and have returned to the centre of public discussions about innovation and labour markets (Brynjolfsson and McAfee 2014; Montobbio et al. 2023; Autor 2022; Acemoglu and Johnson 2023). This paper reviews and evaluates historical evidence for labour displacement following technological change, presenting the findings of existing studies on when and where innovations have replaced workers. While the recent employment effects of technology have been examined (Hötte, Somers, and Theodorakopoulos 2023), previous systematic reviews have not analysed the period before 1980. Evidence of decreasing marginal breakthroughs in the late 20th century (Bloom et al. 2020; Park, Leahey, and Funk 2023) suggests that a longer time horizon may provide a better basis for understanding the potential effects of more transformative future automation (Schneider and Vipond 2023).

We conduct searches of major academic databases and a wide set of economic history journals using terms related to labour displacement and replacement, identifying 3172 sources with our search terms. Of these, 164 sources were advanced to our full-text review. The full-text review and extraction produced a two-part review: (1) a systematic review of studies that quantify employment effects (e.g., Feigenbaum and D. Gross 2020; Bessen 2019; Ridolfi, Salvo, and Weisdorf 2022) and (2) a narrative review of descriptive studies (e.g., J. L. Hammond and B. B. Hammond 1919; Pinchbeck 1930; Bythell 1969). The reviews consider the impacts of technology in four areas. First, we determine whether labour displacement is observed following major technological changes. Second, when labour displacement is measured, we will present the scale observed in the studies that meet the criteria of our systematic review. Third, we consider the locations where displacement is found and determine if there are contradictory findings for the effects of the same innovation. Fourth, we look for evidence of long-run scarring on individuals, families, or locations resulting from labour displacement. As part of our synthesis, we also examine methods used to establish causality in displacement, and identify episodes of

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technological displacement suggested by historians but not yet quantified. The paper aims to contribute to the important and growing debate about the potential effects of ongoing and future innovation (Acemoglu and Restrepo 2019; Autor 2022), and provide an empirical grounding for public and policy debates about whether innovation has produced unemployment.

Our findings reveal clear patterns in the historical relationship between technological change and labour displacement. The systematic review shows that quantitative measurement of displacement was most feasible and pronounced where technology directly substituted for manual or craft labour (e.g., in agriculture, mining, specific manufacturing trades) or automated routine tasks (e.g., in clerical work, telecommunications). Industrial automation and electrification also displaced workers, but these transitions were often accompanied by wage growth for those who adapted to new skill requirements. The narrative review illuminates significant gaps by identifying specific sectors (such as domestic work, cultural industries, and pastoral farming) and worker groups (like artisans or those in informal economies) where major technology-driven shifts occurred but remain largely unquantified, often due to inherent data limitations or measurement complexities. Sectors such as domestic work, cultural industries, and pastoral farming experienced major shifts due to mechanization, yet these episodes remain largely unquantified. The narrative review also reveals that labour displacement was often uneven, with workers in lower-skilled roles and in regions with rigid labour markets facing more severe long-term effects. Across both reviews, we find that institutional responses were critical—displacement had lasting negative consequences when no alternative employment pathways were available, but in cases where displaced workers transitioned into new roles, job losses were often mitigated. Taken together, these findings suggest that while technological progress has repeatedly reshaped labour markets, its effects depend on the broader economic and institutional context. The absence of quantification in key areas, particularly outside of North America and Europe, underscores the need for further research to fully understand the historical dynamics of labour displacement.

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1. Introduction

Debates about the future of work are first and foremost concerned with disemployment effects, principally the risk of permanent technological unemployment—that robots or artificial intelligence (AI) will permanently reduce demand for human labour. Such discussions also consider distributional consequences, including shifts in income and labour displacement. Recent research has also begun to explore how technology affects job quality.

With the feverish interest in this topic, a range of recent studies (typically focusing on the period since 1980) have examined how technologies like AI, robotics, and automation affect employment across sectors and regions. Much of this contemporary literature seeks to understand the overall *net* impact, balancing evidence of displacement against compensatory job-creating forces (Aghion et al. 2022; Hötte, Somers, and Theodorakopoulos 2023). We briefly review the main currents of this debate here to highlight how our paper's historical focus (pre-1980) on the *displacement mechanism* itself offers a distinct perspective and body of evidence.

Of the 20 related contemporary studies (literature reviews as well as systematic reviews focusing on developed countries since 1980) that we identified, nine studies prominently highlight labour displacement as a key effect of technology, particularly in routine and middle-skill occupations. Technologies like AI, robotics, and process automation are frequently linked to job polarization and wage inequality, as they tend to replace routine tasks while favoring high-skill jobs. Studies by Kolade and Owoseni (2022), Goos (2018), and Filippi, Bannò, and Trento (2023) illustrate how these displacement effects are most pronounced in sectors such as manufacturing and administrative services.

On the other hand, eight studies focus explicitly on the compensatory mechanisms that create new jobs. These include the development of new industries, the creation of novel tasks, and increased demand resulting from productivity gains. Aghion et al. (2022) and Hötte, Somers, and Theodorakopoulos (2023) argue that automation and digital technologies often lead to *net* employment gains at the firm and industry levels, especially in high-tech and service sectors. Historical perspectives cited within this contemporary debate, such as those by Mokyr, Vickers, and Ziebarth (2015), suggest that while technological disruptions can cause short-term job losses, long-term employment growth typically follows through the emergence of new sectors and occupations, again pointing towards the importance of countervailing forces over time.

The extent to which contemporary studies find displacement or net job growth varies based on several factors. Process innovations, like automation and robotics, are consistently associated with job losses, particularly in traditional industries, while product innovations tend to stimulate job growth, especially in high-tech sectors. Sectoral differences are also significant;

manufacturing and routine-based sectors are seen as more vulnerable to displacement, whereas service sectors and creative industries appear better positioned to benefit from technological change. Geographically, most studies focus on developed countries, with evidence suggesting that displacement effects may be more severe in regions with less resilient labour markets.

While this contemporary literature grapples with the complex interplay of job destruction and creation in recent decades, often aiming for estimates of *net* change, our study takes a different approach. By systematically reviewing the historical record prior to 1980 for evidence of the *displacement* phenomenon itself (as defined in Section 2), we aim to provide a distinct body of evidence focused specifically on documented instances where technologies replaced workers. Our findings on historical displacement events are therefore different in nature and purpose, and are not directly comparable to contemporary estimates of net employment effects, which rely on assessing countervailing forces often difficult to quantify precisely in earlier periods.

Table A1 in the first appendix summarizes these findings.

Recent systematic reviews of labour displacement or the effects of innovation on employment only study the period since 1980. While such research obviously has benefits such as the availability of higher-quality data, the use of similar innovations, and similar contextual (e.g. institutional) variables, it also provides a narrow perspective on the range of effects and the time horizon of such impacts. Two limitations are particularly salient. First, the declining marginal rate of technological progress in the 20th century may provide a misleading picture of the range of possible employment impacts of technology (Bloom et al. 2020; Park, Leahey, and Funk 2023). If future technological shifts are more transformative than those of the very recent past, then historical studies may provide a more suitable guide to the possible impacts. Second, the recent literature necessarily takes a short-term view, with effects usually only measured over a few years or at most a decade or two. This limitation shapes both the effects observed, as displacement following adoption may be an extended process, and the potential duration of any subsequent unemployment or loss of income (Schneider and Vipond 2023).

Here we search the literature for all studies that consider labour displacement or labour-replacing technology where such innovations began to be adopted before 1980. Therefore, we examine the impacts of a wide variety of technologies at different scales and in a diverse set of institutional settings.

Our search collected 3,127 articles which were screened based on eligibility criteria described below. We then reviewed the full text of 207 articles that met our initial screening criteria, and of these we extracted data from 164 articles. We show that 75 of these contained sufficient information to be included in the systematic review, and a further 65 articles that discuss displacement but do not or cannot provide quantification were considered in the narrative review, highlighting several instances of potential but unmeasured labour displacement.

The paper is organized as follows. Section 2 presents the conceptual framework for our systematic review and the independent and dependent variables of interest. Section 3 explains the process of our review, the databases searched, our exclusion criteria, and the data fields extracted. Section 4 details the studies included in the systematic review and their specific findings categorized by technology type. Section 5 synthesizes the key lessons learned from this quantitative evidence regarding the patterns and contingencies of historical displacement. Section 6 then discusses the limitations of this quantitative evidence base, highlighting significant gaps concerning worker outcomes, demographic detail, and geographic coverage. Section 7 presents the findings from our narrative review, identifying episodes and themes often missed in quantitative work. Section 8 evaluates the results from both reviews, synthesizes the challenges in measuring historical displacement, and proposes a research agenda based on the identified gaps. Finally, Section 9 concludes and summarizes the implications of our study for debates about the future of work.

2. Theoretical and Conceptual Framework

Our first and most important dependent variable is labour displacement, for which we use the definition provided by the International Labor Organization.

> The term "displaced workers" refers to persons permanently separated from their jobs and connotes the disappearance of the job as well as the dislocation of the individual workers from the enterprise. Industrialized countries have been confronting this problem for some time due to the employment impact of technological and structural change.(Evans-Klock et al. 1998)

We focus here only on displacement following technological change. To this end, we use the definition of technology provided by Arthur (2009): "a means to fulfill a human purpose". We define adoption as the deliberate use of technology in a productive, extractive, or service-providing capacity, which may include, but is not limited to, the engagement of workers and/or managers in operating or otherwise interfacing with the technology.

The terminology of "labour displacement" has a long history, dating back at least to the 1930s (Jerome 1932). More recently it has been revived and incorporated in a form that relates displacement to the task framework of Autor, Levy, and Murnane (2003) by Acemoglu and Restrepo (2019). In their formulation, task-level replacement of human labour may be counterbalanced by the creation of new tasks; in this way, displacement can be offset by "reinstatement". Here we examine the literature for evidence of both the *gross* effects of displacement and the *net* effects of displacement less reinstatement, when these are observed. When measured in the studies considered, we include data on re-employment of displaced workers, and changes in wages upon re-employment. As our focus is on displacement, we do not include studies that only examine net employment effects of technological change, or that present data on new jobs created without considering displacement.

In a strict sense, as discussed by Jerome (1932), if a displaced worker is not immediately re-employed, she or he may be considered unemployed. As the deleterious skill depreciation effects of long-term unemployment are well-known, we are also concerned with observing any evidence of such shifts.

Any consideration of a medium- or long-term time horizon guides us towards two related discussions: any potential income effects: whether workers, conditional on finding new employment, are re-employed at lower or higher wages than before they were displaced; and distributional effects: whether specific categories of workers experience more labour displacement, disaggregating by gender, age, race or ethnicity, and skill.

3. Methodology

To locate sources that may contain evidence about historical episodes of labour displacement, we conducted a three-stage systematic literature search and screening process. The full registration of the study is available here. Following pilot searches and the approach of Hötte, Somers, and Theodorakopoulos (2023), in the first stage we used a similar set of search terms ("lab$r replac*" and "lab$r displac*"), but append "history" to both terms to eliminate recent studies. We use these search terms in the full text of Google Scholar, Web of Science, Scopus, and EBSCO Academic Search Complete. In the second search stage, we applied the two search terms without the "history" modifier to the full text of 16 important economic history journals.[2]

All sources identified through our two search stages were then screened independently by the two authors, in two stages: first screening of titles and abstracts, and then screening of full texts. The full screening instructions are available with the study registration, but we summarize them briefly here. We exclude all studies that are focused on future predictions or only

[2]We selected all economic history journals that publish at least some articles in English indexed on Scopus and Web of Science. These are The Economic History Review, the Journal of Economic History, the European Review of Economic History, Explorations in Economic History, the Scandinavian Economic History Review, Asia-Pacific Economic History Review, Rivista Storia Economica, Economic History of Developing Regions, Industrial History Review, African Economic History, Research in Economic History, Journal of European Economic History, Irish Economic and Social History, Indian Economic and Social History Review.

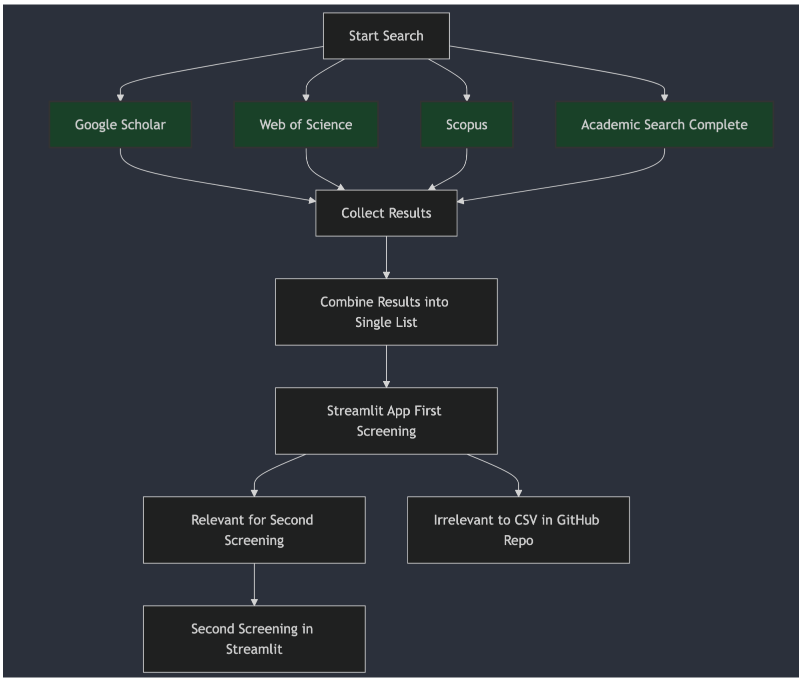

Figure 1: Search and Screening Process Flow Chart

discuss displacement theoretically. Studies that do not quantify displacement but only discuss it qualitatively are considered in the narrative review, Section ??. Research on technological anxiety is also excluded. We only include studies in which the relevant technology began to be adopted before 1980, and we exclude all non-empirical studies, including opinion pieces and literature reviews. For reasons of access, we exclude all publications that are not in English unless a translation is readily available. Finally, any studies for which we are not able to access the full text were excluded at the second (full text) screening stage, with this exclusion reason noted.

The number of studies included in the first screening stage was 3,172. The second screening stage whittled down the number to 164 studies which we could source, because 15 books were unavailable online or via either of the author's university libraries.

Following the two-stage screening, the sources were divided randomly between the two authors for extraction, with one author acting as primary extractor for half of the screened sources and the other author as secondary extractor, and vice versa for the other half of the screened sources.

After completing the extraction process, 75 studies were selected for the systematic review, and 65 for the narrative review. The summary statistics for these are provided in Table 1 and Table 2. The geographic focus of the studies is shown in Figure 2. It is evident that the United States was the most common country studied, followed by Western Europe. In the global south, English-speaking countries dominate, including ex-colonies South Africa and India (and Australia).

The list of studies in the systematic and narrative reviews are included in appendix Tables A2 and A3, respectively.

Statistic	**Value**
Total number of studies	75
Mean publication year	1999
Most common journal/publisher	Journal of Economic History
Most common study type	Quantitative historical analysis
Most common technology studied	Mechanization in Agriculture
Most common geographical focus	United States

Table 1: Summary Statistics of Studies in Systematic Review

Statistic	**Value**
Total number of studies	65
Mean publication year	1994
Most common journal/publisher	Cambridge University Press
Most common methodology	Historical analysis
Most common occupation studied	Agricultural workers
Most common technology studied	Mechanization
Most common geographical focus	United Kingdom

Table 2: Summary Statistics for Qualitative Studies

4. Systematic Review

Technological change has repeatedly displaced labour across different sectors throughout history, leading to diverse impacts on employment levels, wage structures, and patterns of migration. To structure our analysis of these historical transformations, we categorize the reviewed studies into eight key themes based on the primary technological driver or the sector most affected: (1) the advent of steam power and early industrial mechanization, primarily in the 19th century; (2) widespread mechanization and automation in agriculture, particularly during the 19th and 20th centuries; (3) the broader shifts associated with the Industrial Revolution and the rise of factory automation; (4) the impact of electrification and automation in telecommunications; (5) specific instances of labour-saving factory technology across various manufacturing contexts; (6) the onset of automation in service industries, including early office computerization; (7) technological shifts affecting automation in primary industries such as mining and forestry; and (8) automation in transportation, focusing on railroads. This review synthesizes evidence from these distinct areas, examining the scale of labour displacement, the specific occupations affected, and the broader economic consequences stemming from these technological

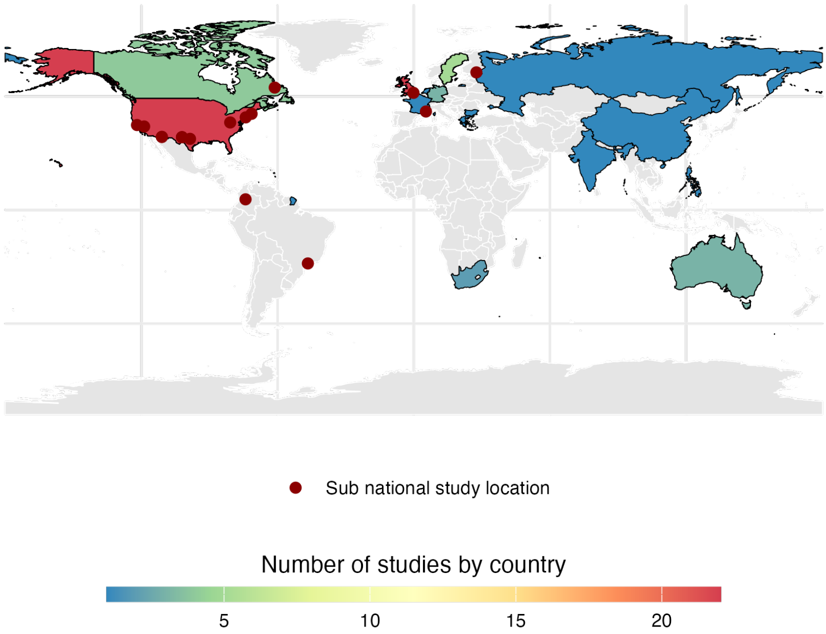

Figure 2: Geographic Spread of Studies in Sample

advancements. The specifics of the studies discussed within each theme are detailed in Table A2, as well as Figure 3.

4.1. Steam Power and Industrial Mechanization

The transformative power of steam and the associated mechanization of industrial processes, particularly evident from the mid-nineteenth century onwards, reshaped labour markets across Europe, though the impacts on workers varied significantly depending on context, sector, and skill. Studies focusing on the iron and steel industries in Sweden and the UK reveal clear instances of labour displacement resulting from technological shifts. The introduction of coke smelting and blast furnaces in Britain increased iron production but displaced traditional furnace workers (Riden 1977). Later, in Sweden, the industrial transformation driven by the Bessemer and Siemens-Martin processes led to the closure of numerous older, artisanal iron production sites between 1880 and 1890. Bengtsson, van Maarseveen, and Poignant (2023) provide compelling quantitative evidence on the consequences for those affected by these closures. Using linked census data, they find that displaced Swedish ironworkers were significantly more likely (23-25 percentage points) to exit the industry compared to their non-displaced counterparts.

AUTHOR (YEAR)	TECHNOLOGY	AFFECTED OCCUPATIONS	START	END	LOCATION	AVG. JOB LOSS (%)	SUMMARY OF FINDINGS
Industrial Revolution & Factory Automation							
Gaskell (1833)	Factory machinery	Spinners, Weavers, Yeomen	1760	1833	England		Hand laborers displaced by machinery and competition.
Ellison (1886)	Looms, Spinning tech	Spinners, Weavers	1764	1885	Britain	100%	Full displacement of hand weavers/spinners; overall employment growth.
Hobsbawm (1952)	Industrial Rev. tech	Artisans, Miners	1800	1914	Europe		Displacement, unrest linked to tech, work intensity, wages.
Hartwell (1961)	Machinery	Handloom Weavers, Laborers	1800	1850	England		Acknowledges underemployment, sees net wage/labor growth.
Ivanov (2022)	Factory system	Textile workers	1870	1910	Bulgaria		Factory jobs didn't fully replace lost proto-industria work.
Atack (2023)	Mechanization	Skilled, Semi-skilled Operatives	1890	1899	USA		36% deskilling observed (mainly labor division).
Gray (2013)	Electrification	Clerical, Manual, Managerial Workers	1900	1940	USA		Decline in middle-skill jobs, shift to low/high skill.
Mechanization & Automation in Agriculture							
Moring (1999)	Set-field agriculture	Family labor	1801	1900	Finland		Reduced need for large families shifted household structure.
Pickard (2008)	Wire fencing	Shepherds	1820	1900	Australia		Economic benefits + land policies drove fencing adoption.
Pickard (2007)	Wire fencing, Poison	Shepherds, Boundary riders	1850	1900	Australia		Tech + cost/land changes drove shepherd replacement.
Lilja (2018)	Wire fencing, Windpumps	Shepherds, Camp walkers	1865	1950	South Africa		Delayed shepherd displacement due to environment.
Olmstead & Rhode (2001)	Tractors	Farm workers	1910	1960	USA		Tractors saved ~1.72 million workers' worth of labor hours.
Musoke (1981)	Tractors, Cotton Pickers	Sharecroppers, Laborers	1915	1960	USA (South)	90%	Sharecropping declined 90% (tech + federal programs).
Whatley (1983)	Tractors (pre-harvest)	Sharetenants, Wage Laborers	1930	1940	USA (South)		AAA policies enabled tenant displacement, then mechanization.
Peterson (1986)	Mechanical Cotton Pickers	Hand Cotton Pickers	1930	1964	USA		Nonfarm wages main pull factor, tech cost secondary.
Heinicke (1994)	Mechanical Cotton Harvesters	African-American Harvesters	1950	1960	USA (South)		24% of African-American migration linked to harvester displacement.
Settele (2018)	Milking machines	Milkers	1950	1980	West Germany	100%	Milker wage labor vanished, work became supervisory.
Steam Power & Industrial Mechanization							
Riden (1977)	Coke smelting, Blast furnaces	Ironworkers	1530	1869	UK		Increased iron production displaced traditional furnace workers.
Ridolfi (2022)	Steam Power	Industrial Workers	1840	1860	France		Steam industries grew faster (+120% employment).
Bengtsson (2023)	Bessemer, Siemens-Martin processes	Ironworkers	1860	1900	Sweden		Ironworkers displaced, migrated, lower pay (10% wage loss).
Pehkonen (2019)	Steam Engine	Seafarers	1869	1914	Sweden		Mid-skilled seafarers lost job prospects, wage premiums decreased.
Hynninen (2013)	Steam engine (shipping)	Mates, Engineers, AB seamen, Ordinary seamen, EORs	1869	1914	Sweden		Demand for mid-skill seamen fell relative to high/low skill.

Avg. Job Loss (%) represents simplification; NA where % not quantified.

Figure 3: Summary of systematic review sources - 1

AUTHOR (YEAR)	TECHNOLOGY	AFFECTED OCCUPATIONS	START	END	LOCATION	AVG. JOB LOSS (%)	SUMMARY OF FINDINGS
Automation in Primary Industries							
Christenson (1962)	Coal mining tech	Hand loaders, Miners	1930	1960	USA	60%	Coal mining tech caused >60% employment drop.
BLS (1979) Mining	Mining automation	Support labor, Operators, Mechanics	1960	1977	USA		Mining automation reduced low-skill labor; skilled roles grew.
BLS (1979) Oil & Gas	Oil & Gas tech	Engineers, Techs, Crews	1960	1977	USA		Offshore oil/gas tech increased demand for skilled roles.
Ostry (1999)	Computerized sawmills	Sawmill workers	1970	1985	Canada (B.C.)	40%	Computerized sawmills cut workforce 40%; major income loss.
Labor-Saving Factory Technology							
O'Rourke (2013)	Mass production	Artisans, Textile Workers	1700	1900	UK/USA		Deskilling, use of female/child labor in early automation.
Caprettini (2020)	Threshing machines	Agricultural laborers	1800	1832	UK		Riots, higher unemployment in mechanized regions.
Barnett (1925) Various	Various machines	Skilled workers	1870	1899	USA/UK		Displacement of skill tied to tech power and adoption speed.
BLS (1927) Glass	Glass machinery	Glass workers	1890	1925	USA		Dramatic productivity increases; child labor eliminated.
BLS (1929) Printing	Printing machines	Typesetters	1896	1926	USA		Huge output gains; initial typesetter displacement, later recovery.
Barnett (1925) Bottle	Bottle machines	Blow workers	1905	1925	USA	50%	Skilled bottle blowers halved; absorbed into lower-paid jobs.
Nelson (1987)	Tire machines	Tire laborers	1910	1939	USA		Major tire laborer displacement; less deskilling than expected.
Best (1935)	Factory tech	Female workers	1921	1931	USA	44%	43.7% avg job reduction in female factory roles.
Seltzer (1997)	Knitting machines	Knitters	1938	1940	USA		Minimum wage accelerated tech adoption, displacing knitters.
BLS (1984) Hosiery	Hosiery machines	Knitters, Packers	1960	1982	USA	41%	Hosiery job losses 41% (some occupations down 80%).
BLS (1984) Can	Can lines	Can makers	1960	1982	USA	30%	Can line automation led to 30% workforce reduction.
BLS (1984) Laundry	Laundry tech	Pressers, Sorters	1960	1982	USA	34%	New fabrics & laundry automation reduced labor by 34%.
BLS (1977) Apparel	Apparel tech	Sewing operators	1960	1975	USA		Apparel tech refined process, increased demand for some skills.
BLS (1977) Footwear	Footwear tech	Shoemakers	1960	1975	USA		Imports + footwear tech reduced demand; some jobs eliminated.
BLS (1977) Auto	Auto tech	Assemblers, Welders	1960	1975	USA		Auto tech shifted demand to maintenance and computer staff.
BLS (1984) Box	Box machinery	Diemakers, Press operators	1963	1982	USA		Tech changed box-making job content, slow employment decline.

Avg. Job Loss (%) represents simplification; NA where % not quantified.

Figure 4: Summary of systematic review sources - 2

AUTHOR (YEAR)	TECHNOLOGY	AFFECTED OCCUPATIONS	START	END	LOCATION	AVG. JOB LOSS (%)	SUMMARY OF FINDINGS
Automation in Service Industries							
Sager (2007)	Household tech	Domestic servants	1890	1931	Canada		Employer tech adoption helped end paid servant role in Canada.
Kornrich (2012)	Household tech	Domestic servants	1900	1980	USA		Domestic servant decline via employer tech adoption & norms.
Riche (1960)	EDP / Computers	Clerical workers	1951	1959	USA (Federal Govt)	48%	48% employment loss in federal check processing units.
Weber (1959)	EDP / Computers	Clerical, Semitechnical	1952	1958	USA (Pittsburgh)	19%	Clerical down 17–21%; increased managerial staff.
Weinberg (1960)	EDP / Computers	Clerical workers	1954	1957	USA	25%	25% decline in routine clerical jobs (attrition used).
Wiener (1962)	EDP, MICR	Bookkeepers, Clerical	1954	1961	USA (Banking)	50%	Bookkeeper demand halved; other clerical roles fell; EDP roles created.
Hoos (1961)	EDP / Computers	Clerical workers	1955	1961	USA		Routinization of office work; higher-skill jobs limited.
BLS (1977) Retail	Computers, POS, Self-service	Stock clerks, Cashiers, Clerks, Seamstresses	1960	1975	USA		Retail tech automated data/labor; roles declined/shifted.
Automation in Transportation							
Yabroff (1963)	Rail tech	Maintenance, Clerks, Laborers	1947	1960	USA	42%	Overall rail jobs -42%; largest drops in low-skill work.
BLS (1977) Rail	Rail automation	Maintenance, Clerks, Crews	1960	1975	USA	46%	Rail automation led to avg. -3.1% employment/year.
BLS (1979) Pipeline	Pipeline automation	Operators, Clerks, Techs	1960	1977	USA	2%	Pipeline automation led to 2% avg. employment decline.
Electrification & Telecommunications Automation							
Ciliberto (2010)	Ring spinning, Looms	Spinners, Weavers	1885	1910	UK		Slow female tech adoption; limited direct displacement.
Feigenbaum (2024)	Telephone automation	Operators	1910	1940	USA	65%	Telephone operator job losses 50–80% locally.
BLS (1979) Utilities	Utilities tech	Plant operators, Line crews	1960	1977	USA		Labor per unit fell; more tech/maintenance jobs emerged.
BLS (1979) Refining	Refining tech	Operators, Lab techs	1960	1977	USA		Operator roles cut; maintenance consolidated; net job decline.
Other / Miscellaneous Cases							
White (1931)	General machinery	Skilled workers	1870	1931	USA		Evidence of skilled worker displacement; service jobs offset.
Barnett (1925) Semi-auto	Semi-auto bottle machines	Bottle blowers	1898	1905	USA		Market growth & union strategy minimized bottle blower displacement.
Heim (1984)	Mass production shift	Old vs. new industry workers	1923	1939	UK		Shift to mass production caused decline in traditional UK sectors.
Mason (1976)	Mechanization	Male vs. female labor	1927	1929	Germany		German mechanization displaced men, increased demand for women.
Clague (1931)	Plant shutdowns	Rubber workers	1929	1930	USA (CT)		Plant shutdown left 23-30% unemployed after 1 year (rubber).
Turner (1967)	Auto assembly automation	Autoworkers	1946	1965	UK		Auto assembly tech drove insecurity, strikes, some job losses.
Kennedy (1982)	Various automation	Industrial workers	1950	1981	USA		Job loss in many industries due to various automation.
Lane (1987)	Soviet automation	Industrial workers	1967	1986	USSR	0%	Soviet automation freed workers; policy ensured retraining.

Avg. Job Loss (%) represents simplification; NA where % not quantified.

Figure 5: Summary of systematic review sources - 3

While unemployment rates remained low for this group (only 2.27% unemployed in 1890, similar to controls), this masked significant economic hardship: displaced ironworkers "ended up in occupations that on average paid 10% less compared to their non-displaced counterparts", an earnings penalty that persisted for at least a decade. Migration was a key adjustment mechanism, with displaced workers being 25 percentage points more likely to migrate internally, and this mobility partially mitigated the long-run earnings shock for some.

The impact of steam technology in shipping, as studied by Hynninen, Ojala, and Pehkonen (2013) and Pehkonen, Neuvonen, and Ojala (2019) using linked Swedish data from 1869-1914, reveals a more complex pattern characterized by skill polarization rather than uniform displacement. Steam adoption reduced the demand for intermediate skills – specifically, able-bodied seamen (ABs) involved in traditional sail handling lost job prospects. However, demand increased for high-skilled workers (mates and newly created engineering roles) who commanded significant wage premiums (average 17-26% initially, though declining over time as the technology diffused), and also for low-skilled engine room operatives. This suggests that steam technology in this context was simultaneously skill-replacing for routine tasks and skill-demanding for new operational and technical roles.

Contrastingly, evidence from mid-nineteenth-century France suggests that steam power adoption at the industry level could be strongly associated with net positive employment outcomes. Ridolfi, Salvo, and Weisdorf (2022) found that, between the 1840s and 1860s, French industries adopting steam power experienced significantly higher growth in both wages (+∼20%) and total employment (+∼120%) compared to non-adopting industries. While this aggregate finding does not preclude displacement from specific tasks or firms within those industries, it indicates that, in the French context studied, the overall expansionary effects associated with steam adoption outweighed potential displacement effects at the industry level.

Taken together, these studies underscore that steam power's impact was not monolithic. It could lead to direct displacement and persistent earnings losses for specific craft groups undergoing industrial rationalization (Swedish ironworkers), induce wage and employment polarization by simultaneously devaluing mid-level skills and creating demand for high and low skills (Swedish seafaring), or correlate with significant net employment and wage gains at the industry level (France). The outcomes depended heavily on the specific industry, the nature of the skills affected, the possibilities for labour mobility, and the broader economic context encompassing the technological transition.

4.2. Mechanization and Automation in Agriculture

Perhaps nowhere are the historical impacts of labour-saving technology more starkly illustrated than in agriculture, where mechanization has repeatedly reshaped production processes and displaced vast numbers of workers across diverse contexts. The quantitative literature documents large-scale transformations, particularly in twentieth-century US cotton farming, nineteenth-century pastoralism in Australia and South Africa, and post-war European dairying and forestry.

The mechanization of cotton production in the American South represents a particularly dramatic and well-documented case. The introduction and diffusion of the general-purpose tractor between 1915 and 1960, followed by the mechanical cotton picker (available from the late 1940s), fundamentally altered the region's labour system. Musoke (1981) documents how tractor adoption, driven by profitability calculations (especially post-WWII) and incentivized by federal farm programs, led to a staggering 90% decline in sharecropper farms between 1930 and 1959. Whatley (1983a) further highlights the role of New Deal AAA policies, arguing they directly incentivized landlords to displace tenants (estimating a 22-37% displacement rate in the Delta during the 1930s) and shift to wage labour, thereby facilitating pre-harvest tractor mechanization even before the picker became widespread (Whatley 1983a). The overall labour-saving impact was immense; Olmstead and Rhode (2001) estimate that tractors saved at least 3.44 billion annual man-hours by 1960 compared to horse technology, equivalent to the labour of approximately 1.72 million workers. The subsequent adoption of the mechanical harvester, particularly in the 1950s, compounded these effects. Heinicke (1994) estimates, as an upper bound, that direct displacement by the harvester accounted for about 24% of the large net migration of African-Americans from the South during that decade, concentrated in the Delta states. However, the precise balance between technology "push" and economic "pull" remains debated. Peterson and Kislev (1986) argue, using a simultaneous-equation model, that the "pull" of rising nonfarm wages was the dominant factor (79%) in reducing the supply of hand-picking labour, while the "push" of falling machine costs played a secondary role (21%).

A different form of agricultural transformation occurred in pastoral farming with the adoption of wire fencing. Studies from colonial Australia by Pickard (2007) and Pickard (2008) detail the replacement of shepherds by fencing, combined with factors like dingo control (strychnine poison) and changes in land tenure legislation (see Pickard 2007, pp. 152–159). Fencing allowed for significant labour savings, replacing numerous shepherds with fewer boundary riders, driven by overall cost savings and productivity gains in wool and lambing. In the Cape Colony of South Africa, Lilja (2018) finds a similar process, though the displacement of shepherds by fencing and windmills/windpumps was initially delayed by environmental factors, namely the continued need for guarding against predators (jackals) and managing access to scarce water resources (Lilja 2018, p. 79). Eventual replacement by 'camp walkers' managing fences occurred from the 1910s onwards, but primarily on 'progressive farms', indicating a phased adoption and displacement process influenced by capital constraints and environmental context (Lilja 2018, p. 85).

Other agricultural contexts also show significant labour impacts from technological or organizational shifts. In post-war West Germany, Settele (2018) observes that the adoption of milking machines (bucket, pipeline, parlour systems) between 1950-1980, driven partly by labour shortages as workers moved to industry, led to a situation where "[w]age labour literally vanished within the barns" (Settele 2018, p. 102). While significantly increasing productivity per worker, mechanization transformed the remaining (often family) labour roles towards supervision and machine maintenance. Looking further back, Moring (1999) demonstrates how a shift in agricultural technique in nineteenth-century Finland – the decline of labour-intensive slash-and-burn methods in favour of set-field agriculture – reduced the need for large co-resident male workforces, contributing directly to a decline in joint-family households and the rise of stem families (Moring 1999).

Overall, the quantitative evidence from agriculture highlights the potential for mechanization to cause massive labour displacement (Olmstead and Rhode (2001)), including the near-complete elimination of specific occupational groups like sharecroppers (Musoke (1981)), shepherds (Pickard (2007), Lilja (2018)), or agricultural wage labourers (Settele (2018)). The pace of displacement can vary significantly, influenced by technology costs, complementary inputs, environmental factors (Lilja (2018)), and crucially, government policies which can actively incentivize displacement (Whatley (1983a)). Furthermore, the relative importance of technological "push" versus external economic "pull" in driving these transitions remains a key area of empirical investigation and debate (Peterson and Kislev (1986)).

4.3. Industrial Revolution and Factory Automation

The cluster of innovations associated with the Industrial Revolution, particularly the rise of the factory system, mechanization in textiles, and later electrification, brought about profound shifts in the nature of work and the structure of the labour force across Europe and North America. A key finding across several historical studies is the significant displacement, deskilling, or downgrading experienced by established groups of workers, particularly artisans and domestic handicraft producers. Early contemporary accounts, such as Gaskell (1833), vividly describe the displacement of domestic hand-spinners unable to compete with factory machinery and the subsequent decline of hand-loom weavers facing competition from power looms and an influx of cheaper labour, often former agricultural workers (Gaskell 1833). Ellison (1886) similarly documents the complete displacement of hand-wheel spinning by machines – stating that "the hand-wheels were all thrown into lumber-rooms" (Ellison 1886) – and the subsequent decline of hand-loom weavers following the rise of the power loom, noting that displacement fears fueled riots and machine breaking (Ellison 1886). Hobsbawm (1952) synthesizes this across Europe, noting the general pattern of displacement and downgrading of groups like weavers and artisans during the period 1800-1914, linking worker unrest and union growth directly to these technological and economic pressures (Hobsbawm 1952).

Later quantitative studies offer further evidence on the nature of these changes. Focusing on late nineteenth-century US manufacturing, Atack, Margo, and Rhode (2023) find evidence of deskilling (defined as skilled artisans being replaced by less-skilled operatives) in 36% of production operations when comparing machine to hand methods, though they attribute this primarily to the increased division of labour facilitated by the factory system rather than mechanization *per se* (Atack, Margo, and Rhode 2023). In the early twentieth century, Gray (2013) demonstrates that electrification in US manufacturing led to a "hollowing out" of the skill distribution between 1900 and 1940; demand for middle-skill, dexterity-intensive jobs declined, while demand shifted towards both higher-skill clerical/managerial roles and lower-skill manual tasks (Gray 2013). This suggests electrification was unskill-biased for blue-collar work but skill-biased overall when considering white-collar growth.

The net impact on overall employment levels, however, remains debated in the historical literature for this era. While the displacement of specific groups like handloom weavers was severe, Hartwell (1961) acknowledges these "pockets of technological underemployment" (Hartwell 1961, p. 400) but argues that overall labour demand increased and displacement did not prevent a rise in average real wages after 1815. Ellison (1886) similarly observes that despite the complete displacement of hand spinning, overall employment in the British cotton trade grew dramatically in the long run. However, this aggregate growth could mask significant regional or sectoral declines. Ivanov and Kopsidis (2023), studying Bulgaria from c.1870-1910, find that the decline of proto-industrial textile employment (driven primarily by falling demand) far outstripped the job creation in the nascent modern factory sector, leading to a significant fall in overall textile employment ($\sim$105k to $\sim$46.5k) as displaced workers shifted primarily into agriculture rather than new factory roles (Ivanov and Kopsidis 2023). These contrasting findings highlight that while the Industrial Revolution involved significant displacement and deskilling for established artisans and domestic workers, the net effect on employment was contingent on the pace of overall economic growth, the ability of new sectors to absorb displaced labour, and specific national or regional contexts.

4.4. Electrification and Telecommunications Automation

The transformative potential of electrification extended beyond the factory floor, enabling new forms of automation in service and process industries during the twentieth century. Perhaps the most striking example of large-scale displacement driven by automation in this period is the mechanization of telephone operation in the United States between 1910 and 1940. Studying this transition, Feigenbaum and D. P. Gross (2024) demonstrate that the introduction of mechanical switching technology caused immediate and severe job losses for the existing workforce of telephone operators, a group overwhelmingly composed of young women. Following the cutover to dial service, local operator positions were reduced by 50-80%. The consequences for these incumbent workers were significant: they were less likely to remain operators, and those finding subsequent employment often moved into lower-paying roles, facing an average decline of 5% in occupational score (Feigenbaum and D. P. Gross 2024). Older operators experienced particularly adverse outcomes, including a higher likelihood of exiting the labour force altogether. This case starkly illustrates how targeted automation could annihilate a major occupational category for a specific demographic, imposing substantial costs on the workers directly affected, even while Feigenbaum and D. P. Gross (2024) find that subsequent cohorts of young women were largely absorbed into other growing clerical and service occupations without a discernible impact on their overall employment rate.

Technological change associated with electrification and computerization also reshaped labour requirements in US utilities and petroleum refining between 1960 and 1977, albeit with less dramatic occupational elimination than in telephony. In US electric and gas utilities, the adoption of computers for plant monitoring and system control, the introduction of larger generating units (including nuclear power), and the mechanization of line work reduced the labour required per unit of output (United States Bureau of Labor Statistics 1979). Similarly, in US petroleum refining, computer process control diminished some operator functions, while changes in maintenance techniques (including craft consolidation and contracting out) reduced the need for certain craft workers (United States Bureau of Labor Statistics 1979). The United States Bureau of Labor Statistics (1979, p. 16) report noted, for example, that "[f]ewer analyzer repairers, operators, and lab technicians may be required where on-line monitoring is possible". In both industries, the skill profile of the workforce shifted, with increased demand for technical and maintenance personnel skilled in handling more complex, automated systems, and reduced demand for routine operational monitoring or manual tasks. The net effect on overall employment varied:

utilities saw slow employment growth during the period, sustained by rising output, while refining projected a net decline (United States Bureau of Labor Statistics 1979; United States Bureau of Labor Statistics 1979). These cases show technology changing the *nature* and *skill requirements* of work, leading to gradual shifts in occupational structure and unit labour needs, contrasting with the more abrupt occupational displacement seen in telephone automation.

4.5. Labour-Saving Factory Technology

The historical record is replete with examples of factory technologies designed primarily to save labour or alter the labour process, spanning from the early Industrial Revolution to the latter half of the twentieth century. These innovations frequently targeted specific manual operations or craft skills, leading to documented instances of labour displacement, although the scale, consequences, and adjustment pathways varied significantly across industries, time periods, and institutional contexts.

Early factory mechanization, particularly in textiles, aimed squarely at replacing skilled artisans with machinery often operated by less-skilled, cheaper labour, predominantly women and children. O'Rourke, Rahman, and Taylor (2013) argue that much technological progress in the early British and American industrial revolutions was skill-saving, making it possible "for employers to use cheaper unskilled workers—women, and even children—in the place of highly paid artisans" (O'Rourke, Rahman, and Taylor 2013, p. 828). Specific examples include the self-acting mule displacing skilled mule spinners and mechanization threatening woolcombers. This process of deskilling, where established craft knowledge was fragmented or made obsolete by new techniques, was a key mechanism of displacement. The theoretical framework for understanding this, as analyzed by Barnett (1925b) using cases like printing, stonecutting, and glassmaking, highlights that the extent of skill displacement—defined as the "loss of the opportunity to sell acquired skill at the rate of remuneration which would have been received if the machine had not been introduced" (Barnett 1925b, p. 596) —depended on the machine's labour-saving power, the speed of its adoption, the mobility (or immobility) of the affected workforce, and the degree to which old skills were transferable to new operations.

The late nineteenth and early twentieth centuries saw the introduction of highly effective automatic machinery in several sectors, leading to massive labour savings and displacement in specific trades. In the US glass industry, the Owens automatic bottle machine, commercialized around 1905, and related technologies led to dramatic productivity increases; for example, output per man-hour for 4-ounce bottles was estimated to be 41 times higher with the Owens machine compared to hand processes (Davis 1927). This caused a drastic reduction in demand for skilled hand blowers, whose numbers in union factories were estimated to have halved between 1907 and 1917, representing a loss of around 5,600 skilled positions (Barnett 1925a). The new technology practically eliminated child labour in the industry but shifted the workforce composition towards mechanics and machine operators (Davis 1927). Similarly, the introduction of line-casting machines (Linotype) in newspaper printing around the 1890s displaced "[t]hree or four hands... out of every five formerly engaged in setting and distributing type" (Kjaer and Statistics 1929). However, in this case, the massive productivity gains spurred industry growth (more pages, higher circulation), which reportedly absorbed the initially displaced workers relatively quickly, illustrating how market demand could act as a powerful mediating factor (see Kjaer and Statistics 1929, pp. 190–191).

Studies focusing on the mid-to-late twentieth century reveal continued labour-saving technological adoption across various manufacturing sectors, often with significant consequences for employment levels and occupational structures. A detailed 1935 study of 115 US plants found that technological changes introduced between 1921-1931 resulted in an average 43.7% employment reduction on the affected processes (Best 1935). Examples included one machine replacing 15 hand labelers/wrappers with 6 operators, and another allowing one girl to replace four men. Nearly half of the women workers interviewed reported lower earnings after the changes (Best 1935). In the US tire industry between 1910-1930s, automation through Banbury mixers, tire-building machines, and especially conveyors led to major labour displacement, particularly affecting material handlers, with Akron's overall industry employment peaking as early as 1920 despite rising output (Nelson 1987). Specific process changes cited large reductions, such as the Banbury displacing 40-60% of mill room workers (Nelson 1987). Later Bureau of Labor Statistics studies documented further impacts: the adoption of automatic knitting machines in the US hosiery industry, accelerated by the FLSA minimum wage, displaced hand-transfer knitters between 1938-1940 (Seltzer 1997); subsequent automation in hosiery (1960-1982) led to a 41% overall employment decline from the 1969 peak, with boarders (-80%) and knitters/fixers (-60%) hit particularly hard (United States Bureau of Labor Statistics 1984); the introduction of two-piece can lines (1960-1982) reduced unit labour requirements by an estimated 25-30%, eliminating steps like lithography feeding and contributing to a 30% fall in total employment from the 1970 peak, with adjustments managed via union agreements; and automation in commercial laundries (1960-1982), especially steam tunnel finishing enabled by polyester fabrics, significantly reduced the need for pressers, contributing to a 34% overall employment decline (also driven by demand shifts). However, the impact was not always drastic displacement; studies of the apparel, footwear, folding paperboard box, and motor vehicle industries during the 1960s-1970s found technology often involved refinements that changed job content (reducing some skills while demanding others, like maintenance or computer literacy) and led to slower employment declines or occupational shifts rather than mass layoffs, frequently moderated by factors like import competition (footwear), union contracts (autos, cans, boxes), slow diffusion due to cost/complexity (apparel, footwear, boxes), or overall industry growth (United States Bureau of Labor Statistics 1984).

Finally, the social consequences of displacement could extend beyond the workplace. The introduction of agricultural machinery, specifically threshing machines in 1830s England, provides a stark example where technology directly fueled social unrest. Caprettini and Voth (2020) found that the adoption of threshing machines significantly increased the likelihood of riots, particularly in areas lacking alternative industrial employment opportunities, linking higher local unemployment (7.6% vs 5.5%) directly to the technological displacement (Caprettini and Voth 2020, IV est. finds 1 extra thresher predicts 6.5 more riots, unemployment 7.6% vs 5.5%).

In sum, labour-saving factory technology consistently reduced labour requirements per unit of output across numerous industries and historical periods before 1980. This frequently involved the displacement of workers from specific tasks or entire occupations, ranging from skilled artisans in the Industrial Revolution (e.g., glass blowers, typesetters) to semi-skilled operatives and labourers facing later waves of automation (e.g., tire builders, knitters, pressers, can makers). While productivity gains were often dramatic (Davis 1927; Kjaer and Statistics 1929), the net impact on employment and worker welfare varied widely. Factors such as the overall growth of the industry (Kjaer and Statistics 1929), the availability of alternative employment (regionally or occupationally) (Caprettini and Voth 2020), the nature of the skills affected (Barnett 1925b), worker resistance, union bargaining power, and government policies (Seltzer 1997) significantly mediated the consequences, leading sometimes to reabsorption but often to deskilling, wage reductions (particularly for those displaced (Best 1935; Barnett 1925a)), periods of unemployment, or social unrest.

4.6. Automation in Service Industries

The automation of service industries, particularly the introduction of electronic data processing (EDP) in office environments from the mid-twentieth century onwards, represents a critical area of study, especially given the dominant share of employment held by the service sector in contemporary economies across the world. Historical analysis of these early transitions provides valuable insights into the mechanisms of displacement and adjustment in white-collar work. The studies reviewed focus primarily on the impact of mechanisation and early computerisation in US government agencies, banking, insurance, and retail, alongside the transformation of paid domestic work in North America.

The primary group affected by early office automation were clerical workers engaged in routine tasks. Studies consistently found significant potential and actual reductions in roles involving posting, checking, maintaining records, filing, computing, tabulating, and keypunching (Weinberg 1960; Wiener 1962; Riche and Alliston 1963; Hoos 1961; Weber 1959). Specific examples include bookkeepers in banking, where EDP was estimated to reduce manpower requirements by approximately 50% (Wiener 1962), and tabulating-machine operators, where nearly 70% of surveyed insurance companies reported employment decreases (Weinberg 1960). In US federal agencies, the automation of check processing led to a 48% net employment decline in the operation, while savings bond automation resulted in 36% of affected employees being laid off (Riche and Alliston 1963). One study estimated conservatively that "for every five office jobs eliminated one is created" (Hoos 1961, p. 72). Displacement also occurred in paid domestic work, with the numbers of domestic servants and especially laundresses declining dramatically over the twentieth century in the US and Canada, partly linked to the adoption of household technologies by employers as substitutes for increasingly scarce or costly labour (Kornrich 2012; Sager 2007).

Technological change occurred through the introduction of electronic computers and associated peripheral equipment, replacing earlier mechanical calculators and punched-card systems (Hoos 1961; Weinberg 1960; Weber 1959). Displacement mechanism primarily involved the automation of routine data handling and calculation, leading to the elimination of specific job roles and the consolidation of functions (Wiener 1962). In retail, POS terminals and early scanning technology automated data capture and reduced manual marking and bookkeeping tasks (United States Bureau of Labor Statistics and Epstein 1978). For domestic service, the mechanism was substitution, where employers adopted appliances and prepared goods, shifting work formerly done by paid servants to unpaid housewives (Kornrich 2012; Sager 2007).

While the labour-saving potential was high, the scale of immediate, direct layoffs in office environments studied in the 1950s and early 1960s was often reported as low (Weinberg 1960; Riche and Alliston 1963; Hoos 1961). A key finding across several studies was that displacement was frequently managed through internal transfers and absorption by normal attrition, particularly exploiting the high turnover rates common among the young, female clerical workforce (e.g., Weinberg 1960, p. 445). A BLS study of 20 offices found "Layoffs were negligible" (Weinberg 1960, p. 48). However, this often masked the curtailment of hiring, impacting new entrants (Hoos 1961; Weinberg 1960), and did not preclude significant job losses in specific cases, such as the 36% layoff rate in the federal savings bond conversion (Riche and Alliston 1963). The decline in domestic service occurred over decades, a more gradual displacement compared to some factory automation cases (Kornrich 2012).

The consequences for workers were varied. While direct unemployment attributable to automation was often minimized in early office case studies through transfers (Weinberg 1960), those who were laid off (e.g., from federal savings bond units) or whose skills became obsolete faced difficulties (Riche and Alliston 1963). Furthermore, the nature of remaining and newly created jobs was often altered. Hoos (1961) strongly argues against general skill upgrading, describing new roles like key-punching as highly routinized and creating an "office factory" environment (Hoos 1961, p. 91). While new technical jobs (programmers, analysts, operators) were created, they were relatively few in number (Weinberg 1960) and often favoured younger, male, educated employees (Hoos 1961). Older workers, despite formal job security policies, faced barriers in accessing these new roles (Weinberg 1960). The shift from paid domestic service represented a transfer of labour to unpaid work within the household, with complex consequences for women's economic roles and the valuation of housework (Kornrich 2012; Sager 2007). Wage impacts for displaced workers are poorly documented in these studies, though protection against downgrading was sometimes implemented (Weinberg 1960).

Several factors mediated the impact of service industry automation. Many early computer introductions occurred during periods of significant economic expansion and rapid growth in clerical workloads, which allowed technology to be used primarily to handle increased volume rather than directly reduce staff (Weinberg 1960; Hoos 1961). Company policies emphasizing advance planning, communication, and job security through transfers and attrition were vital in avoiding layoffs (Weinberg 1960). High labour turnover rates, especially among young female clerical workers, provided a buffer (Hoos 1961; Weinberg 1960). The cost and complexity of early EDP systems also limited their adoption primarily to large organizations initially (Weinberg 1960). Union presence was less widespread than in manufacturing, but where present, unions advocated for protective measures (Riche and Alliston 1963). For domestic service, the key mediating factors were the availability of alternative employment opportunities and changing social norms regarding housework and women's roles (Kornrich 2012; Sager 2007).

4.7. Automation in Primary Industries

Technological change profoundly reshaped labour markets in primary resource extraction industries during the twentieth century, although the nature and extent of labour displacement varied significantly depending on the specific sector, the technology adopted, and the prevailing economic and institutional context. Studies focusing on coal mining, oil and gas extraction, and forestry reveal contrasting stories of workforce reduction, skill transformation, and community impact.

The US bituminous coal industry experienced perhaps the most dramatic technology-induced labour displacement among primary sectors before 1980. Driven by intense competition from oil and gas, rising labour costs under union agreements, and the availability of new machinery, the industry underwent rapid mechanization, particularly after World War II (Christenson 1962). Technologies like mechanical loaders, continuous mining machines, and large-scale surface mining equipment dramatically increased output per worker (Christenson 1962; United States Bureau of Labor Statistics 1979). This productivity surge, however, occurred alongside stagnant or declining demand for coal, leading to a massive reduction in employment. Christenson (1962) documents a fall in production worker employment from over 411,000 in 1948 to less than 150,000 by 1959, a decline of 64%. This displacement was particularly severe for less-skilled workers involved in hand loading and other manual tasks (Christenson 1962). The social costs were immense, resulting in what Christenson (1962) describes as "serious and persisting unemployment [that] plagued coal communities" often located in isolated areas with few alternative job opportunities (Christenson 1962, p. 37). Later technological refinements analyzed by United States Bureau of Labor Statistics (1979) for the 1960-1977 period, such as longwall systems and computer applications, continued to reduce labour requirements for specific tasks like roof support and transport, while increasing the need for skilled maintenance mechanics and technicians.

In stark contrast, the US oil and gas extraction industry saw employment *increase* during the 1960s and 1970s, despite adopting sophisticated technologies (United States Bureau of Labor Statistics 1979). Innovations focused on expanding production into more challenging environments (offshore, Arctic) and enhancing recovery from existing fields. Technologies like improved drill ships, subsea production systems, computer monitoring, and advanced exploration methods increased the complexity of operations (United States Bureau of Labor Statistics 1979). Rather than causing widespread displacement, these changes primarily increased the demand for professional and technical employees, including engineers, geologists, and specialized technicians, particularly for complex offshore operations (United States Bureau of Labor Statistics 1979, p. 31, 35, 36). While some future automation potential was noted (e.g., reducing manual aspects of drill crew work), the BLS study concluded in 1979 that significant technological displacement was not anticipated, with the main challenge being potential shortages of skilled labour required by the new technologies (United States Bureau of Labor Statistics 1979, pp. vii, 31, 40).

The experience of the forestry sector, specifically sawmilling in British Columbia, presents another variation. Ostry (1999) found that technological changes (computerized production, capital-intensive equipment), combined with the recession of the early 1980s, led to a significant workforce reduction of over 40% between 1979 and 1985 in the studied mills (Ostry 1999, p. 197). Younger workers were disproportionately affected by layoffs. Importantly, the study tracked subsequent outcomes, finding that displaced workers who secured jobs outside the high-wage forest products industry faced substantial income losses, earning approximately 33% less in 1985 than in their 1978 sawmill jobs (Ostry 1999, p. 198). This case highlights how technological change, interacting with economic downturns, can increase productivity per worker while simultaneously imposing significant social costs on displaced individuals and reducing the economic viability of resource-dependent communities (Ostry 1999).

Synthesizing these cases reveals that while automation and mechanization consistently aimed to increase labour productivity in primary industries, the impact on employment varied dramatically. In coal mining, technology combined with market decline led to massive, long-term displacement and regional distress (Christenson 1962). In oil and gas, technological complexity associated with finding and extracting resources in difficult environments actually increased the demand for skilled labour, preventing displacement (United States Bureau of Labor Statistics 1979). In forestry, technology interacted with cyclical downturns to cause significant job loss with negative consequences for worker incomes and community stability (Ostry 1999). Across these sectors, however, a common trend was a shift in skill requirements, generally favoring technical, maintenance, and professional roles over traditional manual or operative labour (United States Bureau of Labor Statistics 1979; United States Bureau of Labor Statistics 1979). The ultimate labour market outcome depended heavily on the interplay between the labour-saving potential of the technology, the overall demand for the industry's output, and the capacity of the affected workforce and regions to adapt.

4.8. Automation in Transportation

The transportation sector, particularly railroads and pipelines in the United States, underwent significant technological transformation in the post-World War II era, leading to dramatic shifts in labour requirements and occupational structures. Studies examining this period reveal substantial labour displacement driven by dieselization, mechanization, automation, and computerization, although the scale and nature of the impact varied between sub-sectors like rail and pipeline transport.

The U.S. railroad industry experienced a massive decline in employment between 1947 and the mid-1970s, directly linked to widespread technological adoption. Kelley and Yabroff (1963) documents an overall employment drop on Class I railroads of over 40 percent, representing approximately 600,000 workers, between 1947 and 1960 alone. This trend continued, albeit at a slower rate, with an average annual decline of 3.1% reported between 1960 and 1975 (United States Bureau of Labor Statistics and Epstein 1978). The primary driver was the shift from steam to diesel-electric locomotives, which drastically reduced the need for maintenance personnel, particularly skilled trades like boilermakers (-82% between 1947-60) and blacksmiths (-67%), as well as eliminating the role of firemen on freight trains (Kelley and Yabroff 1963). Simultaneously, extensive mechanization of roadway maintenance replaced large section gangs with smaller, machine-operating crews, decimating employment for track labourers (e.g., section gangmen down -69% 1947-60) (Kelley and Yabroff 1963). Further labour reductions resulted from the introduction of Centralized Traffic Control (CTC), which reduced the need for station agents and telegraphers; automated classification yards, which eliminated jobs for brakemen and switchtenders; and office automation (computers, improved communications), which curtailed clerical employment (Kelley and Yabroff 1963; United States Bureau of Labor Statistics and Epstein 1978). The study by Kelley and Yabroff (1963) emphasized that these cutbacks were generally most severe among less-skilled workers. While specific data on unemployment duration or post-displacement wages for these workers is limited in these sources, the sheer scale of job loss points to significant social costs. Adjustment was heavily mediated by strong union presence and established collective bargaining agreements, often incorporating principles from the 1936 Washington Job Protection Agreement regarding advance notice, income maintenance, severance pay, and transfer rights (United States Bureau of Labor Statistics and Epstein 1978).

Petroleum pipeline transportation (SIC 4612, 4613) also saw significant technological change and productivity growth (7.9% average annual increase 1960-77), but with a less dramatic, though still negative, impact on overall employment compared to railroads (United States Bureau of Labor Statistics 1979). Employment declined at an average annual rate of 2.0% between 1960 and 1977. Key technologies included improved physical infrastructure (wider diameter, higher tensile strength pipe; standardized, larger pumps) and, importantly, computerized scheduling and centralized process control (United States Bureau of Labor Statistics 1979). Automation, particularly through computerization and remote monitoring, reduced the labour requirements for field-based roles. The report notes that "Occupations affected by advanced computer applications include process control operators..., schedulers, gaugers, and accounting clerks whose job duties also are being modified..." (United States Bureau of Labor Statistics 1979, p. 44). Centralized control systems eliminated the need for continuous local manning at pumping stations, and automatic metering reduced manual gauging tasks (United States Bureau of Labor Statistics 1979). This shifted the workload towards central dispatchers and increased the need for skilled technicians capable of maintaining and operating the complex electronic systems, while reducing demand for field operatives and some clerical staff (United States Bureau of Labor Statistics 1979). Unlike railroads, unionization was relatively low, and adjustment mechanisms were less formalized (United States Bureau of Labor Statistics 1979).

In both rail and pipeline transport, technological change adopted before 1980 drove significant increases in labour productivity and reductions in unit labour requirements. In railroads, this resulted in massive job losses across nearly all blue-collar occupations, moderated somewhat by union agreements. In pipelines, productivity gains also led to employment decline, primarily impacting field operations and routine clerical work through centralization and computer control, while increasing demand for skilled technicians.

5. Lessons from Historical Displacement

The quantitative historical evidence reviewed reveals distinct patterns regarding when, how, and for whom technological change led to labour displacement prior to 1980. While each episode possessed unique characteristics shaped by its specific technological, economic, and institutional context, synthesizing the findings allows us to identify common conditions under which jobs were destroyed, the varying scale and consequences of these displacements, and the factors that mediated worker outcomes.

5.1. Direct Substitution and Skill Obsolescence

A dominant pattern observed across diverse sectors and eras is that displacement occurred most severely when new technology directly substituted for existing manual labour or specific craft skills, rendering them economically obsolete or significantly reducing the labour required per unit of output. This was particularly evident in agriculture, where mechanization led to massive workforce reductions. The introduction of the tractor, for instance, eliminated the need for vast numbers of farm workers previously engaged with animal power, saving an estimated 3.44 billion man-hours annually by 1960 (Olmstead and Rhode 2001), while the mechanical cotton picker contributed significantly to the decline of hand harvesting and the displacement of sharecroppers, particularly African-Americans in the US South (Musoke 1981; Heinicke 1994). Similarly, fencing technology fundamentally altered pastoralism in Australia and South Africa, replacing shepherds with capital and fewer boundary riders or 'camp walkers' (Pickard 2007; Lilja 2018). In West German dairying, milking machines directly replaced agricultural wage labour, leading to its near disappearance from barns (Settele 2018).

Manufacturing witnessed analogous substitutions. The Owens automatic bottle machine, vastly more productive than hand methods, led to the displacement of "not less than one half of the hand blowers employed in [1907]" within a decade (Barnett 1925a, p. 286), representing a near-total destruction of that specific craft skill (Davis 1927). Likewise, the Linotype displaced "[t]hree or four hands... out of every five formerly engaged in setting and distributing type" (Kjaer and Statistics 1929). Later automation in the US tire industry, especially conveyors, caused significant displacement, particularly affecting labourers involved in material handling (Nelson 1987). The hosiery industry saw sharp declines in specific roles like boarders (eliminated by process change) and knitters (replaced by faster, automated machines), contributing to a 41% fall in overall employment between 1969-1982 (United States Bureau of Labor Statistics 1984). In transportation, the diesel locomotive's replacement of steam power led to massive job losses for maintenance crafts like boilermakers and blacksmiths, as well as eliminating firemen (Kelley and Yabroff 1963). Mechanized track maintenance similarly displaced large numbers of section gang labourers (Kelley and Yabroff 1963; United States Bureau of Labor Statistics and Epstein 1978).

5.2. Automation of Routine Tasks

Beyond direct physical substitution, automation also targeted routine cognitive and manual tasks, particularly evident in the rise of office automation from the mid-twentieth century. The introduction of Electronic Data Processing (EDP) systems significantly reduced the need for clerical workers performing tasks like bookkeeping, calculation, tabulation, sorting, and filing (Weinberg 1960; Wiener 1962; Hoos 1961; Weber 1959). Studies estimated significant labour savings, such as a potential 50% reduction in manpower for demand deposit bookkeeping (Wiener 1962) and observed net reductions of 25% in affected office units (Weinberg 1960) or 48% in specific operations like federal check processing (Riche and Alliston 1963). The mechanization of telephone switching provides a stark example, where automatic dial systems eliminated 50-80% of operator positions locally, fundamentally displacing the core task of that occupation (Feigenbaum and D. P. Gross 2024). Similarly, automation in petroleum pipelines via computerized scheduling and centralized control reduced the need for field operators, gaugers, and accounting clerks (United States Bureau of Labor Statistics 1979), while retail automation (POS systems, scanning) aimed to reduce labour in price marking, checkout, and bookkeeping (United States Bureau of Labor Statistics and Epstein 1978). This pattern highlights the vulnerability of standardized, repetitive tasks to automation across different service sector environments.

5.3. Scale, Speed, and Consequences of Displacement

The quantitative evidence reveals a wide spectrum in the scale and severity of historical displacement. Some technological shifts induced massive and rapid job losses, reshaping entire industries and regions. The mechanization of US coal mining led to a workforce reduction of over 60% between 1948 and 1959 (Christenson 1962), while US railroads shed over 40% of their workforce between 1947 and 1960 (Kelley and Yabroff 1963). The decline of US sharecropping (Musoke 1981) and the near-elimination of specific crafts like hand glass blowing (Barnett 1925a) or telephone operation (Feigenbaum and D. P. Gross 2024) represent cases where technology contributed to the virtual disappearance of established livelihoods for large groups. In other instances, displacement was more gradual or limited, involving slower declines or shifts in job content rather than mass layoffs, as observed in studies of US apparel, footwear, and folding paperboard box manufacturing in the 1960s-70s (United States Bureau of Labor Statistics and Epstein 1978).

The consequences for displaced workers were often severe. Persistent, long-term unemployment was documented in areas heavily dependent on declining industries like coal mining (Christenson 1962). Studies tracking displaced workers found significant periods of joblessness, such as an average of 4.3-5.2 months in the year following layoff for early 20th-century rubber workers and clothing cutters (Clague and Couper 1931; White 1931), and 12% still unemployed two years after a 1950s plant closure (Clague 1961). Wage loss upon re-employment was a common outcome, with studies reporting average weekly earnings drops of 20-30% for displaced rubber workers (Clague and Couper 1931), a 10% long-term penalty for displaced Swedish ironworkers (Bengtsson, van Maarseveen, and Poignant 2023), a 5% drop in occupational score for displaced telephone operators (Feigenbaum and D. P. Gross 2024), and a 33% income reduction for displaced B.C. sawmill workers finding jobs outside forestry (Ostry 1999). Conversely, wage premiums were observed for workers adapting to certain new technologies, such as steam power in French industry (Ridolfi, Salvo, and Weisdorf 2022) or Swedish shipping (Pehkonen, Neuvonen, and Ojala 2019), suggesting outcomes depended heavily on skill complementarity. Technology often led to deskilling or downgrading (Atack, Margo, and Rhode 2023; Best 1935), though sometimes also created demand for new, higher skills (e.g., maintenance, technical roles (United States Bureau of Labor Statistics 1979; United States Bureau of Labor Statistics 1979; United States Bureau of Labor Statistics and Epstein 1978)). In some cases, displacement directly fueled social unrest, most clearly documented for threshing machines in 1830s England (Caprettini and Voth 2020).

5.4. Mitigating Factors and Contextual Contingency

The quantitative evidence strongly indicates that technological displacement was not an automatic or uniform process; its occurrence and severity were highly contingent on mediating factors. Importantly, the overall rate of economic growth and specific industry demand played a major role. Rapidly expanding industries, such as early newspaper printing (Kjaer and Statistics

1929), mid-19th century French industry adopting steam (Ridolfi, Salvo, and Weisdorf 2022), or post-WWII US banking and insurance (Weinberg 1960; Wiener 1962), often absorbed workers displaced by productivity gains, resulting in slower employment growth rather than absolute decline. The availability of alternative employment opportunities in the local labour market was also critical, influencing whether displacement led to migration, re-employment (even if at lower wages), or social unrest (Caprettini and Voth 2020; Feigenbaum and D. P. Gross 2024).

Labor market characteristics and institutional responses were also vital. High labour turnover rates, particularly among young female clerical workers, allowed early office automation to proceed with minimal layoffs through attrition (Weinberg 1960). The nature of the technology itself mattered: innovations that complemented existing skills or created new tasks, like steam power in shipping leading to wage polarization (Hynninen, Ojala, and Pehkonen 2013) or electrification boosting demand for non-manual labour (Gray 2013), had different net effects than technologies that primarily substituted for core job functions. Management strategies, including advance planning, communication, retraining efforts, and commitment to job security via transfers, were shown to significantly mitigate hardship in some case studies (Weinberg 1960; Rothberg 1956). Union presence and collective bargaining agreements often provided adjustment mechanisms, such as seniority rules, wage protection for downgraded workers, severance pay, SUB plans, and retraining rights, particularly evident in the heavily unionized railroad and metal can industries (United States Bureau of Labor Statistics and Epstein 1978; United States Bureau of Labor Statistics 1984; Rothberg 1957). Conversely, government policies could exacerbate displacement, as argued for US agricultural programs incentivizing mechanization (Whatley 1983a), or accelerate it, as with the FLSA minimum wage pushing low-wage hosiery firms to automate (Seltzer 1997). Finally, environmental and contextual factors, such as the presence of predators delaying the labour-saving impact of fencing in South Africa (Lilja 2018) or geological constraints influencing coal mechanization (Christenson 1962), demonstrate that adoption and impact are never solely determined by the technology itself.

5.5. Conclusion: Synthesizing Historical Displacement

The quantitative historical evidence reviewed confirms that technological change frequently led to significant labour displacement before 1980, particularly when new methods directly substituted for core manual, craft, or routine clerical tasks. Industries undergoing large-scale mechanization or automation, such as agriculture (cotton harvesting, shepherding, dairying), mining (coal), manufacturing (glass, textiles, tires, cans, hosiery), transportation (railroads), and office work (telephone operation, routine data processing), experienced substantial reductions in labour demand for specific occupations, sometimes resulting in the near-complete elimination of established roles.

The consequences for displaced workers often included periods of unemployment, difficulty in finding comparable work, and significant earnings losses, especially for older workers or those whose skills became obsolete. However, the severity of displacement and the success of worker adjustment were highly contingent. Key mitigating factors included the overall rate of economic growth, the availability of alternative jobs in the local economy, high labour turnover rates, the nature of the technology (substitution vs. complementarity), proactive management strategies focused on retraining and reassignment, and the presence of strong institutional support mechanisms, particularly collective bargaining agreements providing job security and income maintenance provisions. Conversely, displacement was often more severe in declining industries, in regions lacking economic diversification, and where institutional shock absorbers were weak or absent. Thus, while technology was a powerful force reshaping labour markets, the historical record underscores that its impact on workers was consistently mediated by the broader economic, social, and institutional environment.

6. Limitations and Gaps in the Quantitative Evidence

While our systematic review identified a number of quantitative studies examining the initial displacement effects of technology adoption before 1980, a closer analysis reveals significant gaps in the literature regarding the subsequent experiences of displaced workers. Fully understanding the welfare consequences of technological change requires moving beyond simple headcount reductions to investigate what happens to workers after they lose their jobs. Two critical dimensions often missing from the historical quantitative record are the duration for which displaced workers remain unemployed and whether they permanently exit the labour market.

6.1. The Paucity of Evidence on Unemployment Duration and Labour Market Exit

A significant limitation of the existing quantitative historical literature on technological displacement is the general scarcity of information concerning the fate of workers after job loss. Most studies focus on the extent of initial displacement or wage changes, leaving the duration of subsequent unemployment or potential exit from the labour force largely unmeasured. However, a few studies provide valuable, albeit fragmented, insights into these adjustment outcomes.

Evidence on unemployment duration suggests that technological displacement could lead to significant periods out of work, particularly in the early-to-mid 20th century. A detailed survey of rubber workers displaced by plant shutdowns linked to mechanization in 1929 found workers lost an average of around 4.3 months of work in the first year, with older workers facing greater difficulty Clague and Couper 1931. Similarly, drawing on an earlier study of displaced clothing cutters from the same era, White 1931 reported an average unemployment duration of 5.2 months, with nearly 13% experiencing joblessness for over a year White 1931. Further evidence of long-term unemployment comes from the Mt. Vernon steel car plant shutdown in the 1950s, where 12% of displaced workers were still unemployed two years later Weinberg 1961; Clague 1961. Displaced service workers, such as New York elevator operators facing automation in the 1950s-60s, also tended to face longer spells of unemployment than average workers at the time Palladino 1987. Looking much further back, Schneider 2025 presents compelling qualitative evidence suggesting that the destruction of hand-spinning during the British Industrial Revolution resulted in unemployment for women that persisted over decades Schneider 2025. These studies collectively indicate that unemployment following technological displacement was often not a brief, transitory phenomenon.

Data on permanent labour market exit following displacement is even rarer. The Mt. Vernon study provides a quantitative estimate, finding 9% of workers had left the labour force two years after the shutdown Weinberg 1961; Clague 1961. The decline of hand-spinning also led to reduced labour force participation among women Schneider 2025. Furthermore, the automation of telephone operation appears to have induced higher rates of labour market exit among older displaced operators Feigenbaum and D. P. Gross 2024. While limited, this evidence suggests that technological displacement can push some workers, particularly those who are older or whose skills become obsolete, out of the labour force entirely.

The scattered nature of these findings highlights a major gap in the quantitative economic history of technological change. The duration of unemployment and the propensity for labour market exit are crucial determinants of the social costs associated with technological transitions. The general lack of systematic investigation into these outcomes across different technologies, time periods, worker groups, and institutional settings hinders our ability to draw comprehensive historical lessons. Future research focused specifically on reconstructing the post-displacement trajectories of workers affected by historical technological change is therefore essential for a more complete understanding of technology's long-term impact on labour markets and worker welfare.

6.2. Sparse Evidence on Post-Displacement Wage Changes

Beyond the duration of unemployment, another critical outcome for displaced workers is their subsequent earnings trajectory, should they find new employment. When setting out to write this paper, we aimed to synthesize evidence on whether technologically displaced workers recovered their previous wage levels or faced long-term earnings penalties. However, the quantitative historical studies identified in our review rarely provide this specific information. While several studies analyze aggregate wage trends or wage premiums for those who remained employed and adapted to new technology (e.g., Pehkonen, Neuvonen, and Ojala 2019; Ridolfi, Salvo, and Weisdorf 2022), or note declining real wages in sectors undergoing mechanization Musoke 1981, very few track the specific individuals who were displaced into new jobs and report their subsequent earnings compared to their pre-displacement wages. The exceptions that do provide such data, like the survey of displaced rubber workers by Clague and Couper 1931 showing significant wage reductions, or the linked data analysis of Swedish ironworkers by Bengtsson, van Maarseveen, and Poignant 2023 finding a 10% wage loss, are valuable but uncommon. This scarcity likely reflects the inherent difficulties in historical research of tracking individuals across different employers and obtaining reliable longitudinal wage data before the advent of modern surveys or administrative records. Consequently, the existing quantitative literature makes it difficult to systematically assess the extent to which technological displacement historically led to long-term wage scarring, a crucial component for understanding the full welfare impact.

6.3. Limited Systematic Analysis of Demographic Impacts

This paper also sought to determine if specific demographic groups were consistently more vulnerable to displacement or faced worse outcomes across different historical episodes, considering factors like age, gender, skill level, and race or ethnicity. The quantitative studies reviewed provide some insights but lack the granularity for a systematic comparative analysis. The differential impact on skilled versus unskilled workers is a recurring theme in several studies Gray 2013; O'Rourke, Rahman, and Taylor 2013; Bengtsson, van Maarseveen, and Poignant 2023. Gender features prominently in specific cases, such as the study of telephone operators Feigenbaum and D. P. Gross 2024. Age is highlighted as a barrier to re-employment in the work of Clague and Couper 1931. However, the primary studies themselves often lack the detailed, disaggregated data necessary to compare impacts intersectionally (e.g., by age *and* gender *and* skill simultaneously) or to facilitate robust comparisons across different studies, technologies, and periods. Information relating displacement specifically to race or ethnicity was particularly scarce in the quantitative studies identified by our review. This limitation within the primary historical sources restricts our ability to draw strong conclusions from the quantitative literature about the differential demographic burden of historical technological change.

6.4. Uneven Coverage and Challenges in Cross-Level Synthesis

When we initiated this review, we aimed to assess the breadth of quantitative historical research on technological displacement. The body of literature identified through our search process revealed a notable concentration. As shown previously (Figure 2), quantitative studies focus overwhelmingly on the United States and Western Europe. Similarly, certain time periods and technologies, such as the British Industrial Revolution or early twentieth-century agricultural mechanization, appear to have received more scholarly attention than others. It is crucial, however, to acknowledge a limitation in our own review methodology: our search strategy primarily encompassed sources published in English and indexed in major English-language academic databases. Therefore, while the literature accessible to this review appears geographically biased towards high-income economies of the Global North, we cannot conclude that relevant quantitative studies concerning other regions, perhaps published in other languages, do not exist. The apparent concentration reflects the scope of the readily available English-language historical scholarship meeting our systematic review criteria.

Furthermore, we sought to connect findings across different scales of analysis – comparing, for instance, studies focusing on individual firms with those examining entire industries or regions. The existing literature presents challenges for such synthesis, as individual studies typically focus on a single level. Studies that explicitly link micro- or meso-level technological change to broader labour market or social outcomes remain relatively uncommon, though valuable examples exist. For instance, Feigenbaum and D. P. Gross 2024 connect city-level technology adoption to individual worker outcomes using linked census data. Heinicke 1994 relates county-level mechanization to regional migration, and Caprettini and Voth 2020 links parish-level technology adoption to regional social unrest. While these studies offer models for bridging analytical levels, the general lack of such work within the quantitative historical literature makes it difficult to systematically trace how localized displacement events aggregate or dissipate at wider economic scales.

7. Narrative Review

Beyond the studies amenable to systematic quantitative analysis, a rich historical literature describes episodes where technological change was perceived by contemporaries or argued by historians to have displaced workers. While these narrative accounts may lack the precise metrics sought in our quantitative review – often for reasons related to the availability and nature of historical sources – they are useful to understand technological labour displacement. They serve as pointers, identifying moments, technologies, and affected groups where displacement likely occurred, even if its scale remains unmeasured. This narrative review explores these instances, drawing on qualitative historical scholarship to understand the perceived impacts of technology on employment before 1980. By highlighting these episodes and the challenges in quantifying their effects, we aim to identify fertile ground and articulate a call to action for future quantitative research in economic history, urging deeper investigation into these potentially significant but under-quantified moments of technological disruption.

7.1. The Mechanization of the Workshop: Artisans, Craft Skills, and Domestic Industries

One of the most prominent themes in the historical literature concerns the impact of early industrial machinery and factory production on artisans, craft workers, and those employed in domestic industries. The transition from hand-based methods to mechanized production, particularly in textiles, generated widespread contemporary debate and concern. Historians describe the profound disruption caused by innovations like the spinning jenny, water frame, mule, and power loom, which fundamentally altered production processes and labour markets. Rubin 1979, analysing the period through the lens of classical economics, highlights the fate of handicraft workers facing the factory system, noting, for instance, "[t]he ruin of the hand weavers, who continued a hopeless struggle against the machine for several decades, represented the final phase in the decline of handicrafts production in England" Rubin 1979, p. 235. The plight of groups like the handloom weavers and framework knitters became central to the "machinery question" that preoccupied economists and policymakers in the early nineteenth century Berg 1980. The scale of this perceived crisis was such that it famously led David Ricardo, a stalwart defender of classical economics, to add a chapter 'On Machinery' to the third edition of his *Principles*, acknowledging that the introduction of machinery could indeed render portions of the labouring class redundant and worsen their condition relative to capital Berg 1980, pp. 63, 269. Similar narratives exist for other crafts potentially affected by mechanization, such as printing Eisenstein 1980 or shoemaking, where traditional skills faced obsolescence.

Quantifying the extent of displacement in these sectors, however, presents significant challenges. Many affected workers, particularly in domestic industries like hand-spinning or weaving, were geographically dispersed, often worked irregularly or part-time (especially women), and operated within informal economic structures that left few systematic records suitable for quantitative analysis Schneider 2025. Pre-industrial or early industrial censuses often lack the necessary occupational detail or longitudinal perspective to track these individuals over time. Defining and consistently measuring 'skill' itself poses difficulties when comparing craft techniques to factory operations. Consequently, while the historical narrative strongly suggests significant displacement, the precise numbers remain elusive, highlighting a critical area where innovative quantitative methods applied to potentially unconventional sources (like parish records or guild archives, where available) might shed further light.

7.2. Reshaping Production Lines: Factory Work, Process Innovation, and Skill Hierarchies

Beyond the initial wave of mechanization that challenged craft production, historical narratives also detail subsequent transformations *within* factory walls and established industries, where new processes and more sophisticated automation reshaped production lines and labour requirements. While sometimes occurring alongside employment growth in expanding industries, these changes often involved the displacement of specific skills or groups of workers, effects which are again challenging to quantify precisely. The rise of scientific management and new systems of factory organization, as described by historians like Nelson 1995, while often aimed at increasing efficiency and management control, frequently intertwined with technological changes that eliminated traditional skilled roles. Nelson argues that in many industries adopting continuous-process operations or advanced mechanization towards the end of the nineteenth and early twentieth centuries, "mechanization eliminated many skilled workers" and "continuous-process operations required few skilled production workers" Nelson 1995, p. 7, replacing them often with semi-skilled operatives performing more specialized, machine-tending tasks.

Specific examples of dramatic labour displacement driven by process automation within factories also feature in the historical literature. George Barnett's contemporary study of the introduction of the Owens automatic bottle machine around 1905 provides a stark illustration Barnett 1925a. This technology revolutionized glass bottle production, effectively replacing earlier semi-automatic methods that still relied on skilled and semi-skilled glass blowers. Barnett describes the impact unequivocally: "The machine process practically eliminated the skilled workmen formerly required in the blowing department" Barnett 1925a, p. 123, leading to significant unemployment and requiring painful adjustments for the displaced craftsmen. While Barnett also presented quantitative estimates (included in our systematic review), his qualitative description powerfully conveys the disruptive nature of the innovation. Similarly, historical accounts of industries like coal mining describe recurring tensions and displacement fears associated with the introduction of mechanization, such as coal-cutting machines, which threatened the roles and autonomy of traditional miners Knox 1999. While automation might create new roles (e.g., in maintenance), the historical narratives often emphasize the loss of existing jobs and skills.

Quantifying the net employment effects of such changes within established industries, however, remains complex. Technological change is often deeply interwoven with shifts in market demand, management strategies aimed at deskilling or labour control independent of specific machinery, business cycle fluctuations, and the influence of trade unions Nelson 1995. Firm-level adjustments might involve internal transfers, retraining, or reliance on attrition rather than direct layoffs, making displacement harder to observe in aggregate data Freeman 1966. Furthermore, historical company records providing the necessary detail on workforce composition and reasons for separation are often incomplete or inaccessible. Occupational titles used in censuses or surveys may not adequately capture the subtle but significant shifts in task content and skill requirements resulting from process innovations. Thus, while historical narratives strongly suggest that process innovations and factory automation displaced specific groups of workers and skills, rigorously isolating and measuring the technological component of this displacement remains a challenge for quantitative analysis, beckoning further investigation perhaps through detailed firm-level case studies or the innovative use of company archives where available.

7.3. The Transformation of 'White-Collar' and Service Work

While narratives of technological displacement often center on manufacturing and craft production, historical accounts also point to significant, though perhaps less visible or easily quantifiable, transformations in service and clerical ('white-collar') employment driven by new technologies prior to 1980. The introduction of early office machinery, such as the typewriter, adding machines, and calculators, from the late nineteenth century onwards, represents a key example. Carlopio 1988 argues that these innovations fundamentally reshaped office work, previously dominated by male clerks performing tasks like bookkeeping and correspondence manually. The typewriter, in particular, "required less skill and training than bookkeeping or stenography," facilitating the large-scale entry of women into newly created, often lower-paid, secretarial and typing roles Carlopio 1988, p. 98. While this created new employment opportunities, especially for women, Carlopio notes that contemporary debates occurred where "opponents argued that... female 'typewriters' would displace male clerks, driving them into the already overcrowded market for manual labour" Carlopio 1988, p. 101. This suggests a potential gendered displacement, where technology contributed to replacing traditionally male roles with feminized, often less autonomous, positions.

Concerns about automation impacting white-collar and service work intensified in the mid-twentieth century with the advent of early computers and electronic data processing (EDP). Contemporary observers and studies, such as those summarized by Weinberg 1961 and Clague 1961, frequently discussed the potential for widespread displacement of clerical workers due to office automation Weinberg 1961, pp. 1-3. While acknowledging that rapid expansion in these sectors often absorbed labour, these accounts reflected significant anxiety about the future of routine clerical tasks Clague 1961, pp. 6-7, 15. Some specific case studies from the era, like the introduction of EDP at the Internal Revenue Service, indicated that careful planning involving retraining and attrition could mitigate large-scale layoffs Riche and Alliston 1963. However, the underlying potential for labour-saving in routine data processing tasks was widely recognized. Similar concerns, though perhaps less documented in the specific sources reviewed here, likely existed regarding mechanization in other service areas like retail (e.g., cash registers) or transportation (e.g., automation impacting ticketing or scheduling clerks).

Quantifying displacement in these sectors faces particular hurdles. Occupational classifications for clerical and service work have often been less standardized and more fluid than those in manufacturing or agriculture, making historical tracking difficult Carlopio 1988. The rapid overall growth of these sectors throughout much of the twentieth century could easily mask underlying displacement caused by technology – high job churn and the creation of entirely new roles may obscure the elimination of older ones in aggregate statistics. Furthermore, technology in office environments often altered the tasks *within* jobs rather than eliminating positions outright, a nuance hard to capture quantitatively. The relative lack of detailed, long-term firm-level data for office environments compared to factories also hinders precise measurement. Consequently, while historical narratives point towards significant technology-driven transformations and potential displacement in white-collar and service work, the quantitative footprint remains faint, presenting another key area for future investigation by economic historians adept at navigating complex occupational data and organizational change.

7.4. Synthesizing the Narrative: Common Themes and Avenues for Research

The historical narratives explored in the preceding sections, while diverse in their specific contexts, reveal several recurring themes regarding the perceived impact of technology on employment before 1980. A dominant pattern is the vulnerability of established craft skills and manual expertise to mechanization. From the artisans displaced by the early Industrial Revolution's textile machinery Rubin 1979; Berg 1980 to the skilled glass blowers made redundant by the Owens bottle machine Barnett 1925a, new technologies were often seen as directly substituting for human dexterity and judgement acquired through long apprenticeships. Secondly, technological change frequently intersected with existing social structures, particularly gender roles. Innovations sometimes displaced workers in male-dominated fields while simultaneously creating new, often lower-paid and lower-status, roles predominantly filled by women, as argued in the case of early office mechanization Carlopio 1988. Conversely, the destruction of female-dominated domestic industries like hand-spinning represented a massive, albeit poorly measured, loss of employment for women Schneider 2025. Thirdly, the introduction of potentially labour-saving technology consistently generated contemporary anxiety, debate, and sometimes overt resistance, reflecting a deep-seated societal concern about technological unemployment that predates modern computing Berg 1980; Weinberg 1961.

These rich narrative accounts stand in contrast, however, to the relative scarcity of corresponding quantitative evidence detailed earlier. Synthesizing the discussions above, the reasons for this quantitative gap are multifaceted but stem fundamentally from the nature of historical data and the complexity of isolating technological effects. Key challenges recurring across different contexts include: the difficulty of tracking geographically dispersed workers, particularly those in informal or domestic industries lacking systematic records; the frequent intertwining of technological change with simultaneous shifts in markets, management practices, and labour relations; the fact that adjustments often occurred through internal redeployment, attrition, or changes in task content rather than easily measurable layoffs; and the limitations inherent in historical datasets, such as inconsistent occupational classifications or lack of access to detailed, longitudinal firm-level records.

Acknowledging these challenges is not cause for abandoning quantitative inquiry into these historical episodes. Rather, the contrast between the compelling narrative evidence and the quantitative gaps underscores a clear call to action for economic historians. The instances highlighted in this narrative review – the decline of specific crafts, the reorganization of factory labour, the transformation of clerical work – represent crucial areas where our understanding of technology's historical impact remains incomplete. Future research should be directed towards these under-quantified areas. Progress may require methodological innovation, such as developing techniques suited to fragmented or non-traditional datasets. It will likely involve the painstaking exploitation of under-utilized sources, potentially including parish registers, guild archives, company records (where accessible), legal documents, or even material culture. Detailed, context-rich case studies that carefully combine qualitative insights with targeted quantitative analysis may prove particularly fruitful for disentangling the complex factors at play. By directing quantitative scrutiny towards the episodes and groups identified in the historical narrative, economic historians can significantly enrich our understanding of when, where, and for whom technological change has historically led to labour displacement, providing a firmer empirical grounding for understanding the long-run relationship between innovation and employment.

8. Discussion

This review set out to examine the historical record, prior to 1980, for evidence specifically concerning labour displacement following technological change. This historical focus distinguishes our contribution from contemporary analyses often centered on net employment effects or utilising data predominantly from recent decades. By adopting a longer time horizon and employing a dual methodology combining systematic quantitative review with narrative qualitative assessment, we aimed to build a more comprehensive understanding of when, where, and for whom innovation has historically destroyed jobs, providing potentially valuable context for current debates surrounding automation.

Our systematic review of quantitative studies confirms that significant, measurable labour displacement occurred repeatedly before 1980. The clearest patterns emerged where new technologies directly substituted for existing manual labour or craft skills, as seen in the mechanisation of agriculture, mining, and specific factory processes like glassmaking, or where automation targeted routine cognitive and clerical tasks, exemplified by the mechanisation of telephone operation and early electronic data processing. These quantified episodes often involved substantial reductions in employment for specific occupations, alongside consequences such as deskilling, wage penalties for displaced workers, migration, and sometimes wage polarisation. However, the quantitative evidence also underscores the profound contingency of these outcomes. Factors such as the overall rate of economic and industry growth, the potential for labour mobility, the degree to which new technology complemented existing or generated new skills, proactive management strategies involving retraining or internal transfers, and the strength of institutional frameworks, particularly collective bargaining agreements, significantly mediated the extent and severity of displacement.

Despite these insights, the quantitative historical literature exhibits critical gaps, particularly concerning the experiences of workers after displacement. A major limitation is the scarcity of systematic data tracking post-displacement trajectories. Information on the duration for which displaced workers remained unemployed, their propensity to exit the labour force permanently, and the extent of long-term wage scarring upon re-employment is rarely available in the studies identified. This paucity hinders a full assessment of the welfare consequences of historical technological transitions. Furthermore, the existing quantitative studies often lack the granular demographic detail required for systematic comparison of impacts across age, gender, and racial or ethnic groups. Methodological challenges, such as robustly synthesising findings across different levels of analysis—from the firm to the industry or region—also persist.

The narrative review proves invaluable in highlighting significant historical episodes and affected groups that remain largely unquantified, often due to data limitations inherent in the historical record. Qualitative accounts vividly detail the profound disruption experienced by artisans and domestic industry workers, such as handloom weavers and spinners, during early industrialisation—a transformation whose scale is difficult to measure precisely. Similarly, narrative sources point to significant technology-driven shifts within service and clerical work, including the potential gendered displacement associated with early office machinery, and later concerns surrounding electronic data processing, impacts often obscured by the rapid overall growth of these sectors. Displacement within cultural industries, affecting occupations like musicians or film projectionists, also surfaces primarily in qualitative accounts. Both reviews underscore a notable geographic bias in the existing literature towards North America and Western Europe. Consequently, the dynamics of technological displacement in the Global South—within colonial economies, specific agricultural transitions, or early industrialisation outside the West—are frequently described in narrative histories but lack systematic quantitative investigation, partly due to challenges in accessing relevant data and overcoming language barriers.

Synthesising the findings and identified gaps points towards a clear agenda for future quantitative economic history research on labour displacement. There is a pressing need to expand the geographic scope beyond the traditional focus on the Global North, actively seeking out and utilising archival sources from Asia, Africa, and Latin America, potentially leveraging new digital tools to overcome access and language barriers. Research should prioritise quantitative investigation of historically significant but currently under-measured sectors and groups, including domestic service, specific crafts, cultural industries, and the crucial gendered dimensions of technological change. A major priority must be the development and application of methods, likely involving longitudinal or linked datasets where feasible, to track the long-term fates of displaced workers regarding unemployment duration, labour force status, and wage trajectories. Methodological innovation is essential for tackling fragmented historical data, inconsistent occupational classifications, and the complexities of causal inference. Addressing these research priorities is vital not only for enriching our historical understanding but also for providing a more robust and globally representative empirical foundation to inform ongoing discussions about the relationship between technological innovation and the future of work.

9. Conclusion

This paper synthesised historical evidence on labour displacement resulting from technological change prior to 1980, combining systematic quantitative review with narrative assessment. Our findings confirm significant instances of technology-driven job destruction, particularly where innovations directly substituted for manual skills or automated routine tasks, although the severity and consequences for workers were highly contingent upon specific economic, institutional, and technological contexts. Crucially, this review highlights substantial gaps in the quantitative historical record regarding the long-term fates of displaced workers, differential demographic impacts, and the experiences of regions beyond North America and Europe, particularly in sectors like domestic service and cultural industries often surfaced only in narrative accounts. Bridging these gaps through targeted quantitative research, potentially leveraging new digital methodologies and expanding the geographic and sectoral scope of inquiry, is essential for developing a more comprehensive and globally representative understanding of the long-run relationship between technological advancement and labour market transformations, thereby providing a firmer historical grounding for contemporary policy debates.

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Appendix A: Summary of Related Contemporary Studies

Table A1: Summary of Recent Literature on Technology and Labor Displacement

Author(s)	**Time Period Covered**	**Technology Focus**	**Key Findings**	**Geographic Focus**
Autor (2022)	1980–2020	AI, Digital Technologies	Job polarization: growth in high- and low-skill jobs, decline in middle-skill roles; rising wage inequality due to automation of routine tasks	United States
Kolade & Owoseni (2022)	2011–2022	AI, Robotics, Remote Work	Digital transformation leads to job polarization, technological unemployment, and gig economy precarity	Advanced Economies

Author(s)	**Time Period Covered**	**Technology Focus**	**Key Findings**	**Geographic Focus**
Goos (2018)	1980–2018	Digital Revolution	Routine-biased technological change (RBTC) leads to U-shaped job distribution; skilled workers benefit more, unskilled are displaced	Developed Countries
Aghion et al. (2022)	2000–2023	Robotics, AI	Automation increases productivity and employment in automating firms but displaces workers in non-adopting firms	France, Germany, US

Author(s)	**Time Period Covered**	**Technology Focus**	**Key Findings**	**Geographic Focus**
Hötte et al. (2023)	1988–2021	ICT, Robotics	Net positive employment effects from technology due to compensatory mechanisms like job creation and increased demand	Developed Countries
Filippi et al. (2023)	2014–2021	Industrial Robots, AI	Mixed employment effects across sectors; displacement in some industries, job creation in others	US, France, Spain
Calvino & Virgillito (2017)	2000–2017	Product and Process Innovation, Digitalization	Product innovation creates jobs; process innovation displaces labour; firm-level growth does not guarantee industry-wide gains	US, Italy, France, Japan

Author(s)	**Time Period Covered**	**Technology Focus**	**Key Findings**	**Geographic Focus**
Corrocher et al. (2024)	2015–2024	Robotics, AI	Employment impacts vary by sector and country; product innovation creates jobs, process innovation saves labour	Western Europe, Japan, South Korea, US
Lane & Saint-Martin (2021)	2010–2021	AI	AI reorganizes tasks rather than eliminating jobs; complements high-skilled labour but increases income inequality	United States

Author(s)	**Time Period Covered**	**Technology Focus**	**Key Findings**	**Geographic Focus**
Mokyr et al. (2015)	1772–Present	Mechanical Innovations, Information Technology	Short-term job disruption but long-term benefits; technology consistently generates new industries and jobs	Western World
Mondolo (2020)	2003–2020	R&D, ICT, Robotics, AI	Technology displaces workers in the short term but creates new industries in the long term; effects vary by technology type	High-Income Countries

Appendix B: Systematic Review Study List

Table A2: Summary of Studies on Labor Displacement due to Technological Change

Authors (Key)	**Technology**	**Occupations**	**Time Period**	**Location of Study**	**Findings**
1. Steam Power and Industrial Mechanization					
Bengtsson, van Maarseveen, and Poignant (2023)	Bessemer, Siemens-Martin processes	Ironworkers	1860-1900	Sweden	Ironworkers displaced by site closures; many migrated and took lower-paid jobs. Wage loss of 10%.
Pehkonen, Neuvonen, and Ojala (2019)	Steam Engine	Seafarers	1869-1914	Sweden	High-skilled seafarers saw wage premiums (avg 17-26%), but mid-skilled workers (ABs) lost job prospects. Premiums decreased over time.
Ridolfi, Salvo, and Weisdorf (2022)	Steam Power	Industrial Workers	1840-1860	France	Wages and employment grew more in steam-adopting industries (+ 20% wage growth, + 120% employment growth) than in non-adopting ones.
Riden (1977)	Coke smelting, Blast furnaces	Ironworkers	1530-1869	UK	Increased iron production but displaced traditional furnace workers.
Hynninen, Ojala, and Pehkonen (2013)	Steam engine (shipping)	Mates, Engineers (high skill), Able-bodied seamen (mid skill), Ordinary seamen, Engine room operatives (low skill)	1869-1914	Sweden	Steam tech had skill-replacing aspects; demand for intermediate skills (ABs) fell relative to high-skilled (mates, new engineer roles) and low-skilled (OS, EORs). Evidence supports wage polarization.
2. Mechanization and Automation in Agriculture					

Continued on next page

Authors (Key)	**Technology**	**Occupations**	**Time Period**	**Location of Study**	**Findings**
Musoke (1981)	Tractors, Cotton Pickers	Sharecroppers, Laborers	1915-1960	USA (South)	Sharecropping declined by 90%, driven by tractor profitability (esp. post-WWII) and federal programs, leading to widespread displacement of sharecroppers.
Whatley (1983a)	Tractors (pre-harvest)	Sharetenants/Sharecroppers, Wage Laborers	1930-1940	USA (South)	AAA policies incentivized landlords to displace tenants and shift to wage labour, facilitating pre-harvest mechanization (tractors) before the picker arrived. Estimated displacement rate 22-37% in Delta.
Olmstead and Rhode (2001)	Tractors	Farm workers	1910-1960	USA	Tractors reduced annual labour use by at least 3.44 billion man-hours (equivalent to 1.72 million workers) by 1960 compared to horse power technology.
Heinicke (1994)	Mechanical Cotton Harvesters	Cotton Harvesters (African-American)	1950-1960	USA (South)	Upper bound estimate: 24% of African-American net migration from the South was directly due to harvester displacement, concentrated in Delta states.
Peterson and Kislev (1986)	Mechanical cotton picker (spindle picker)	Cotton pickers (hand labour)	1930-1964	USA (12 Southern States)	Reduced demand for hand picking labour driven primarily (79%) by rising nonfarm wages ("pull") and secondarily (21%) by falling machine costs ("push").

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Lilja (2018)	Wire fencing, Windmills/windpumps	Shepherds, Camp walkers	1865-1950	South Africa (Cape Colony)	Expected displacement of shepherds delayed by predators/water scarcity. Eventual replacement by 'camp walkers' on progressive farms from 1910s; demand persisted elsewhere.
Pickard (2007)	Fencing (wire), Strychnine poison	Shepherds, Boundary riders	Mid-late 19th C.	Australia	Transition required conjunction of factors (tech, tenure, dingo control, labour costs). Fencing eventually replaced shepherds with fewer boundary riders, driven by overall cost savings and productivity gains (wool/lambing).
Pickard (2008)	Fencing (wire)	Shepherds	1820s - late 19th C.	Australia	Shepherding dominant until late 19th C. Replaced by fencing due to tenure changes, dingo control, wire availability, and economic benefits (labour saving, productivity). Led to displacement of shepherds.
Settele (2018)	Milking machines (bucket, pipeline, parlour)	Agricultural workers, Milkers (wage and family)	1950-1980	West Germany	Machines replaced unavailable/costly wage labour due to industrial pull. Productivity per worker increased significantly, transforming work to supervision/mediation. Wage labour "vanished".

Continued on next page

Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Moring (1999)	Shift from slash-and-burn to set-field agriculture	Farmers, Family labour	19th Century	Finland (Virolahti parish)	Decline of labour-intensive slash-and-burn reduced need for large co-resident male workforce, leading to decline in joint-family households and rise of stem families.
3. Industrial Revolution and Factory Automation					
Gray (2013)	Electrification	Clerical, Manual, Managerial Workers	1900-1940	USA	Middle-skill (dexterity-intensive) jobs declined; skill distribution shifted towards clerical/managerial (skill-biased overall) and manual (unskill-biased blue-collar) tasks.
Atack, Margo, and Rhode (2023)	Mechanization (Inanimate power)	Skilled artisans, Semi-skilled operatives	1890s (data collection)	USA	36% of production operations showed de-skilling (skilled replaced by less-skilled) when comparing machine to hand methods. Driven more by division of labour than mechanization per se.
Ivanov and Kopsidis (2023)	Factory system (textiles) vs. Proto-industry	Proto-industrial textile workers, Factory textile workers	c.1870-1910	Bulgaria	Proto-industry declined due to falling demand; Factory output replaced proto-industrial output. Overall textile employment fell significantly (105k to 46.5k) as factory jobs (6.8k) did not offset proto-industrial losses.

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Authors (Key)	**Technology**	**Occupations**	**Time Period**	**Location of Study**	**Findings**
Hobsbawm (1952)	Industrial Revolution technologies (Mechanization, Factory system)	Artisans, Hand-workers, Factory workers, Miners etc.	1800-1914	Europe (esp. Britain)	Displacement/downgrading of established groups (e.g., weavers, artisans); worker unrest/union growth linked to technological/economic pressures and conditions (e.g., work intensity, wage pressure).
Gaskell (1833)	Steam power, Factory machinery (spinning, weaving)	Domestic spinners, weavers, yeomen	1760-1833	England	Displacement of domestic hand-spinners unable to compete; displacement of hand-loom weavers by power looms and influx of cheaper labour; yeomen displaced by inability to compete.
Hartwell (1961)	Industrial Revolution machinery	Handloom weavers, Labourers (general)	1800-1850	England	Acknowledges ”pockets of technological underemployment” (e.g., handloom weavers) but argues overall labour demand increased and displacement did not prevent rise in average real wages post-1815.
Ellison (1886)	Spinning Jenny, Water-Frame, Mule, Power-Loom	Hand-spinners, Hand-loom weavers	1764-1885	Great Britain (esp. Lancashire)	Complete displacement of hand-wheel spinning by machines. Displacement fears led to riots/machine breaking. Decline of hand-loom weavers with rise of power loom. Overall employment grew dramatically long-term.
4. Electrification and Telecommunications Automation					

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Feigenbaum and D. P. Gross (2024)	Telephone Automation (Mechanical Switching)	Telephone Operators	1910-1940	USA	Automation cutovers reduced young women operator jobs by 50-80% locally. Incumbent operators faced reduced work likelihood and lower pay if reemployed (-5% avg occupation score). Future cohorts absorbed into other jobs.
Ciliberto (2010)	Ring Spinning, Automatic Looms	Cotton Spinners, Weavers	1885-1910	UK (Lancashire)	Slow adoption of rings (female labour) vs mules (male skilled) linked to specialization in fine yarns. Faster adoption of automatic looms by integrated firms post-1902 suggests awareness of complementarities, altering industry structure but limited overall displacement data provided.
United States Bureau of Labor Statistics (1979)	Computers, Nuclear Power, EHV Transmission, Mechanized Line Work	Plant operators, Dispatchers, Line crews, Technicians, Maintenance workers	1960-1977	USA	Tech reduced labour requirements per unit (e.g., fewer operators for larger units, smaller line crews with mechanization, remote control reduced some roles), but overall employment grew slowly. Skill shifts towards technical/maintenance roles.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
United States Bureau of Labor Statistics (1979)	Computers, Advanced Cracking/Desulfurization/Reformer, Maintenance tech	Operators, Lab technicians, Analyzing, repairers, Maintenance craft workers, Laborers	1960-1977	USA	Computer control/automation reduced some operator/technician tasks. Maintenance changes (consolidation, contracting) reduced direct craft labour. Other processes increased unit labour. Net employment projected decline. Skills shifted to monitoring/technical.
5. Labor-Saving Factory Technology					
Caprettini and Voth (2020)	Threshing Machines	Agricultural Laborers	1800-1832	UK	Increased likelihood of riots (6.5 more per machine - IV est.); unemployment higher (7.6% vs 5.5%) in mechanized regions. Riot effect weaker near industrial towns (exit option).
O'Rourke, Rahman, and Taylor (2013)	Textile Machinery, Mass Production, Factory System	Textile Workers, Artisans (Mule spinners, Woolcombers)	1700-1900	UK/USA	Skilled artisans displaced by mass production using cheaper, unskilled labour (women/children) + machines (e.g., self-acting mule). Initial favoring of unskilled labour ("deskilling").
Autor, Chin, et al. (2024)	Robotics, Automation	Professional, Service, Production, Clerical Workers	1940-2018	Global	Automation reduced traditional jobs but created new job categories, balancing effects. (Note: Relevance questionable for pre-1980 focus)

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Best (1935)	Improved machines (feeds, multi-units, conveyors), Hand-to-machine shifts, Payment system changes	Manufacturing workers (various, primarily women)	1921-1931	USA (East/Midwest)	Affected processes saw 43.7% avg employment reduction. Nearly 50% of interviewed workers earned less after change. Specific examples: 1 man replaced 20 women (punch press); machine replaced 15 hand labelers/wrappers with 6 operators; 1 girl replaced 4 men (tube forming).
Seltzer (1997)	Automatic knitting machines (hosiery)	Hand transfer knitters, Knitters	1938-1940	USA (South)	FLSA minimum wage induced low-wage southern firms to adopt automatic machines faster, displacing hand transfer knitters. Sample knitters decreased by 17.5% (786 jobs).
Barnett (1925a)	Automatic Bottle Machines (Owens, Flow/Feed)	Hand blowers, Semi-automatic operators	1905-1925	USA	Massive displacement: Skilled workforce fell from 9,600 (1907) to 4,000 (1917); Semi-auto operators fell from 2,000 (1917) to 300 (1924). Hand blowers nearly eliminated. Some absorption into lower-paid attendant roles.
Barnett (1925b)	Linotype, Stone-planer, Bottle machines	Hand compositors, Stonecutters, Bottle blowers	Late 19th / Early 20th C.	USA/UK	Conceptual analysis using cases. Significant 'displacement of skill' (loss of earnings potential). Linotype power 4:1, Planer 8:1, Owens 18:1. Displacement depends on machine power, adoption speed, labour mobility, demand effects, skill transferability.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Davis (1927)	Automatic machinery (Bottle, Bulb, Tube, Window/Plate Glass)	Glass blowers, Hand pressers, Child helpers (mold boys, etc.)	1890s-1925	USA	Dramatic productivity increases (e.g., 41x bottles, 31x bulbs) displaced skilled blowers and virtually eliminated child labour. Workforce shifted to mechanics/machine operators.
Kjaer and Statistics (1929)	Line-casting machines (Linotype), Rotary presses, Autoplate	Hand compositors, Stereotypers, Pressmen	1896-1926	USA	Massive productivity gains vs hand methods (e.g., composition 500%+, presswork 8000%+). Significant initial displacement of hand typesetters ("3 or 4 hands... eliminated, out of every five") but reabsorbed by industry growth.
Nelson (1987)	Banbury mixers, Tire-building machines, Vulcanizers, Conveyors	Mill room workers, Tire builders, Curing workers, Laborers/Material handlers	1910-1930s	USA (Akron)	Significant displacement, esp. labourers (conveyors). Banbury displaced 40-60% mill workers. Watchcase vulcanizer displaced ¿90% curing crew. Overall Akron employment peaked 1920. Less deskilling than expected for operators.
United States Bureau of Labor Statistics (1984)	Automated knitting/sewing machines, Process elimination (boarding)	Knitters, Fixers, Boarders, Packers	1960-1982	USA	High productivity growth (6.8% avg) led to employment decline (-41% 1969-82). Specific occupations heavily reduced: Boarders (-80%), Knitters/Fixers (-60%), Packers (-50%) 1970-81.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
United States Bureau of Labor Statistics (1984)	Automated diemaking (CAD/CNC/Laser), Faster presses, Automatic stripping/gluing/packing	Diemakers, Cutting/creasing press operators, Strippers, Bundler-packers	1963-1982	USA	Technology reduced labor needs for specific tasks, causing cutbacks/skill changes for diemakers and press operators. Slow employment decline overall (-1.1% avg). Displacement not widespread.
United States Bureau of Labor Statistics (1984)	Two-piece can lines (D and I, D and R), Welded seams	Skilled/Unskilled can makers (litho feeders/unloaders, material handlers, etc.)	1960-1982	USA	Two-piece cans eliminated steps, significantly reducing unit labor (est. 25-30%) and displacing/deskilling workers. Employment fell 30% from 1970 peak. Adjustment via union agreements.
United States Bureau of Labor Statistics (1984)	Polyester fabrics, Steam tunnel finishing, Automated washing/handling/sorting	Pressers, Material handlers, Sorters/Markers/Assemblers	1960-1982	USA	Blended fabrics/steam tunnels eliminated need for pressing, significantly reducing presser employment. Automation reduced handling/sorting labor. Overall employment declined (-34% 1960-82), driven also by demand shifts.
United States Bureau of Labor Statistics and Epstein (1978)	Refined cutting/sewing machinery (NC, automatic attachments), Computers (management)	Sewing operators, Cutters, Markers, Mechanics	1960-1975	USA	Technology primarily refined existing processes, reducing skill for some roles (e.g., sewing) but increasing demand for others (mechanics, computer staff). Minimal displacement expected; productivity gains modest.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
United States Bureau of Labor Statistics and Epstein (1978)	Synthetic materials, Water jet/laser cutting, NC stitching, Flow molding, New lasting/bottoming methods	Pattern cutters, Sewing operators, Lasting operators, Bottoming workers (trimmers, sole attachers)	1960-1975	USA	Slow tech adoption overall. Technology reduced unit labor requirements and simplified/de-skilled jobs (e.g., lasting, bottoming). Some occupations eliminated. Significant employment decline driven primarily by imports.
United States Bureau of Labor Statistics and Epstein (1978)	Computers (design/control), NC machines, Transfer lines, Robots (welding), Automated assembly, New materials	Drafters, Keypunch operators, Machine tool operators, Inspectors, Welders, Assemblers, Maintenance personnel	1960-1975	USA	Technology reduced unit labor in machining, welding, assembly. Occupational shifts: more computer/maintenance, fewer routine operators/clerks. Overall employment projected slight decline.
6. Automation in Service Industries					
United States Bureau of Labor Statistics and Epstein (1978)	Computers, POS terminals, UPC scanners, Microfilm, Source marking, Self-service	Stock clerks, Cashiers, Bookkeepers, Credit clerks, Delivery workers, Gas station attendants, Seamstresses	1960-1975	USA	Technology automated data handling, reducing unit labor for marking, checking, bookkeeping. Self-service grew. Significant displacement unlikely due to industry growth/turnover, but job content shifted and some roles projected decline.
Weinberg (1960)	Electronic Data Processing (EDP) / Computers	Clerical workers (posting, checking, filing, computing, tabulating), Keypunch operators, Supervisors	1954-1957	USA (20 large offices)	EDP reduced need for routine clerical/tabulating jobs (25% reduction in affected units). Layoffs avoided via attrition/transfer. Created new EDP roles (programmer, operator). Older workers faced barriers accessing new jobs.

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Authors (Key)	**Technology**	**Occupations**	**Time Period**	**Location of Study**	**Findings**
Wiener (1962)	Electronic Data Processing (EDP) / Computers, MICR	Bookkeepers, Proof/transit clerks, Accounting clerks, Tabulating-machine operators	1954-1961 (proj. 1975)	USA (Banking)	EDP adoption slowed overall employment growth. Significant reduction in demand for bookkeepers (50%) and related clerical roles. New EDP jobs created. Layoffs minimized by growth/attrition.
Riche and Alliston (1963)	Electronic Data Processing (EDP) / Computers	Clerical workers (check processing, savings bond accounting)	1951-1959	USA (Federal Govt)	Check processing automation led to 48% net employment decline in operation, managed via transfers/attrition (few layoffs). Savings bond automation led to 36% layoffs due to location/skill mismatch.
Hoos (1961)	Electronic Data Processing (EDP) / Computers	Clerical workers (tally clerks, bookkeepers, file clerks, etc.), Key-punch operators	Mid-1950s - 1961	USA	EDP eliminated many routine clerical jobs, often managed via attrition/curtailed hiring. Created few higher-skill jobs. Resulted in routinized, "office factory" work for many remaining/new EDP roles.
Weber (1959)	Electronic Data Processing (EDP) / Computers, Tabulating equipment	Clerical/Semitechnical staff (payroll, inventory, accounting)	1952-1958	USA (Pittsburgh area)	Significant decrease in clerical employment (-17% to -21% in affected units). Increase in managerial staff, largely due to programming/implementation needs.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Kornrich (2012)	Household technologies (appliances, etc.), Prepared goods	Domestic servants, Laundresses	1900-1980	USA	Decline of domestic servant/laundress occupations linked partly to technology adoption by employers (households) making labor easier or redundant, alongside changing social norms and alternative jobs.
Sager (2007)	Household technologies (stoves, vacuum, washers, irons)	Domestic servants	1890s-1931	Canada	Technology adopted by employers partly in response to servant labor shortages/costs, facilitating the decline of the paid servant occupation and shift to unpaid housewife labor.
7. Automation in Primary Industries					
United States Bureau of Labor Statistics (1979)	Continuous miners, Longwall systems, Computers, Surface mining equipment	Roof support labor, Transport operators, Machine operators, Maintenance mechanics, Engineers, Technicians	1960-1977	USA	Reduced labor requirements for some tasks (roof support, transport), increased need for skilled maintenance/technical staff. Productivity declined 1970s due to regulations/labor issues. Overall employment grew late 1960s/70s due to demand.
United States Bureau of Labor Statistics (1979)	Offshore tech, Enhanced recovery, Computers, Exploration/Drilling tech	Professional/technical (Engineers, Geologists), Support staff, Drill crews	1960-1977	USA	Technology increased need for skilled technical/professional staff, esp. offshore. Displacement not anticipated; focus on meeting growing labor demand and potential skilled shortages.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
Christenson (1962)	Mechanization (Mechanical loaders, Continuous miners, Strip mining equipment)	Coal miners (esp. hand loaders, less skilled)	1930-1960	USA (esp. PA, WV, KY, OH, IL)	Massive employment decline (¿60% 1948-59) due to mechanization and falling demand. Led to persistent unemployment in coal regions. Shift towards surface/maintenance jobs.
Ostry (1999)	Computerized sawmill technology, Capital-intensive equipment	Sawmill workers	Late 1970s - 1985	Canada (B.C.)	Technology adoption + recession led to 40% workforce reduction. Displaced workers faced 33% income loss if re-employed outside forestry. Increased productivity per worker, potentially increasing ecological impact.
8. Automation in Transportation					
United States Bureau of Labor Statistics and Epstein (1978)	Dieselization, CTC, Computers, Automated yards, Mechanized maintenance	Maintenance workers, Firemen, Yard crews, Clerks, Station agents, Passenger service workers, Laborers	1960-1975	USA	Massive employment decline (-3.1% avg annual) across most occupations (esp. maintenance) due to technology and traffic shifts. High productivity growth (4.9% avg). Adjustment managed via union agreements.
Kelley and Yabroff (1963)	Dieselization, Mechanized maintenance, CTC, Office machines, Automated yards	Maintenance workers, Firemen, Station agents, Telegraphers, Clerks, Laborers, etc. (most occupations saw declines)	1947-1960	USA	Widespread technological change led to sharp employment decline (-42% overall), especially affecting maintenance (-50-55%) and less-skilled roles. Shifted occupational structure towards relatively more operating/white-collar jobs.

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Authors (Key)	Technology	Occupations	Time Period	Location of Study	Findings
United States Bureau of Labor Statistics (1979)	Computerized scheduling/control, Improved pipe/pumps/installation, Automatic metering	Process control operators, Schedulers, Gaugers, Accounting clerks, Maintenance technicians, Laborers	1960-1977	USA	Automation led to significant employment decline (-2.0% avg annual) and high productivity growth (7.9% avg). Reduced need for field operators/clerks/manual maintenance, increased need for central/technical staff.
9. Other/Miscellaneous Cases					
kennedy1982LaborTechnologyUnion	Automation, Robots, Computers, Scanners, CNC, New processes (e.g., boxed beef)	Assembly workers, Clerks, Meat cutters, Machinists, Printers, Telecom workers, etc.	1950s-1981	USA	Various industries saw job elimination/displacement and deskilling. Numbers cited include: 10k meat processing jobs lost (1974-80); 300k auto workers laid off (some permanent); printer production jobs declined 50k (1970s). Union responses varied.
turner1967LabourRelationsMotor	Automation (transfer machines), Assembly lines	Autoworkers (skilled, semi-skilled, unskilled)	Post-WWII - 1965	UK (comparison USA, Europe)	Automation displaced semi-skilled operators but overall displacement often linked to market downturns (e.g., Standard 1956: 3,500 redundant). Technology contributed to insecurity and complex wage disputes, driving high strike rates.

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Authors (Key)	**Technology**	**Occupations**	**Time Period**	**Location of Study**	**Findings**
Clague and Couper (1931)	Plant shut-down (linked to mechanization/reorganization)	Rubber workers (tire, footwear)	1929-1930	USA (CT)	Plant closures displaced 1900 workers. 1 year later, 23-30% still unemployed. Re-employed faced avg. wage cuts of 20-30%, median loss 30-40%. Avg 4.3 months unemployment in first year.
White (1931)	Labor-saving machinery (general); Specific examples (glass, clothing)	Various (Glass blowers, clothing cutters, handicraft workers)	1870-1931 (analysis/examples)	USA	Cites studies showing displacement (e.g., GBB union decline, 5.2 months avg unemployment for cutters). Argues aggregate data (1870-1920) shows occupational shifts, not rising permanent unemployment, due to service sector growth.
lane1987SovietLabourEthic	Mechanization, Automation, Reorganization (Shchekino, Brigades)	Industrial workers, Manual workers, Administrative staff	1967-1986	USSR	Technology/reorganization led to 'displacement' (vysvobozhdenie). Shchekino freed 56k workers by 1975; 968k freed 1976-80 via similar methods. Workers typically retrained/reabsorbed internally due to full employment policy/labor shortage.
Heim (1984)	Mass production methods, New industry technologies	Workers in declining industries (coal, cotton, ship, steel) vs. expanding (motors, electrical, services)	1923-1939	UK	Structural change led to displacement from declining sectors (727k job losses). Expanding sectors preferentially hired 'new' labor (women, youth, agricultural) due to lower cost/adaptability, limiting reabsorption of displaced workers.

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Authors (Key)	**Technology**	**Occupations**	**Time Period**	**Location of Study**	**Findings**
Caplan (1995)	Industrial rationalization / Mechanization	Skilled male labour vs. Unskilled female labour	Late 1920s	Germany	Rationalization displaced skilled male labor in some consumer goods industries (clothing, footwear, chemicals, electrical, light engineering), increasing demand for cheaper, unskilled female labor.
Barnett (1925a)	Semi-automatic bottle machines	Hand blowers, Machine operators (gatherers, pressers)	1898-1905	USA	Potential displacement of 1500 hand blowers largely avoided by market growth/transfer. Union secured machine jobs for members. Workers transitioning to machines initially earned 50% less, but reached parity by 1905.

Appendix C: Narrative Review Study List

Table A3: Narrative Review Study List

Study (Key)	Technology	Occupation(s) Displaced/Affected	Location(s)	Period Studied
Rubin (1979)	Textile Machinery (Jenny, Water Frame, Mule, Power Loom), Steam Engine, Factory System	Hand spinners, Weavers, Craft/Cottage Labourers	England (& Scotland)	c. 1775 - c. 1825
O'Rourke, Rahman, and Taylor (2013)	Factory System, Mechanization, Self-acting Mule, Wool Combing Machinery, Framework knitting machines	Skilled Workers (Artisans, Mule Spinners, Woolcombers, Woodworkers, Butchers, Bakers, Glassblowers, Shoemakers, Smiths)	England/Britain, USA (Context)	Early 19th C / Industrial Revolution (Context)
Carlopio (1988)	Looms (Manual, Jacquard), Framework Knitting Machines, Factory Machinery, Jigs/Fixtures	Silk Weavers, Framework Knitters, Hosiers, Textile Workers, Finishers, Machinists/Toolmakers	England (Nottingham, Lancashire), France (Lyons)	Focus 17th-19th C (Luddism early 19th C)
Schaffer (1994)	Calculating Engines (Difference/Analytical), Portsmouth Block-making Machinery	Human 'Computers' (Calculators), Craft Woodworkers (Portsmouth)	London, Portsmouth (England)	Focus c. 1810s/20s - 1840s/50s
A. Wente and Buhler (2018)	Mechanical Musical Instruments (Player Pianos, Automatic Organs), Sound Synchronization	Cinema Musicians (Pianists, Organists, Orchestra Members)	USA, Ireland, Britain	c. 1895 - c. 1931
Burrows (2018)	Organizational Shift to Permanent Cinemas, Potential Simplification of Projector Tech	Cinema Projectionists (Operators - deskilled/degraded)	Britain (esp. London)	1907 - 1919
Hobsbawm (1952)	Industrial Revolution Tech (Mechanization, Factory), Specific changes (Printing, Engineering, etc.)	Handloom weavers, Artisans (Tailors, Furniture Makers, Woolcombers/Spinners)	Primarily Britain, Europe examples	1800 - Early 20th C
Rose (1988)	Mechanization, Self-acting Mule (Cotton), Steam-driven Machines (Hosiery), New Looms (Carpet)	Skilled Male Workers (Spinners, Tailors, Hosiery Operatives, Silk Throwsters, Carpet Weavers, Compositors, Brassworkers) replaced by females	Britain (England, Scotland)	c. 1818 - Late 19th C
north-coombes1984SlaveryIndentureForced	Abolition of Slavery (trigger), Indenture System (replacement mechanism), Steam Mills (increased demand)	Ex-apprentices/Emancipees (former Plantation Labourers)	Mauritius	1834 - 1867

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Study (Key)	Technology	Occupation(s) Displaced/Affected	Location(s)	Period Studied
saunders1984WorkersParadoxIndentured	Central Mill (industry restructuring), White Australia Policy (political driver)	Pacific Islander & other non-European indentured labourers (replaced by white workers); Earlier: Convicts/Exiles	Queensland, Australia	c. 1860s - 1920
Ivanov and Kopsidis (2023)	Shift from Proto-industrial (handicraft) to Factory Production (Textiles)	Proto-industrial Textile Workers (Woollens - aba, gaytan)	Bulgaria	c. 1870 - 1910/11
Lilja (2018)	Wire Fencing, Windmills/Windpumps	Shepherds (partially replaced by camp walkers)	Cape Colony/Province, South Africa	1865 - 1950 (Displacement mainly 1910s+)
Moring (1999)	Shift from Slash-and-burn to Set-field Agriculture	Co-resident Male Workforce (reduced need within household)	Virolahti parish, Eastern Finland	Focus 19th C (Data 1818-1876)
Pickard (2008)	Fencing (wire fences)	Shepherds (replaced by boundary riders)	Colonial Australia	Mid-to-late 19th C
Whatley (1987)	Tractor (All-purpose), Mechanical Cotton Picker (potential/delayed)	Sharecroppers/Tenants (Displacement impeded by contracts)	Cotton South, USA	Primarily pre-WWII (focus)
Heim (1984)	Mass Production Methods, New Manufacturing Tech (Motors, Electrical, etc.)	Workers in Declining Industries (Coal, Cotton, Shipbuilding, Iron & Steel)	Great Britain	Interwar (1923-1939)
coyle1982SexSkillOrganisation	Mechanization (Bandsaw), Rationalization (Subdivision, Work Study)	Skilled Male Craftsmen (Tailors, Cutters)	Great Britain	Interwar & Post-WWII (analyzed up to 1982)
armstrong1982IfOnlyWomen	Automation (Flash Removal), Capital-intensive Moulding Presses, Shiftwork Introduction	Female workers (flash removal, press operators, cementing dept)	Greater Manchester, UK	c. 1977-1979 (Fieldwork period)
Palladino (1987)	Automatic Elevators (various types)	Elevator Operators	New York City, USA	1934 - 1970
randall1986PhilosophyLuddism	Spinning Jenny, Scribbling Engine, Gig Mill, Shearing Frame	Spinners (Warp, Abb), Scribblers, Shearmen (Croppers)	West of England	c. 1790 - 1809
A. R. Wente (2022)	Player Piano (incl. Reproducing Pianos)	Amateur Pianists (skill displacement?), Live Musicians (commercial venues)	Primarily USA	Early 20th C (peak 1923, decline post-1930)

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Study (Key)	Technology	Occupation(s) Displaced/Affected	Location(s)	Period Studied
frances1993PoliticsWork	Sewing Machines, Cutting Machines, Sole-Sewing/Lasting/Finishing Machines (Boots), Linotypes	Bootmakers (finishers, lasters), Compositors, Hand book-sewers, Clothing finishers	Victoria, Australia	1880 - 1910 (focus of excerpt)
vandenende1994NumberFactory	Punched-card Machines (Hollerith)	Manual Counting/Sorting Clerks	Netherlands	1916 - Mid-1960s
Hartwell (1961)	Industrial Revolution Tech (Mechanization, Factory, Steam)	Handloom weavers (mentioned as affected)	England	1800 - 1850
Pickard (2007)	Fencing (wire), Strychnine poisoning (dingo control)	Shepherds (replaced by boundary riders)	Colonial Australia	Mid-to-late 19th C
Whatley (1983b)	Tractors / Mechanization (facilitated by AAA policy)	Sharetenants, Sharecroppers	US Cotton South (esp. Delta)	1930s (response to AAA)
lane1987SovietLabourEthic	Mechanization, Automation, Reorganization (Shchekino)	Various Industrial Workers (manual, auxiliary, admin)	USSR	Post-1930 to mid-1980s (Shchekino from 1967)
Blackburn, Coombs, and Green (1985)	Mechanisation (Primary/Secondary/Tertiary), Automation (Transfer lines, NC, IT), Fordism	Craft workers, Assembly workers, Machinists, Clerical workers	UK/USA primarily	c.1850 - c.1985
van Zanden (1991)	Land-saving (Fertilizers, Feeds), limited Labour-saving (Cream separators, Threshers)	Agricultural wage labourers (esp. Britain, Ireland)	Europe (esp. contrast Britain/France vs. Continent)	1870 - 1914
raven2015industrialRevolutionsBook	Steam presses, Mechanized papermaking, Stereotyping, Linotype/Monotype, Machine binding	Printers, Compositors, Hand-binders (implicitly)	Europe (esp. Britain), North America	19th Century
Ostry (1999)	Sawmill automation (Computerized production tech)	Sawmill workers	British Columbia, Canada	Late 1970s - 1985
Berg (1980)	Machinery, Steam power, Factory system (esp. Textiles)	Handloom weavers, Artisans	Great Britain	1815 - 1848
Seltzer (1997)	Hosiery knitting machine conversion/replacement (automatic)	Hand transfer knitting machine operators	Southern US (hosiery)	1938 - 1940 (response to FLSA)

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Study (Key)	Technology	Occupation(s) Displaced/Affected	Location(s)	Period Studied
Kornrich (2012)	Household appliances, Finished goods (food, clothing)	Domestic servants, Laundresses	United States	20th Century (focus on decline pre-1980)
Caplan (1995)	Rationalization / Mechanized production processes	Skilled male labour (older trades)	Germany	Late 1920s / 1930s
P. Phillips and E. Phillips (2000)	Mechanization (dairying, textiles, sewing), Typewriter	Home producers, Dairy workers, Artisans, Clerical workers	Canada	19th / Early 20th C (relevant sections)
Sen (1999)	Factory system (jute), later mechanization (feeding, sewing)	Jute mill workers (women in preparing, sewing)	Bengal, India	1890 - 1940
Alderton and Internationales Arbeitsamt (2004)	Automation, Containerization, Satellite communications (GMDSS)	Seafarers (OECD nationalities), Radio Officers	Global (focus on OECD displacement)	1960s onwards (effects analyzed up to early 2000s)
Ellison (1886)	Spinning Jenny, Water-frame, Mule, Power-loom, Steam engine	Hand-spinners, Hand-loom weavers	Great Britain (esp. Lancashire)	1760s - 1885
Kjaer and Statistics (1929)	Line-casting machines (Linotype), Rotary press, Autoplate stereotyping	Compositors (hand typesetters), Hand press workers, Hand stereotypers	United States	1896 - 1926
monthlylaborreview1928ProductivityLaborIndustry	Various (”mass production machinery”, automatic machines)	Various (Railroad trainmen, shoe workers, tool makers, steel workers, etc.)	United States	Focus on 1928 context, examples pre-1928
Weinberg (1961)	Mechanization (Mechanical loading, continuous miners, strip mining equipment)	Coal miners (esp. hand loaders, pick miners)	United States (esp. PA, WV, KY, OH, IL)	1930 - 1960 (focus post-WWII)
bowden1932TechnologicalChangesEmployment	Mechanical/Administrative (Canceling/Sorting machines, conveyors, vehicles, accounting machines, organizational changes)	Various postal workers (clerks, carriers, railway mail clerks)	United States	1908 - 1931
Best (1935)	Various factory machines (improved/automatic feeds, conveyors, hand-to-machine conversions)	Various female manufacturing workers (punch press, packing, assembly, sewing, etc.)	United States (East/Midwest)	1921 - 1931

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Study (Key)	Technology	Occupation(s) Displaced/Affected	Location(s)	Period Studied
freedman1966ImpactOfficeAutomation	Electronic Data Processing (EDP) / Computers	Clerical workers (tabulating, bookkeeping, calculating, filing)	United States (Insurance industry offices)	1954 - 1963 (adoption/impact period)
usdepartmentoflabor1963ImpactOfficeAutomation	Electronic Data Processing (EDP) / Computers	Routine office/clerical workers	US Federal Government (IRS Atlanta Region focus)	1959 - 1962 (initial impact analysis)
Weber (1959)	Computers / EDP systems	Clerical/semitechnical (inventory, payroll, accounting)	Pittsburgh area, USA	1952/1955 - 1958
bls1956AdjustmentsAutomationTwo	Printed circuit/Automatic insertion (Electronics); Electronic Computer (Insurance)	Assemblers/Handwirers (Electronics); Clerical/Punchcard operators (Insurance)	United States (Electronics plant, Insurance office)	Early 1950s (studied up to 1955)
uslaborstatistics1977TechnologicalChangeLaborApparel	Cutting/sewing refinements, computers (mgmt/patterns), NC sewing	Sewing machine operators, cutters (potential de-skilling/shift)	United States	1960 - 1975 (historical focus)
uslaborstatistics1977TechnologicalChangeLaborFootwear	Synthetics, Water jet/laser cutting, Computer stitching, Flow molding, New lasting machines, Injection molding	Lasting operators, Bottoming workers (edge trimmers, sole attachers), Sewing operators	United States	Approx 1957 - 1975 (focus of tech changes)
uslaborstatistics1977TechnologicalChangeLaborMotor	Computers (CAD, control), NC machine tools, Transfer lines, Automation/Robots (welding)	Drafters, Keypunch operators, Machine tool operators, Inspectors, Welders, Assemblers	United States	1960 - 1975 (historical focus)
uslaborstatistics1977TechnologicalChangeLaborRailroads	Dieselization, Mechanized maintenance, Automated yards, Computers, CTC, Communications	Maintenance workers, Firemen, Yard crews, Clerks, Station agents, Line workers, Passenger service workers, Laborers	United States	1960 - 1975 (main analysis period)
uslaborstatistics1977TechnologicalChangeLaborRetail	Computers, POS terminals, UPC scanners, Source marking, Automated credit check, Microfilm	Stock clerks, Cashiers, Bookkeepers, Credit clerks, Delivery workers (potential reduction/shift)	United States	1960 - 1975 (historical focus)
belitsky1984TechnologicalChangeLaborHosiery	Automated knitting machines, Automatic sewing (toe closing, gusseting), Electronic controls, Elimination of boarding	Boarders, Knitters, Fixers, Packers	United States	1960 - 1982

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Study (Key)	Technology	Occupation(s) Displaced/Affected	Location(s)	Period Studied
lyon1984TechnologicalChangeLaborFolding	Offset/gravure printing, Faster cutting/creasing presses, Automated diemaking (CAD/CNC/laser), Auto stripping/finishing	Diemakers, Cutting/creasing press operators, Strippers, Bundler-packers	United States	1963 - 1982
bell1984TechnologicalChangeLaborMetal	Two-piece cans (D&I, D&R), Welded side seams	Solder bodymaker operators, Litho feeders/unloaders, Material handlers	United States	1960 - 1982 (Two-piece adoption mid-1960s)
critchlow1984TechnologicalChangeLaborLaundry	Automated washing/finishing (Steam tunnels), Blended fabrics, New detergents	Pressers	United States	1960 - 1982
United States Bureau of Labor Statistics (1979)	Continuous miners, Longwall, Surface mining equipment, Computers	Coal miners (esp. roof support, transport)	United States	1960 - 1977
United States Bureau of Labor Statistics (1979)	Computers, Improved cracking/desulfurization/reforming, Maintenance tech	Analyzer repairers, operators, lab techs, maintenance crafts, laborers	United States	1960 - 1977
United States Bureau of Labor Statistics (1979)	Computers (scheduling, control), Automatic metering, Improved pipe/pumps/installation	Schedulers, Accounting clerks, Gaugers, Process control operators, Maintenance technicians	United States	1960 - 1977
United States Bureau of Labor Statistics (1979)	Computers, Nuclear power, EHV transmission, Mechanized line work	Control room operators, Dispatchers, Line crews, Fuel/ash handlers	United States	1960 - 1977
mann1960AutomationWorkerStudy	Automation in power plants (unit system, feedback controls, centralization)	Power plant operators (specific roles eliminated/combined)	United States (two plants)	Mid-1950s (studied 1954-1955)
Rothberg (1956)	Increased mechanization (bulk handling, automatic bread line)	Material handlers, bread-mixer helpers, wrapping personnel, foremen	United States (large bakery)	1950 - 1955
Rothberg (1957)	Automatic process units (fluid catalytic cracking, delayed coking, catalytic reforming)	Stillmen, operators, helpers, coke cleanout workers	United States (oil refinery)	1948 - 1956
bls1956AdjustmentsAutomationTwo	Printed circuitry/Automatic insertion (Electronics); Electronic Computer (Insurance)	Assemblers/Handwirers (Electronics); Clerical/Punchcard operators (Insurance)	United States (Electronics plant, Insurance office)	Early 1950s (studied up to 1955)

Appendix D: Deduplication of Search Results

The CSV files containing the records and the python files used to manipulate them available in the github repository/replication package at this repository.

To ensure that our systematic review did not include duplicate records, we implemented a two-step deduplication process across the four databases: EBSCO, Google Scholar, Scopus, and Web of Science. Below, we outline the search strategy and the deduplication process.

Search Strategy

We conducted searches using the terms `lab$r replac*` and `lab$r displac*`, to account for both British and American spellings of "labor" and "labor" and to capture variations such as "replacement", "replacing", and "replaced." To focus on historical contexts, we appended the term `history` during the first stage of the search.

In the second stage, we removed the `history` modifier and targeted 16 major economic history journals indexed in Scopus and Web of Science. For Google Scholar, we constrained the results to the top 1,000 entries for each term, given the large volume of results.

The initial search results were as follows:

- **EBSCO:** 699 results
- **Google Scholar:** 2,000 results (1,000 per search term)
- **Scopus:** 1,026 results
- **Web of Science:** 751 results

We performed the journal-specific search using the Scopus API, yielding an additional 261 records, distributed across journals as shown in Table A4. Combined, this resulted in a total of 4,736 records. These were the processed for deduplication.

Deduplication Process

To identify and remove duplicate records, we followed these steps:

Step 1: Exact Matching

We removed duplicates based on exact matches of the DOI (if available). For records without DOIs, we standardized the title field by:

- Converting all text to lowercase.
- Removing non-standard punctuation.
- Stripping excess whitespace.

Table A4: Number of Records from Journal-Specific Search

Journal Name	Number of Records
The Journal of Economic History	73
Explorations in Economic History	56
The Economic History Review	43
Cliometrica	24
Economic History of Developing Regions	14
The Scandinavian Economic History Review	12
The European Review of Economic History	12
Low Countries Journal of Economic and Social History	11
Indian Economic and Social History Review	7
Research in Economic History	5
African Economic History	3
Journal of European Economic History	1

We retained only one instance of records with identical standardized titles. This step reduced the total from 4,736 to 3,195 records.

Step 2: Similarity Matching

We calculated the cosine similarity between the standardized titles of remaining records to identify potential duplicates with slight title variations (e.g., different punctuation or missing colons). Titles with high similarity were manually reviewed and consolidated where appropriate. This process further reduced the count from 3,195 to 3,172 records.

Results

The deduplication results are summarized in Table A5. The diagonal values represent the unique records from each database, while the off-diagonal values indicate the number of overlapping records between database pairs.

Table A5: Number of Common Entries Between Search Sources

Source	Google Scholar	Scopus	EBSCO	Web of Science
Google Scholar API	1,615	108	57	53
Scopus		1,080	256	383
EBSCO			668	252
Web of Science				737

This method ensured that the final dataset was free from duplicate entries.

Appendix E: GRADE-CERQual Approach

9.1. Quality Assessment Using GRADE-CERQual Criteria

To assess the confidence in our qualitative findings, we applied the GRADE-CERQual (Confidence in the Evidence from Reviews of Qualitative Research) approach, which evaluates four key components:

1. Methodological Limitations: We examined the quality of the primary studies contributing to each review finding, assessing potential biases or flaws in study design and execution.
2. Coherence: We evaluated the consistency and clarity of the data supporting each review finding, determining whether the evidence was well-aligned and convincingly supported the conclusions drawn.
3. Adequacy of Data: We assessed the richness and quantity of data underpinning each review finding to ensure there was sufficient evidence to substantiate the conclusions.
4. Relevance: We considered the applicability of the primary data to the specific context of our review questions, ensuring the evidence was pertinent to the study's objectives.

In the context of our systematic review of historical social science research, we adapted the GRADE-CERQual criteria to account for the unique challenges presented by historical data. This adaptation involved evaluating the methodological rigor of historical studies, the coherence of historical narratives, the adequacy of historical data, and the relevance of historical contexts to our research questions.

Each study included in the systematic review was scored according to these four criteria. These scores reflect our assessment of the confidence in the evidence provided by each study. The full scoring for all studies is available in the replication data, which can be accessed in the associated GitHub repository: `https://github.com/j-jayes/systematic-review`.

By employing this adapted GRADE-CERQual approach, we aim to provide a transparent and systematic assessment of the confidence in our qualitative findings, thereby enhancing the robustness and credibility of our systematic review.