Technological Unemployment in Victorian Britain: A Tasks Based Approach

Hillary Vipond [1]

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Abstract

There is no quantitative record of jobs lost to, and generated by, creative destruction as industries mechanized in Great Britain over the 19th century. Such a record would enable a long run view of the impact of occupational decline, adding a dimension to debates on the future of work. I create a new, sub-industry, level of occupation for England between 1851-1911, using text recorded in individual level English census observations, as digitized by the Integrated Census Microdata project (ICeM), as data. I focus on the impact of mechanization on the bootmaking industry, and assign 1.3 million English bootmakers to the sub-industry "tasks" they performed. I show that technological unemployment obscured at an industry level analysis is revealed at the task level. In bootmaking, the occupational structure was transformed as the industry mechanized. Approximately 152 000 jobs disappeared as skills became obsolete, and another 144 000 jobs, demanding new skills, were generated. The new jobs went almost entirely to young bootmakers, and incumbents were not able to transition into the new employment opportunities.

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For three centuries sustained economic growth has been powered by the invention and adoption of new technologies. These innovations have made jobs obsolete, and displaced workers. Simultaneously, they have generated new employment opportunities. The two outcomes have been modelled as countervailing forces, with jobs created offsetting jobs lost (Acemoglu and Restrepo, 2019). Research on the future of work has investigated which workers are most likely to be exposed to labour displacement driven by the adoption of new technology (Frey and Osborne, 2017), and the individual consequences of occupational decline (Edin et al., 2019). A long-run view on the impacts of occupational decline would contribute an additional dimension to the debate. However, data on labour displacement in historical contexts rarely exists. This paper proposes an approach which reveals and quantifies technological unemployment in England between 1851-1911, and thereby opens the door to research on the inter-generational impacts of labour displacement.

Labour displacing technologies have been the norm since the British industrial revolution, and a hallmark of modern economic growth. Lamplighters in New York lost their jobs to electricity in the early 1900s (Frey, 2019), and tens of thousands of American women lost their jobs as telephone operators in the 1920s (Feigenbaum and Gross, 2020). In the present day, nearly 2 million American truck drivers risk unemployment if their industry is automated. A much discussed paper has estimated that up to 47% of jobs in America are at risk of automation in the next few decades (Frey and Osborne, 2017). Yet, for all that the parade of new technologies has displaced labour, making skills and jobs obsolete, it has simultaneously generated new jobs, and created demand for entirely new skillsets. This "reinstatement" of labour has, up to the present day, outpaced labour displacement. An early attempt to quantify the emergence of new jobs estimated that 8.5% of American workers in 1980 were employed in occupations which did not exist in 1965 (Lin, 2011). Building on this work, new research estimates that more than half of the jobs which currently employ Americans did not exist prior to 1940 (Autor, 2022; Autor et al., 2022).

With the fourth industrial revolution on the horizon, long-standing anxieties about the impacts of new technologies on the future of work have resurfaced. Two key questions are at stake. The first is whether new technologies will continue to be able to create jobs at the rate they displace them. There are scholars who believe that recent developments in AI herald the end of this era, with AI now out-competing human labour on multiple fronts (Susskind, 2020). The second is whether the cyclical waves of technological adoption tilt access to opportunity, as some segments of the labour market capture the newly generated job opportunities, and other groups are left behind. The asymmetrical impacts of creative destruction on demand for labour is being studied. Research on who is most at risk of technological unemployment is extensive. To date, there is agreement that those working in routine jobs (Bank, 2018; Autor et al., 2022), and older workers (Autor and Dorn, 2009)are most at risk. A much smaller body of literature considers the individual consequences of occupational decline (Edin et al., 2019; Braxton and Taska, 2023; Acemoglu and Restrepo, 2022).

History is well placed to offer insight into how consecutive waves of technological adoption impacted access to opportunity in the labour market. It should grant a wide-angle lens on the question, and be able to consider whether the consequences of the shocks ripple through generations. However, labour displacement in historical contexts has seldom been quantified, and this is a prerequisite to investigating these questions. The existing literature consists of a handful of studies. This includes new research from Feigenbaum and Gross (2020), which explores the impacts of the mechanization of the telephone industry in the United States. They find that incumbents were pushed out of the labor market or into lower-paying jobs. However, they also learn that the mechanization of this particular industry did not have a deleterious impact on opportunities for future generations of young women, as new employment in other sectors became available to fill the gap. Other papers have taken a more comprehensive, but less direct, approach to the question. Kogan et al. (2021) draws on nearly two centuries of patent data, matches it with administrative data, and finds that technological innovation in the United States has been correlated with declining wages and fewer employment opportunities for incumbents in impacted industries. Atack et al. (2019) makes use of the Hand and Machine Labour Study, commissioned in the United States in 1894, to discover the relative cost and productivity of hand and machine labour. They find that mechanization in various industries led to both job loss and job creation.

However, this constitutes a small number of studies for what may have been a watershed moment in labour displacement history. Even in Great Britain, which was the first country to industrialize, and where the events of the Industrial Revolution have been scrutinized, the impact of mechanization on labour displacement has not been well explored. Certainly, British workers at the time were concerned that the new technologies would lead to labour displacement: there is narrative evidence of this from the Luddite uprisings, from the Swing Riots, and in the hive of union activity arising from technological anxiety. Leading intellectuals of the time – Karl Marx and David Ricardo, amongst others - were alarmed. However, we do not know if labour displacement swept across England in the wake of the unprecedented adoption of the new technologies. Scholars hold radically diverging views. David Landes, for instance, claims that the adoption of the new technologies "…destroyed the livelihood of some and left others to vegetate in the backwaters of the stream of progress...the victims of the Industrial Revolution were numbered in the hundreds of thousands or even millions" (Landes, 2003), while others doubt whether this took place at all (Mokyr et al., 2015). This profound difference of opinion is viable only because there is so little data to bring to bear on the question.

This paper proposes a solution which allows job loss and job creation in 19th century England to be quantified. I propose a tasks-based approach, which uncovers the impact of the adoption of new technologies in 19th century Britain on the occupational structure. It is informed by research on routine biased technological change (RBTC), which has found that the impact of new technologies on wage premiums is often visible at the "task" level of occupation (Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2019; Autor, 2022; Autor et al., 2022). In RBTC models wage penalties reflect weakened demand for certain types of labour, as demand shifts in response to the adoption of new technologies. While weakening demand for labour can drive wages down, a collapse in demand can result not only in decreasing wages, but in job losses in the industry and, eventually, in occupational decline - there are so few gas lamplighters in the United States in the 21st century because there is so little demand for them. A tasks based approach to identifying job loss and job creation has seldom been used, even with modern data, because individual level data on occupation is rarely available at the task level.

At present, 19th century English census data tracks occupation at the industry level. This masks and obscures shifts in the occupational structure taking place at more granular levels. By moving to a tasks based approach the transformations to the occupational structure taking place at a sub-industry level can be revealed. I develop a new, "task" level categorization structure, using text recorded in individual level English census observations, as digitized by the Integrated Census Microdata project (ICEM) (Schurer et al., 2022), as data. I apply this new approach to assessing the impact of mechanization on one industry, English bootmaking.

The bootmaking industry was large, employing approximately 220 000 people, nearly a fifth of whom were women. This makes for a total of 1.3 million observations of individuals working in the bootmaking industry over the six English census returns taken between 1851-1911. Mechanization was precipitated by the introduction of the sewing machine in 1858, and continued through to the early 20th century. I assign 1.29 million observations of English bootmakers, or 97% of the total population of bootmakers during the period, to the sub-industry level ”tasks” they performed.

Analysis at this level reveals that approximately 152,000 jobs were lost in England and Wales as the new technologies rendered skills obsolete, and another 144,000 jobs, demanding new skills, were created. Incumbent bootmakers were not able to keep up with the shifting demands of the industry. They did not transition out of obsolete “tasks” and into the newly generated ones. Instead, new opportunities went to young people, particularly those born in the geographical locations in which the new jobs had been being generated.

This new, “task-based”, approach to occupation opens the door to quantifying technological unemployment across all industries in Great Britain over the latter half of the 19th century. It is a stepping stone to research exploring the welfare consequences of technological unemployment over the long-run. It is worth noting that, as a term, technological unemployment has largely been retired from the lexicon. Popularized by John Maynard Keynes in the 1930s (Keynes, 1930), it tends to refer to permanent technological unemployment, which occurs only when no new jobs are generated to offset those lost to creative destruction. A less specific term, “labour displacement”, has now been widely adopted to describe the temporary unemployment which emerges from cycles of creative destruction, and has the advantage of not evoking connotations of permanent technological unemployment. However, since both unemployment and technology are salient elements of the process being discussed, the term ”transitional technological unemployment” has the advantage of being more accurate.

The paper is organised as follows. Section 1 reviews the historical setting for the mechanization of the English bootmaking industry. Section 2 introduces the ICeM census data, and the methodology used to construct the new task level occupational classification. Section 3 shows the results of taking a task level approach, with previously masked shifts in the occupational structure now revealed. It considers the scale and pace of these changes. Section 4 considers whether incumbents were able to transition out of the old, declining jobs and into the new opportunities. Section 5 discusses, section 6 concludes.

1 Historical Context

Bootmaking was the single largest craft industry in 19th century Britain, and the fifth most important occupation. [1] Bootmakers made up 2.9% of the working population in England in 1851. It was an industry responsible for directly employing nearly a quarter of a million people, a fifth of whom were women. Indirectly, it provided a household income for just over a million people, a substantial share of the 18 million individuals who lived in England in 1851. Boots have always been desirable products in the context of British weather, and in times of war the government invested heavily. The Napoleonic wars, for example, provided a major boost to the industry. [2]

The mechanisation of the English bootmaking industry was precipitated by the introduction of the bootmaking sewing machine in 1858, and evolved through the second half of the 19th century. This period coincides with the window for which high quality individual-level census data is available. Since the census returns include individual level information on occupation, it is possible to explore the impact of mechanization on workers in the bootmaking industry.

A comprehensive narrative treatment of the evolution of the bootmaking industry in England does not exist, although several papers consider earlier periods, in the 18th century (Riello, 2002), and on changes in the bootmaking industry in the first half of the 19th century (Church, 1970). Additionally, there is a rich literature on the evolution of the industry at the county level (Hatley and Rajczonek, 1971; Greenfield, 1998; Mounfield, 1965), and a small collection of articles which treat with the process of mechanization in Britain (Church, 1968; Menuge, 2001).

In contrast, the history of the American Bootmaking industry has been well documented, and can inform an understanding of the British case. The first task of bootmaking to be mechanised was in "binding": the sewing together of the leather pieces which form the upper part of the shoe. The sewing machine, patented by the American Elias Howe in 1846, was modified in 1852 to be able to do the heavy work of sewing together boot leather (Thomson, 1989). The second task of bootmaking to be mechanised was in "finishing": affixing the sole of boot to the leather "uppers". The Blake Sole sewing machine represented the first breakthrough in this area, in the 1860s. Several years later, the innovation of the first Goodyear welt machine was introduced, in 1972, and by the

[1] In order, the largest industries are: domestic workers, agriculture, general labourers, coal mining, bootmakers, and dressmakers

[2] In 1857 it was estimated that each man in the army required 2 pairs of boots a year. Select Committee on Public Contracts, B.P.P. 1857, 11, 661 (Church, 1970)

1880s an improved version dominated this process (Thorn, 1987). The final category of bootmaking tasks, "clicking", or cutting out the leathers of the upper part of the shoes, was highly skilled, and was not mechanised until later in the 20th century.

Many of the breakthrough innovations in the shoemaking industry were developed by workers, and the invention of a sewing machine suitable for bootmaking was no exception. A foreman in the shop of a major shoemaking concern in Lynn, Massachusetts, had recognised the potential of applying the Singer sewing machine to the work of bootmaking, and made the required modifications. The sewing machine had been labour saving – a shirt that had taken a skilled tailor 14 hours to sew by hand could be assembled in one hour on the machine, and it was clear there was similar potential in bootmaking. This turned out to be the case: once the boot-leather sewing machines were developed, workers with the machine could produce more than four times a worker without the machine. Estimates from the Hand and Machine Labour study in the United States indicate that mechanization was responsible for an 80% savings in labour input as the bootmaking industry transitioned from craft to machine production (Atack et al., 2019).

In the United States, the introduction of the sewing machine to bootmaking had three key impacts. Firstly, it was labour saving, and resulted in technological labour displacement. Secondly, it proved pivotal in catalysing the further mechanisation of the bootmaking industry. Finally, it drove the shift from craft to factory production. Technological unemployment in the particular task of "binding" was an immediate result of this innovation. It was a task which almost exclusively employed women, and, in Lynn - one of the main shoemaking production cities in Massachusetts - the employment of women fell from 6500 to 3900 between 1850-1860 following the introduction of the bootmaking sewing machine. This is a small sample, geographically limited, but illustrative of the labour displacing impacts of the new machine. The labour displacement has been attributed to the machine introducing a temporary mismatch between productivity in binding the uppers and in the other tasks that made up the process of assembling shoes: the ratio of people needed for each task in the assembly of boot making changed, resulting in unemployment in the task which had been made more efficient (Thomson, 1989).That bottleneck then resulted in the second impact of the sewing machine: an incentive to mechanize the next task as rapidly as possible. By the end of the 1870s every conceivable task of bootmaking was being mechanised. The sewing machine not only precipitated a cascade of further innovation, it also drove the shift from cottage industry to factory production (Thomson, 1989).

The mechanisation of the boot making industry in England followed a similar trajectory. An important difference, however, can be found in resistance from organised labour. The rapid adoption and integration of the machine in the United States stands in stark contrast to the reception it had in much of the rest of the world, where the process was more fraught, as tailors and bootmakers worried that the machine would make their labour obsolete. Indeed, one of the reasons that the sewing machine is an American invention at all is the result of labour resistance. The first functioning sewing machine was invented in France, by M. Thimonnier, in 1830, a full two decades before the American sewing machine began to establish itself. He was able to patent his machine, and secure financial backing. He then managed to win a contract with the military. However, 200 local tailors rioted, and burned down his workshop, with its 80 wooden, flammable, sewing machines. He was not able to recover, and the machine had to wait for its American inventors to take its place on the world stage.

English manufacturers made an attempt to introduce the American bootmaking sewing machines in 1855. They faced effective and concerted resistance from organised labour, and were delayed. Nonetheless, in 1857 the first of these machines were imported and set to work. In Northamptonshire and Staffordshire, two well established centres of bootmaking in England, there was uproar. A letter from a manufacturer in Northampton, who introduced one of the first machines in 1857, declares that he was immediately met by a deputation of bootmakers who demanded that he get rid of the machine, and that when he did not do so, there followed a strike lasting 15-18 months, in which the workers "swore that they would drive [him] and [his] machine out of town altogether". His letter is dated 1865, and he notes with some satisfaction that the workers were not able to achieve either objective, and that more than 1500 machines are now at work in the town. This might not have matched the response produced in Ireland, where an oversized replica of the machine was smuggled into a local theatrical performance, with the intention of infuriating striking tailors, and where the owner engaged in a formal boxing match with tailors outside the theatre itself, but it was considerably more robust. Rather than a few bouts of angry exchange, the adoption of the machine in England sparked a two year strike, from 1857-1859, with 2000 men from Northamptonshire and Staffordshire out on the tramp (Thorn, 1987).

Nonetheless, by the 1860s the sewing machine revolution was well underway across the United

Kingdom. Starting with sales of a few thousand machines per year in the early 1860s, extremely rapid uptake resulted in sales of nearly 50 000 machines per year only a decade later. By the 1890s around 150 000 sewing machines of all types were being sold in England every year. In total, a minimum of 4.3 million sewing machines, designed for all types of textile work, would have been sold in the UK between 1865-1911 (Godley, 1996). The shockwaves were those of the adoption of a new general purpose technology. To understand the impact of this technological shock on labour displacement and reinstatement in the English bootmaking industry I turn to occupational data recorded in the British census.

2 Data Construction

Every British census between 1851 to 1911 asked individuals to describe their occupation. William Farr, the superintendent of the statistical department at the General Register Office (GRO) at the time, advised that the description of occupation was meant to reflect five key aspects of work: "skill, talent, or intelligence; tools, instruments, machinery or structures; materials; processes; products" [3], and indeed these elements of the work are often present in the responses householders provided to the occupation question. The responses given ranged from parsimonious one-word summaries through to detailed descriptions. See the variable for "Occupation", given in table 1, below, for an example.

Table 1: Occupation in 19th Century English Census Data

Year	Occupation	Occode	HISCO	Task
1851	CORDWAINER	663	80100	Cordwainer
1851	BOOT AND SHOE MAKER - MASTER EMPLOYING 4 MEN 4 WOMEN and 5 APPS	663	80100	Maker
1851	BOOT AND SHOE BINDER	663	80100	Binder
1851	BOOT AND SHOE RIVETTER	663	80100	Rivetter

Note: Individual level observations. First three columns as in ICEM digitized data. Final column showing the newly constructed "task" variable as derived by the author

When the GRO received the census enumerators' books for the decennial census taken in 1851, the records contained hundreds of thousands of unique character strings describing occupation. For the bootmaking industry alone there were more than 60 000 unique descriptions. The GRO

[3] Census (1861): general report

realized that managing the data at this level of granularity was untenable, and devised a taxonomy of approximately 800 industries. Clerks employed by the GRO were responsible for assigning each individual observation to the correct industry, and analysis based on English and Welsh census data has predominantly been conducted at the industry level of occupation from that point onwards.

The Integrated Census Microdata project (ICeM) has recently digitized the original English Census data for the decades between 1851-1911, excluding census year 1871. The new ICeM dataset makes individual level census observations digitally available for the first time (Schurer et al., 2022), and has substantially expanded the frontiers of research on British occupational structure over the second half of the 19th century. However, when the ICeM project digitized the data, they retained the pre-existing, industry level, categorization of occupation. This left encrypted the more granular information on occupation which has been available – if all but hermetically sealed into the text by the constraints of processing big data - for nearly 200 years.

I construct a sub-industry level "task" classification scheme by extracting information from the original textual description of employment. An example of this is given above in Table 1: the final column contains the new "task" variable, which indicates the type of work the individual did within their industry. The process of constructing this "task-level" classification proceeds in three steps: all unique strings describing occupation are collected, tokenized, and a set of categories is constructed from the most frequent "task" terms.

Firstly, I collect the complete set of bootmakers in England across all census years [4]. There are approximately 200 000 bootmakers observed in each decennial census for England, resulting in a total of ~1.3 million individual level observations. I then extract all the unique textual descriptions of occupation in this industry: there are 60 137 unique strings. There are fewer unique strings than individual level observations, because unique strings are found multiple times. For example, the description "Cordwainer" is given for thousands of individual observations, whereas the character string "Boot & Shoe Maker (Master Employing 4 Men 4 Women & 5 Apps)" occurs only once in the census records.

The second step is to determine the main set of tasks present in the unique strings. This is a topic discovery process, approached both with and without machine learning. I employ a filtration process to subset to the "tasks" which occur most frequently in the strings. The first part of the

[4] See Appendix A Appendix A for more detail on this process.

filtration leverages Zipf's law, the highly skewed distribution of the strings. I extract the "task" words available in those strings. These are now identified categories of bootmaker "tasks". The remaining unique character strings, those not accounted for by the initial sweep, are then extracted and tokenized. The frequency of individual words are tallied. "Task" words found to be most frequent are added to the set of bootmaker "tasks".

Finally, once the categories - or types of task - have been discovered, the strings in the "occupation" are parsed and assigned to the new "task" categories. The topic modelling process results in the construction of a dictionary, with topic categories assigned to keywords and their spelling variations. From this point, assigning strings to task categories based on the presence of the keywords in the string is straightforward. For example, in Table 1, the third observation includes the keyword "Binder", so this person will be assigned to the category binder. It should be noted that the "task" level could be further disaggregated further. For example, all "Cutters" are collected into one category, irrespective of what type of material they cut. Likewise, the category of "Binders" includes all those who do binding work, irrespective of whether this is for slippers, boots, shoes, or whether it takes place in a hospital or any other environment.

It is certainly the case that some descriptions of occupation contain more than one keyword. However, these are rare. In the bootmaking industry, of 1.29 million individual observations, 51 000 (3.8%) contain two or more keywords. When several keywords exist within one description of occupation, the assignment of the observation to a category is based on a pre-established hierarchy of keywords. This can be conceptualized as a matrix of word pairs, in which the ranking of each keyword, vis-a-vis all the others, is given. For example, if the keyword "machinist" is set at the top of the hierarchy, this means that any individual who describes their occupation as both "machinist" and "shoemaker" will be assigned to the "machinist" group. Were I to put "machinist" at the bottom of the hierarchy of keywords then all other keywords would be given priority, and the individual would be assigned to the "machinist" task only if the description contained no other keywords. The hierarchy of keywords used, together with sensitivity checks on the impacts of using a different hierarchies, is available in Appendix B. The hierarchy is set to maximize granular information. The least specific occupational descriptions, for example "Shoemaker", "Worker", "Hand", are at the bottom of the hierarchy. If there is any other keyword present in the text description, the person will be assigned to that category. An individual who described their occupation as a "Riveter

Shoemaker", for example, is categorized as a Riveter. The top of the hierarchy is given to keywords which reflect mechanization: a "Machinist Binder" will be registered as a Machinist.

The final step in the process is to check that the set of keywords identified can allocate at least 95% of all individual level observations in each year to a sub-industry level "task". This is done by merging the crosswalk back into the complete population data for English bootmakers, and checking what proportion of observations are not allocated to a "task" category. If the set of tasks does not cover at least 95% of strings in each year then an additional task category is added to the set from the frequency of tokenized words. The process is reiterated until the set of keywords is sufficient to meet the threshold. The process was devised with the intention of producing crosswalks for every industry in the census, to enable the construction of a "task" level variable across the entirety of the ICeM dataset.

3 Change in the Occupational Structure

Having classified the textual descriptions of occupation for the set of 1.3 million individual level observations of English bootmakers from 1851-1911 into "tasks", it is now possible to assess the impact of mechanization on the occupational structure of the bootmaking industry at both the existing industry level of occupation and the newly available sub-industry task level. There are two key findings.

Firstly, the new "task" level analysis reveals labour displacement which is almost entirely masked at the industry level. An analysis of the impacts of mechanization on net employment in the bootmaking industry, conducted at the industry level, shows only a minimal shock. See Figure 1: A, below. Prior to mechanization, in 1851, the English bootmaking industry employed approximately 220 000 workers. Following a minor dip, it employed approximately 213 000 workers in 1911. At this level of analysis, any labour displacement which might have occurred is invisible.

The new "tasks" level analysis makes it possible to pry open this black box. Figure 1:B and 1:C show the evolution of "old" and "new" tasks in the English bootmaking industry over time. Two things are immediately apparent. Firstly, job loss and creation did take place as the industry mechanized: the number of people employed in "old" bootmaking tasks declined by about 152 000, while 144 000 new jobs were generated in emerging work.

Secondly, it is sharply clear that increasing specialization accompanied mechanisation. The category of "old" tasks is defined as including the five tasks which account for the employment of 95% of English Bootmakers prior to mechanization. In the decennial census data prior to the adoption of the new machines, 97% of bootmakers were employed as "Shoemakers", "Cordwainers", "Cloggers", "Binders", "Closers". As mechanization set in a rapid fragmentation of the occupational structure at sub-industry level took place. New types of employment emerged, including, but not limited to: sewing machinists, riveters, operators, and the foremen and managers who took up the new jobs in the factories. The intensification of specialization continued through to 1911. It may be appropriate to conceptualize this sequence in terms of a modern production process displacing an older, more traditional, one.

[5]

[5] Increasing specialization can be seen in that the set of 30 "tasks" account for a decreasing percentage of the individual observations in the data. In the 1851 census, the set accounts for 99% of bootmakers, by 1911, it accounts for 95%.

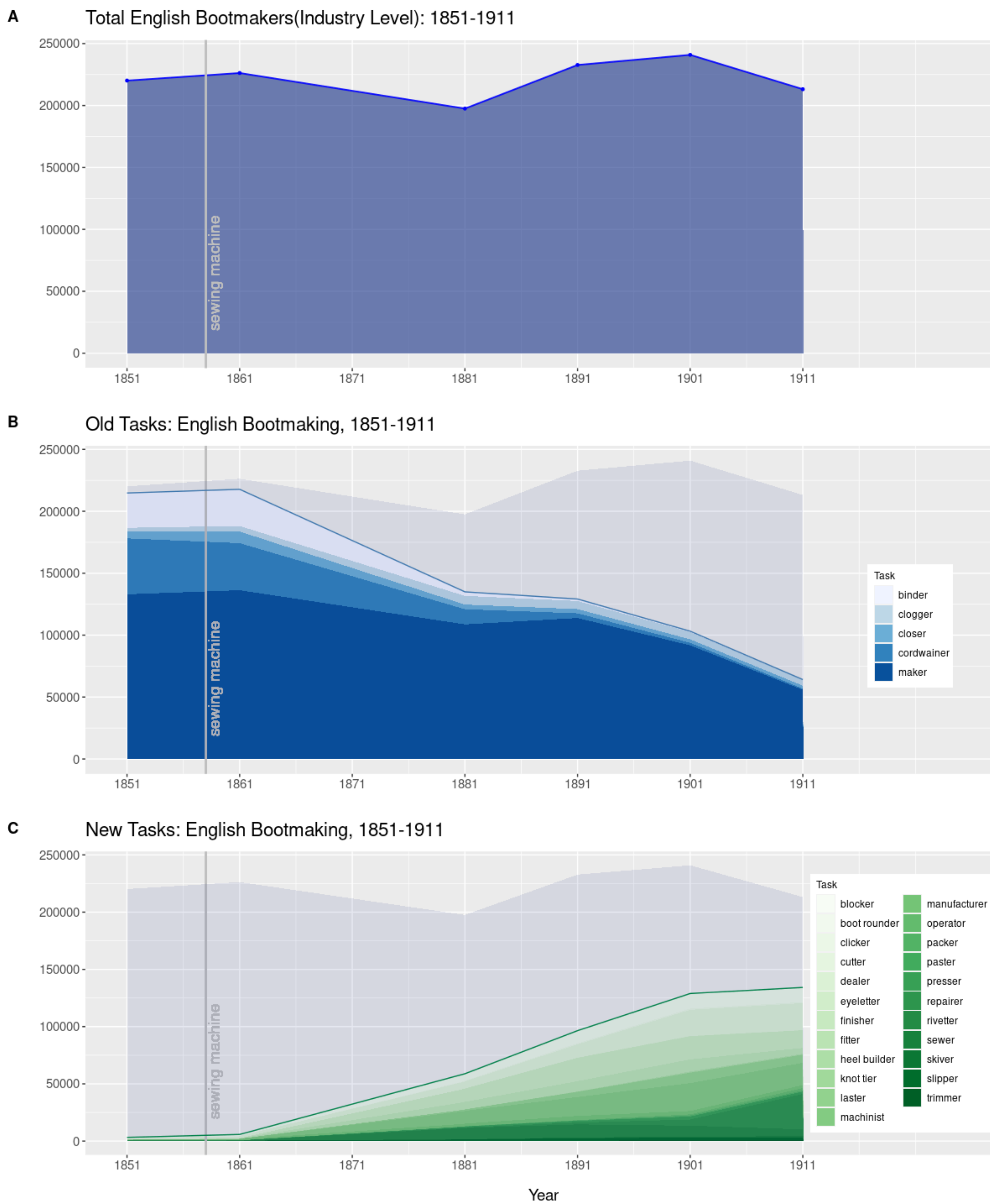


Figure 1: Number of Bootmakers Employed - Industry and Task Level, 1851-1911

Source: data derived by author from ICeM census records.
Note: observations with small sample size of less than 50 removed in 1851 and 1861

The graph above summarizes the total change which occurred between 1851 and 1911. If we break this down by decade the scale and the pace of the shift in the occupational structure becomes more clear. Please see Table 2, below.

Table 2: Pace of Change by Decade

	Total Change in #New Jobs	**Total Change in #Old Jobs**	**Geographical Concentration**
Period 1: 1851-1861	2399	3643	10.02
Period 2: 1861-1881	49729	-78423	15.05
Period 3: 1881-1891	35625	-378	25.57
Period 4: 1891-1901	22979	-14814	35.09
Period 5: 1901-1911	10578	-38579	41.31

Note: The LQ based measure of the geographical concentration of the industry is taken from cross-sectional data. It is based on the first census year in the period.

There was very little change in the occupational structure between 1851-1861, in the decade prior to the onset of mechanization. Few "new" jobs emerged during this period, and few of the "old" jobs declined. If anything, there seems to have been an increase in the number of bootmakers employed in the "old" jobs, possibly reflecting an increase in demand for footwear. The most rapid period of change took place between 1861-1881, although the two decade span must be noted here. The reconfiguration of the occupational structure continues through to 1911.

Changes in the geographical concentration of the industry followed a similar trajectory. To calculate geographical concentration I use a location quotient (LQ). This compares the bootmaking industry's share of employment in a county with its share of total employment. See Appendix C for county level information on the pace of the change in the occupational structure. The formula is given by:

$$LQ = \frac{\left(\frac{E_{i,c}}{E_c}\right)}{\left(\frac{E_i}{E}\right)} \tag{1}$$

$E_{i,c}$ represents the employment in the bootmaking industry i in county c, E_c represents total employment in county c, E_i represents total employment in the bootmaking industry i, and E represents total employment in England. A value of 1.0 means that an industry share of employment in county c is the same as its share of national employment in England. For example, if the bootmaking industry makes up 5% of employment in county c and also 5 % of employment in England, then the denominator and the numerator are the same, and returns a value of 1. A value greater than 1.0 means that employment in the bootmaking industry in county c makes up a larger share of employment in the local area than at the national level. To calculate a summary statistic for each year I sum the absolute value of the variance from 1 for each county in England. The LQ scores in Table 2 show the geographical concentration of the industry over time.

4 Outcomes for Workers

Now that the new task level data has revealed and quantified the job loss and creation which took place in tandem with the technological shock, it becomes possible to consider the impact on workers. Were incumbents able to transition into the newly available opportunities? I assess this question in terms of gender, geographical location, and age, and then turn to panel data to confirm findings.

4.1 Gendered Division of Labour

The technological shock, however profound, did not alter the gendered division of labour within the industry [6]. Any assessment of the distribution of burden and opportunity induced by the technological shock therefore has to be considered as two distinct experiences. Figure 2, below, shows the decline and reinstatement of selected tasks by gender.

[6] See Appendix D: Occupational Segregation by Gender

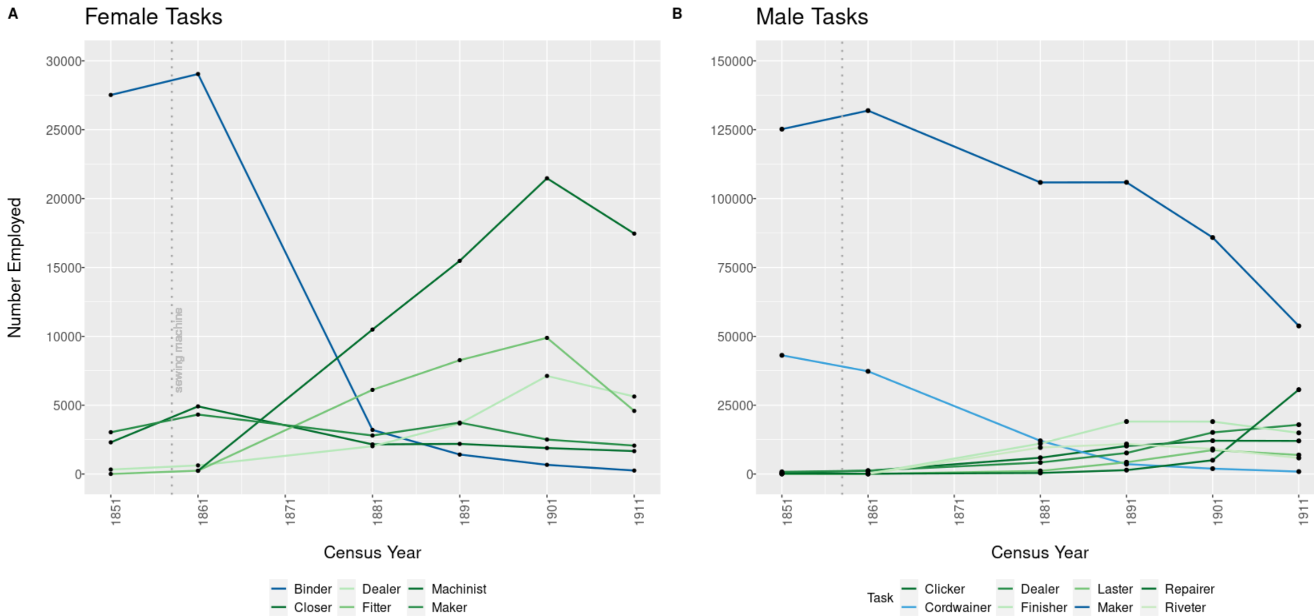


Figure 2: Selected Bootmaking Tasks, 1851-1911

Note: Tasks are included in the graph such that together they account for at least 75% of all employment, by gender, in each year. Given the increasing specialization over time, the set of tasks depicted in Figure 2 tend to account for as much as 95% of all employment in 1851 and 1861, but only around 80% of occupation by 1911

For men, the broad categories of Shoemaker and Cordwainer experienced the greatest occupational decline. While Shoemakers were made up of male bootmakers providing labour at piece work rates, Cordwainers tended to be independent craftsmen who made the entire shoe. For example, Riello (2002) asserts that "Cordwainers and shoemakers were used to indicate different social and occupational identities", and earlier research notes that Cordwainers paid an average of £13 11s in rent, while Shoemakers paid £6, indicating a different class of worker (Green, 1990). The British Shoemaking Trade Journal declared in 1892 that "The man who could years ago cut, close and make is now rather an object of curiosity than an agent of utility"(Thorn, 1987), and this can be seen in the decline of both Cordwainers and Makers over this period, in tandem with the rise of the more specialised tasks. Research on unionization during this period notes that:

> "It is an historical fact of the utmost irony that by the time the Amalgamated Society of Cordwainers established itself as the first successful national union of shoemakers in March, 1863 the technical base upon which it stood had almost been eroded. The use of the ancient name of cordwainer instead of shoemaker in its title indicated the predominance of a mentality of byegone times. Such nomenclature was singularly inappropriate

in London where the complete shoemaker, or corduainer, had almost disappeared amidst the division of labour. . . " (Thorn, 1987).

Over this period employment for 40 802 Cordwainers and 71 951 Makers disappeared. Work opportunities for Cordwainers underwent a particularly sharp decline, with 29 945, or 72%, of these jobs vanishing between 1851-1881. The "Shoemakers" category experienced a slower decline, which was more pronounced in the second half of this period. However, the decline in employment for Cordwainers and Shoemakers was almost completely offset by the emergence of a number of new, more specialist employment in the industry. These include opportunities for "Lasters", "Riveters", "Manufacturers", and the new and extensive network of shoe and boot salesmen.

Female bootmakers had a different experience. Firstly, women were much more exposed to the technological shock. Binders made up 83% of all women employed in the English bootmaking industry in 1851, and 74% in 1861. In this role they hand-sewed the leather "uppers" of the boot together, and assembled the top part of the boot. The introduction of the sewing machine mechanised this process, and simultaneously divided this one task into two new tasks, "fitting" and "machining". Fitters prepared and positioned the pieces of cut leather, so that the sewing machinist could rapidly sew the material together (Thorn, 1987).

In 1861 there were nearly 30 000 Binders in England. However, by 1881 every English county had lost close to 90% of their "Binders". This sharp occupational decline coincided closely with the introduction of the sewing machine, which was first introduced to bootmaking in England in 1857, and then diffused rapidly over the subsequent two decades. This happened in parallel with the emergence of a new task in the textual descriptions of occupation recorded in the English census records, that of the (Sewing) "Machinist", which was also a gendered female occupation. The Sewing Machinists were responsible for the same kind of work that Binders had previously done by hand: sewing the "uppers" of the shoe or boot together [7].

Mechanisation drove both obsolescence penalties and skills premia. While Binders experienced rapid labour displacement, the new Sewing Machinists were not only able to find employment, but may also have enjoyed a temporary skills premium. I collect a small dataset of approximately 100

[7] Prior to the introduction of the sewing machine, 98% of binders were women. When this task was mechanized, it remained highly gendered - 91% of the new sewing machinists were women. Note that not all machinists are specifically designated as sewing machinists. It is the gendered nature of employment in the industry which leads me to conclude that the machinists are almost all "sewing machinists", and responsible for sewing together the uppers of the shoe, work which was previously done by binders.

advertisements, from London papers running between 1855-1885, digitized by the British Newspaper Archives project [8]. These were advertisements offering training on the bootmaking sewing machine. The adverts first emerged in 1860. Prices for the training declined over the next twenty years, before disappearing entirely. That learners were willing to pay for the lessons may reflect evidence that a skills premia was initially available to the new Sewing Machinists in the bootmaking industry in England as it mechanised. See Appendix E

Whether displaced bootmakers were able to retrain and remain in the industry is an open question, which is taken up in the next two sections. It is possible that women who had formerly been Binders, and men who had formerly been Cordwainers and Makers, were able to move into the new employment opportunities being generated by the mechanization of the industry. However, re-skilling would not have been sufficient: the challenge would have been complicated by additional dimension - a shift in the geographical location of employment. For both women and men, new employment opportunities in the bootmaking industry were not generated evenly, but were instead heavily concentrated in only a few counties in England.

4.2 Geography of Employment

The task level analysis of the geography of employment reveals that the newly generated opportunities emerged in only a few counties, while the decline in employment in the "old" tasks took place in every county in England. Figure 3, below, illustrates the total change in the number of bootmakers employed in "new" and "old" tasks in each English county between 1851-1911 [9].

The overall picture is one in which the "older" and more general types of work declined everywhere, while employment opportunities in the "new" tasks emerged only in a select few counties. In the majority of English counties the loss of employment in the old tasks was not matched by the emergence of new opportunities, and the outcome was a net loss of workers employed in bootmaking. In a few English counties the loss of employment was matched by the emergence of employment

[8] The British Newspaper Archive (BNA) project, a collaboration between the British Library and FindMyPast, which started in 2011, is in the process of digitizing the British Library's Newspaper collections. These contain most of the publications run in England from the start of the 19th century through to 1950: a total of 40 million newspaper pages will have been digitized by the time it concludes in 2021.

[9] These categories are defined as they were when first introduced in the previous section.The old tasks are those which, together, were responsible for the employment of 97% of bootmakers in 1851 and 1861, prior to mechanization. These include: "binders", "cloggers", "closers", "makers", and "cordwainers".

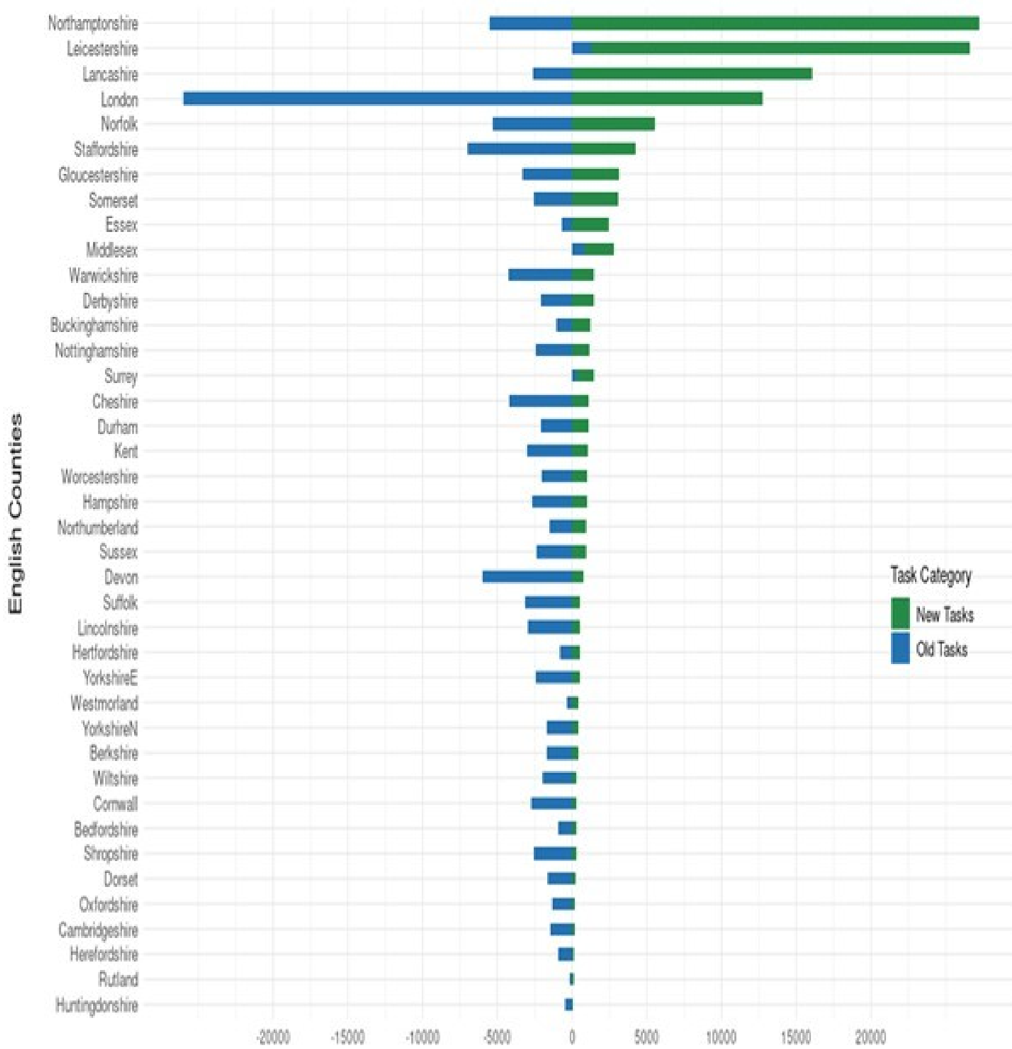


Figure 3: Change in Number of Bootmakers Employed
Source: data derived by author from ICeM census records.

opportunities in the new bootmaking tasks. In these counties there was no net change in the number of bootmakers employed in the industry. Finally, in three English counties – Northamptonshire, Lincolnshire, Lancashire – the loss of employment in the older, traditional tasks was more than compensated for by the surge of employment opportunities available in the new kinds of work.

The net result of these countervailing forces of job loss and job creation, interpreted geographically, was a tectonic shift in the location of the industry. Northamptonshire and Leicestershire became enclaves of the English bootmaking industry during this period, and the industry contracted substantially in other counties. Nearly half of the new jobs - 44% - were generated in Leicestershire and Northamptonshire alone.

To illustrate the process of geographical concentration of employment at the "task" level see Figure 4. This compares the distribution of Binders and Sewing Machinists in 1861, immediately prior to the technological shock, and in 1881, in the first census taken after the introduction of the sewing machine. Binders had been located across the breadth of the country (except in northern England, which was coal mining territory, and where women were in general less active in the labour force). The new jobs, for Sewing Machinists, were however heavily concentrated in only two counties: Northamptonshire and Leicestershire.

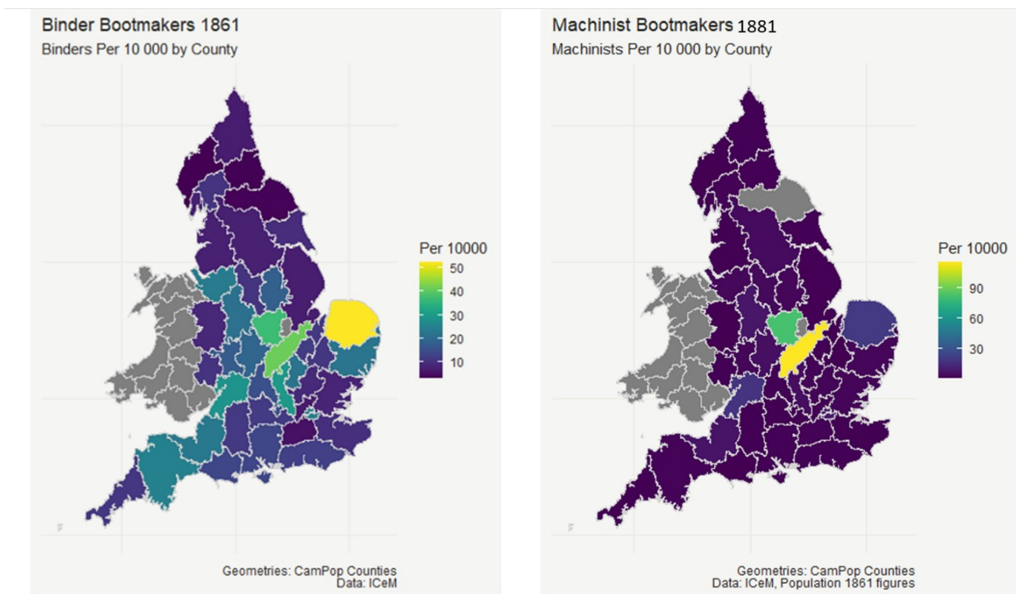


Figure 4: Geographical Distribution of Binders and Sewing Machinists
Source: data derived by author from ICeM census records.

The new types of work which emerged as the industry mechanized reflect a shift from craft to factory production. Many of the new jobs only existed in factories and larger enterprises: for example, foremen, supervisors, operators, factory workers, and some of the new sewing machinists. Since these new jobs emerged in only a few counties it seems that the shift to factory production in the bootmaking industry did not unfold uniformly across England, but instead primarily took place in only a few counties. The British Business Census of Entrepreneurs (BBCE) project identifies employers and proprietors between 1851-1911, and details how many workers were employed by each employer (Van Lieshout et al., 2021). Making use BBCE data I find that large companies became increasingly concentrated in the counties in which the new kinds of work emerged: Leicestershire, Northamptonshire, and London. In the regression below I explore how the share of new bootmaking jobs is correlated to the number of companies of different sizes, the total number of bootmakers, and how these relationships may have changed over time.

$$\begin{aligned}\text{ShareNew}_{c,t} = \alpha + \beta_1 \text{NumCompany}^k_{c,t} + \delta_1 \text{NumCompany}^k_{c,t} \cdot \text{Year}_t \\ + \beta_2 \text{TotalBootmakers}_{c,t} + \beta_3 \text{Year}_{j,t} + \varepsilon_{c,t}\end{aligned} \tag{2}$$

The regression looks at the correlation between the number of bootmaking companies of different sizes (small, medium, and large) and the share of "new" bootmaking jobs in a given county and year. The dependent variable $\text{ShareNew}_{c,t}$ represents the share of bootmaking jobs in county c at time i which are "new" tasks. The term $\beta_1 \text{NumNompany}^k_{c,t}$ reflects the overall effect of the number of companies of different sizes (k) on the share of new jobs. There are three bands for company size: small (1-3 employees), medium (4-10), and large (11+). The term $\delta_1 \text{NumCompany}^k_{c,t} \cdot \text{Year}_t$ represents the interaction between company size and the specific years, indicating how the relationship between company size and new job share changes over the years. The coefficient $\beta_2 \text{TotalBootmakers}_{c,t}$ accounts for the effect of the total number of bootmakers in a county, while $\beta_3 \cdot \text{Year}_{j,t}$ accounts for the overall effect of the different years compared to the baseline year.

In Table 3, below, we see the sharp increase in the total number of new job between 1861 and 1881. The interaction terms show that the relationship between company size and the share of bootmaking jobs constituted by "new" tasks did not change from the baseline in 1851 for small or medium sized companies. However, it does change for large companies. This is consistent with factory production emerging in a few locations.

By 1881 there were 154 businesses which employed more than 20 people. Of these, 29 were based in Northamptonshire (19%), 26 in Leicestershire (17%), and 14 in London (9%). There were 32 very large companies, employing more than 100 people. These were primarily located in Northamptonshire, which had 5 (16%), and in Leicestershire, which had 12(38%). The two largest businesses were based in Northamptonshire and Leicestershire and employed 1500 and 1000 a people respectively.

The emergence of the new opportunities in the bootmaking industry being concentrated in only a few English counties meant that, for workers exposed to the technological shock, re-skilling would not have been sufficient to remain in the industry. They would have also had to migrate. Did they? All evidence suggests no. Two counties, Leicestershire and Northamptonshire, offered the majority of the new work opportunities generated in the English bootmaking industry. However, those counties did not experience an increase in the share of bootmakers who had been born elsewhere. In 1851, prior to mechanization, 31% of the bootmakers in Leicestershire were born outside the county. In Northamptonshire the figure stood at 24%. By 1881, with mechanization well underway, and a substantial increase in the net number of bootmakers, workers born outside the country account for 20% and 23%, respectively. For Leicestershire, generating a large share of the new employment opportunities, the proportion of bootmakers born outside the county drops. For Northamptonshire it remains fairly stable. Most of these new jobs went to workers born in these counties.

Table 3: Geography - New Tasks and Large Businesses

	Dependent variable:		
	ShareNew		
	(1)	(2)	(3)
SmallCompanies	-0.045**		
	(0.020)		
MediumCompanies		-0.206***	
		(0.060)	
LargeCompanies			0.307**
			(0.143)
TotalBootmakers	0.001***	0.001***	-0.001**
	(0.0002)	(0.0002)	(0.0002)
Year 1861	2.855	2.253	3.214
	(3.115)	(2.776)	(2.024)
Year 1881	14.441***	12.751***	10.539***
	(3.012)	(2.681)	(1.892)
SmallCompanies * Year1861	-0.039		
	(0.029)		
SmallCompanies * Year1881	0.007		
	(0.029)		
MediumCompanies * Year1861		-0.072	
		(0.070)	
MediumCompanies * Year1881		0.066	
		(0.077)	
LargeCompanies * Year1861			0.003
			(0.180)
LargeCompanies * Year1881			1.217***
			(0.142)
Constant	2.131	2.678	1.198
	(2.430)	(2.100)	(1.428)
Observations	130	130	130
R^2	0.487	0.514	0.706
Adjusted R^2	0.462	0.490	0.692
Residual Std. Error (df = 123)	9.081	8.839	6.871
F Statistic (df = 6; 123)	19.438***	21.659***	49.253***
Note:	*p<0.1; **p<0.05; ***p<0.01		

If we look directly at the 12 000 new bootmaking jobs created in Leicestershire between 1861-1881, we find that 74% went to people born in Leicestershire, and another 14% went to people who were born in four neighbouring counties: Northamptonshire, Warwickshire, Nottinghamshire, and Stafforshire. This leaves just 12% of the new opportunities in Leicestershire to be taken up by individuals born further afield, or approximately 1400 jobs. This is a small fraction of the jobs lost elsewhere. It therefore is not possible that bootmakers in places where the industry was in decline were migrating to the new centres of industry. If anything, incumbent bootmakers exposed to the technological shock may have migrated to counties which continued to use the older craft techniques. In 1851, the average share of bootmakers born outside in the county in which they worked hovered around 35%. By 1911 that had increased to 45%. In every county the share of bootmakers born outside the county is much higher for bootmakers working in the "Old" jobs. That is, bootmakers may have been migrating to counties in which the industry remains locked to the old craft processes, and where their human capital was still in demand.

4.3 Age in Employment

The final approach to understanding whether incumbents were able to transition out of the old and declining jobs into the new, emerging opportunities is via an assessment of the mean age of workers in different tasks.

A task level analysis of access to employment by age reveals that the older workers, whose skills were rendered obsolete by the new technology, did not take up the new employment opportunities generated by the creation of the "new" bootmaking tasks. Those new jobs went predominantly to young people. See Figure 5, below.

Between 1851-1911, the population mean age of bootmakers stayed fairly constant, at around 35 years of age. Prior to the technological shock, the mean age in most of the "tasks" bootmakers performed hovered close to this, with the exception of "Closers", who are younger. Following the introduction of the new technology, a sharp polarization is observed. The mean age of bootmakers working in the "old" tasks soared, increasing by 10 years or more. In contrast, the "new" tasks were taken up by young people: the mean age in those tasks is well below population mean age.

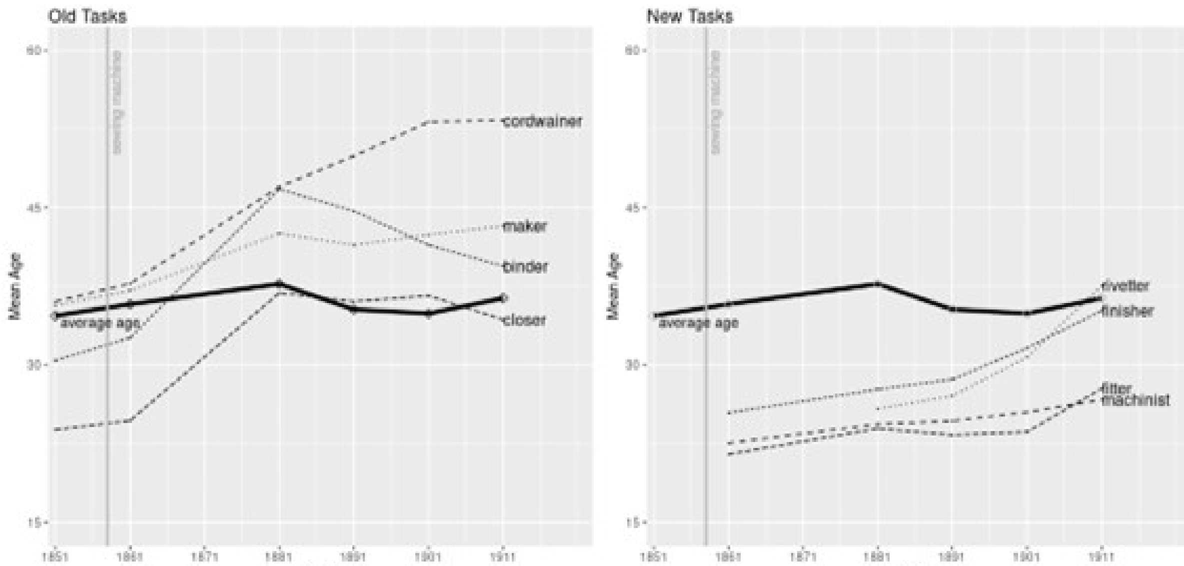


Figure 5: Age in Old and New Tasks
Source: data derived by author from ICeM census records.

4.4 Panel Data: 1861-1881

To this point, I have relied on population level data to explore whether incumbents were able to transition into the emerging opportunities. However, it is possible to ask the question directly. Using census linking methods, I create panel data for 1861-1881. This was shown in the previous section to be the period of most rapid transformation. I have a match rate of 22% for men and 9% for women. This generates a sample group of 45 235 people. [10]

The rationale for taking a population level approach prior to looking at panel data is that census linking is rife with challenges. False matches, and the systematic biases introduced by the census linking process, impact conclusions. It is therefore reasonable to look to the panel data only once a broad view of the situation has been established. Here, panel data confirms that incumbents were not able to move out of the old and declining jobs and into the new, emerging ones. This is the case for both men and women. See Figure 6, below. For women, approximately 3% of the incumbents transitioned into the new jobs. For men, this was marginally higher, with 6% of the group transitioning into the new kinds of work.

Without a counterfactual, or a comparison to the more general experience, it is not possible to assert that women were more vulnerable to the technological shock. However, it is clear that the

[10] For a detailed discussion of the code for the census linking please see Appendix F.

rate of exit from the industry was experienced differently between men and women. Nearly 90% of female incumbents left the industry as the jobs in "Binding" were replaced by "Sewing Machinists". Of those who left bootmaking, more than 50% are recorded as having no occupation in the 1881 census. In contrast, a far smaller share of men left the industry, and of those who left, almost all found employment in other industries.

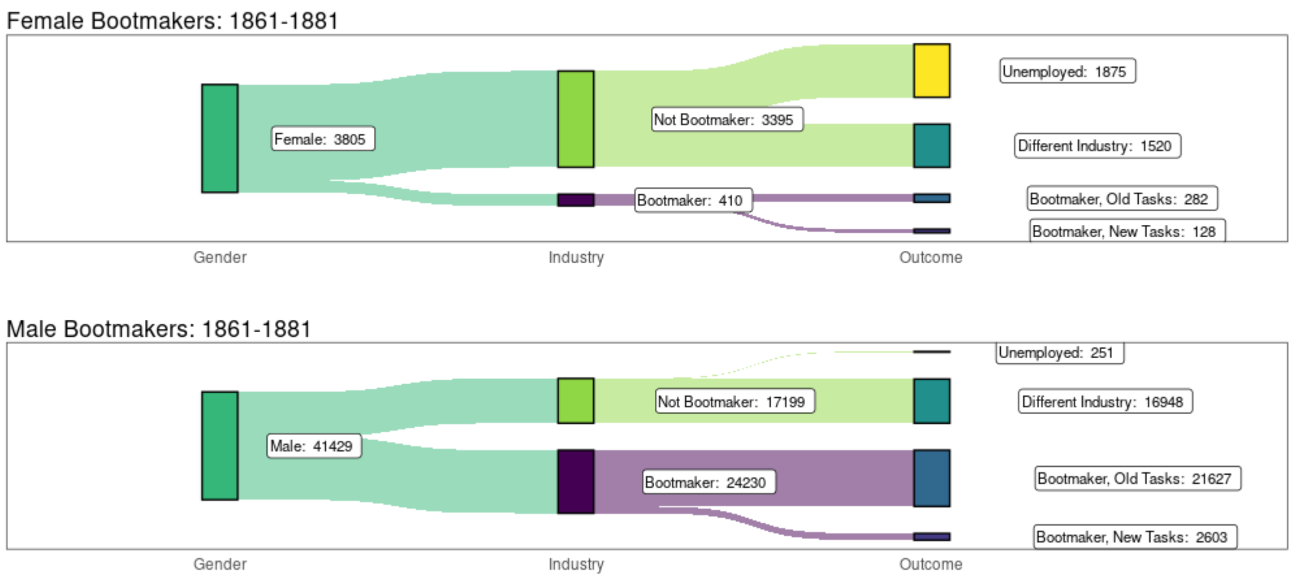


Figure 6: Switching Out of Bootmaking, By Gender
Source: data derived by author from ICeM census records.

5 Discussion

This paper has identified shifts which occurred within the occupational structure of the English bootmaking industry as it mechanized over the latter half of the 19th century. The division of labour evolved, with some types of task disappearing from the production process, and others emerging. Net employment in the industry remained fairly constant while these sharp shifts took place internally, despite a substantial increase in productivity. The sewing machine, which has been described as one of the great general purpose technologies of the second industrial revolution, increased productivity by at least 500% (Mokyr, 1992). If demand for boots had remained constant, the absolute number of workers employed in the industry would have decreased - that it did not is testament to what must have been an increasing aggregate demand for British made boots.

The broader context of the Second Industrial revolution can be taken into account here. This was a period in which the increases to total factor productivity were finally being felt, following Engel's pause (Feinstein, 1998). Households in England began to have more disposable income. If this increase in wages did translate into increases in consumption, there may be an entire set of industries in which increased consumption offset the labour displacing impacts of the adoption of new technologies.

With this new task level analysis having revealed radical shifts in the structure of employment within the bootmaking industry as it mechanized, the question of whether individual workers would have been able to keep pace with these shifts comes into focus. The analysis above shows that both retraining and migration would have been necessary for incumbents to have transitioned out of the old jobs and into the new ones, and that they did not do so.

Does this then mean that incumbent bootmakers were forced out of the industry? Perhaps the change in the occupational structure was gradual enough that young people not taking up jobs in the obsolete and disappearing tasks would have been sufficient to manage the occupational decline. In this case the variation in the impact of the shock between different tasks within the industry could prove instructive. If bootmakers were forced out the industry by the changes in the occupational structure, what happened to them? Were they able to secure employment in other industries? Of equal skill and status? These questions can only be investigated with panel data, following incumbent bootmakers through time. This will be the subject of the next paper.

The gains and loses of the shock must be considered on multiple dimensions. The costs which may have been born by workers who discovered their skills were made obsolete constitute one vital dimension of the question. A second dimension would be the gains and losses distributed to those taking up the new opportunities. It may be that that access to opportunity was impacted more by the uneven distribution of the access to new opportunity rather than the loss felt by incumbents. Finally, the third dimension to consider must be in terms of the wider society. The equilibrium impacts of labour displacement may have had impacts on other industries. The gains for consumers are clear - prices for boots went down precipitously during this period, and these decades mark the point at which even labourers might aspire to purchase a brand new pair of boots for themselves, rather than relying on worn second hand products.

6 Conclusion

This paper has three main findings. Firstly, I show that it is possible to generate sub-industry, "task" level occupational data for individual level observations in the British census data over the latter half of the 19th century. This has a range of applications. Secondly, I show that analysis at the sub-industry, "task", level of occupation can illuminate the impact of mechanization on occupational structure. These changes are entirely masked at the industry level of analysis. The more granular level data on occupation reveals extensive labour displacement and reinstatement: in the bootmaking industry, 152 000 jobs were lost, and 144 000 created, as mechanization set in. The geographical location of employment shifted, as the new types of production became concentrated in Leicestershire and Northamptonshire. We see indications of a shift to factory production. Finally, I find that incumbent bootmakers in England were not able to transition out of the old, declining occupations and into the new employment opportunities.

References

Acemoglu, D. and Autor, D. (2011). Skills, tasks and technologies: Implications for employment and earnings. In *Handbook of labor economics*, volume 4, pages 1043–1171. Elsevier.

Acemoglu, D. and Restrepo, P. (2019). Automation and new tasks: How technology displaces and reinstates labor. *Journal of Economic Perspectives*, 33(2):3–30.

Acemoglu, D. and Restrepo, P. (2022). Demographics and automation. *The Review of Economic Studies*, 89(1):1–44.

Atack, J., Margo, R. A., and Rhode, P. W. (2019). " automation" of manufacturing in the late nineteenth century: The hand and machine labor study. *Journal of Economic Perspectives*, 33(2):51–70.

Autor, D. (2022). The labor market impacts of technological change: From unbridled enthusiasm to qualified optimism to vast uncertainty. Technical report, National Bureau of Economic Research.

Autor, D., Chin, C., Salomons, A. M., and Seegmiller, B. (2022). New frontiers: The origins and content of new work, 1940–2018. Technical report, National Bureau of Economic Research.

Autor, D. and Dorn, D. (2009). This job is "getting old": measuring changes in job opportunities using occupational age structure. *American Economic Review*, 99(2):45–51.

Bank, W. (2018). *World development report 2019: The changing nature of work*. The World Bank.

Braxton, J. C. and Taska, B. (2023). Technological change and the consequences of job loss. *American Economic Review*, 113(2):279–316.

Church, R. (1970). Labour supply and innovation 1800–1860: the boot and shoe industry. *Business History*, 12(1):25–45.

Church, R. A. (1968). The effect of the american export invasion on the british boot and shoe industry 1885–1914. *The Journal of Economic History*, 28(2):223–254.

Edin, P.-A., Evans, T., Graetz, G., Hernnäs, S., and Michaels, G. (2019). Individual consequences of occupational decline.

Feigenbaum, J. and Gross, D. P. (2020). Automation and the fate of young workers: Evidence from telephone operation in the early 20th century.

Feinstein, C. H. (1998). Pessimism perpetuated: real wages and the standard of living in britain during and after the industrial revolution. *The Journal of Economic History*, 58(3):625–658.

Frey, C. B. (2019). The technology trap. In *The Technology Trap*. Princeton University Press.

Frey, C. B. and Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological forecasting and social change*, 114:254–280.

Godley, A. (1996). Singer in britain: the diffusion of sewing machine technology and its impact on the clothing industry in the united kingdom, 1860–1905. *Textile history*, 27(1):59–76.

Green, E. M. (1990). The taxonomy of occupations in late eighteenth century westminster. *Work in Towns, eds. Corfield and Keene.*

Greenfield, J. (1998). *Gender and Technology in the East Midlands Boot and Shoe Industry: 1850-1911*. PhD thesis, University of Warwick.

Hatley, V. A. and Rajczonek, J. (1971). *Shoemakers in Northamptonshire: 1762-1911 a Statistical Survey*. Northampton Historical Series.

Keynes, J. M. (1930). Economic possibilities for our grandchildren. In *Essays in persuasion*, pages 321–332. Springer.

Kogan, L., Papanikolaou, D., Schmidt, L. D., and Seegmiller, B. (2021). Technology, vintage-specific human capital, and labor displacement: Evidence from linking patents with occupations. Technical report, National Bureau of Economic Research.

Landes, D. S. (2003). *The unbound Prometheus: technological change and industrial development in Western Europe from 1750 to the present*. Cambridge University Press.

Lin, J. (2011). Technological adaptation, cities, and new work. *Review of Economics and Statistics*, 93(2):554–574.

Menuge, A. (2001). Technology and tradition: the english heritage survey of the northamptonshire boot and soe industry. In *From industrial revolution to consumer revolution: Transactions of the 11th International Congress of TICCIH*, pages p–101.

Mokyr, J. (1992). *The lever of riches: Technological creativity and economic progress*. Oxford University Press.

Mokyr, J., Vickers, C., and Ziebarth, N. L. (2015). The history of technological anxiety and the future of economic growth: Is this time different? *Journal of economic perspectives*, 29(3):31–50.

Mounfield, P. (1965). The footwear industry of the east midlands (iii) northamptonshire, 1700-1911. *The East Midland Geographer*, 3(24 Part VIII).

Riello, G. (2002). *The boot and shoe trades in London and Paris in the long eighteenth century*. University of London, University College London (United Kingdom).

Schurer, K., Higgs, E., et al. (2022). Integrated census microdata (i-cem), 1851-1911.

Susskind, D. (2020). *A world without work: Technology, automation and how we should respond*. Penguin UK.

Thomson, R. (1989). *The path to mechanized shoe production in the United States.* UNC Press Books.

Thorn, G. (1987). London bootmakers and the new unionism. *The London Journal*, 13(1):17–28.

Van Lieshout, C., Bennett, R. J., and Smith, H. (2021). The british business census of entrepreneurs and firm-size, 1851–1881: New data for economic and business historians. *Historical Methods: A Journal of Quantitative and Interdisciplinary History*, 54(3):129–150.

7 Appendices

7.1 Appendix A: Construction of the "Bootmakers" Group

The group of "English Bootmakers" could be defined in various ways. I use the complete census data for England and Wales, for all six census returns between 1851-1911 (excluding 1871). The data is then filtered down to the four bootmaking industries: categorized as 663, 664, 665, and 666 with the ICeM project's time-invariant variable for occupation. All individual level observations are aggregated together into one dataset. This contains 1,391,852 observations of bootmakers in England and Wales between 1851-1911. I filter to bootmakers born in England, which leaves 1,330,646 observations.

Finally, I remove all individual observation in which "retired", "formerly", or "unemployed" appears in the text description of the occupation. There may be a concern as to whether the four main occupational codes for bootmakers have captured the large majority of bootmakers. It may be the case that many bootmakers are, erroneously, recorded under other occupational codes. I therefore run a search for bootmakers in other "industry" codes. Given that this returns only a few thousand bootmakers I do not include them.

It is worth noting that the bootmaking group is unusual in being so well collected by the industry variables in ICeM. Each census taking between 1851-1911 had its own set of "Industries". When the ICeM project digitized the British census data, they constructed a "time invariant" set of categories for occupation. This cuts across the different decennial categories in the census data, and the result is that people of the same occupation sometimes are collected into different "time invariant" bins.

As an exceptionally large industry, bootmakers had a category (or several), in each of the decennial census reports. This has meant that the time invariant category in ICeM does capture them quite well.

7.2 Appendix B: Hierarchy of Keywords

Tasks are assigned to the textual descriptions in sequence. Any textual description which contains more than one task keyword is assigned to the task category ranked highest in the hierarchy specified. For example, if an individual's occupation is recorded in the text as "sewing machinist in factory, uppers", they are categorized as machinists rather than factory workers. The hierarchy is set to maximize the extractraction of the most granular information about what type of work individuals were doing. Please see table 4 below.

Table 4: Hierarchy of Keywords

1. machinist	10. finisher	19. eyeletter
2. factory	11. laster	20. trimmer
3. employer	12. fitter	21. packer
4. manufacturer	13. closer	22. dealer
5. binder	14. rivetter	23. cordwainer
6. repairer	15. operator	24. clogger
7. presser	16. foreman	25. slipper
8. manager	17. cutter	26. maker
9. clicker	18. sewer	

There are 9665 descriptions of task which contain more than one task key keyword. This represents 51 155 of the total observations (some of these descriptions are observed multiple times), or 3.8% (51 155/1 330 644). There are three dyads which each have more than 6000 observations: maker-dealer, clogger-maker, and maker-repairer. None of the dyads following have more than 2000 observations. The distribution of these is as shown below in Figure 7.

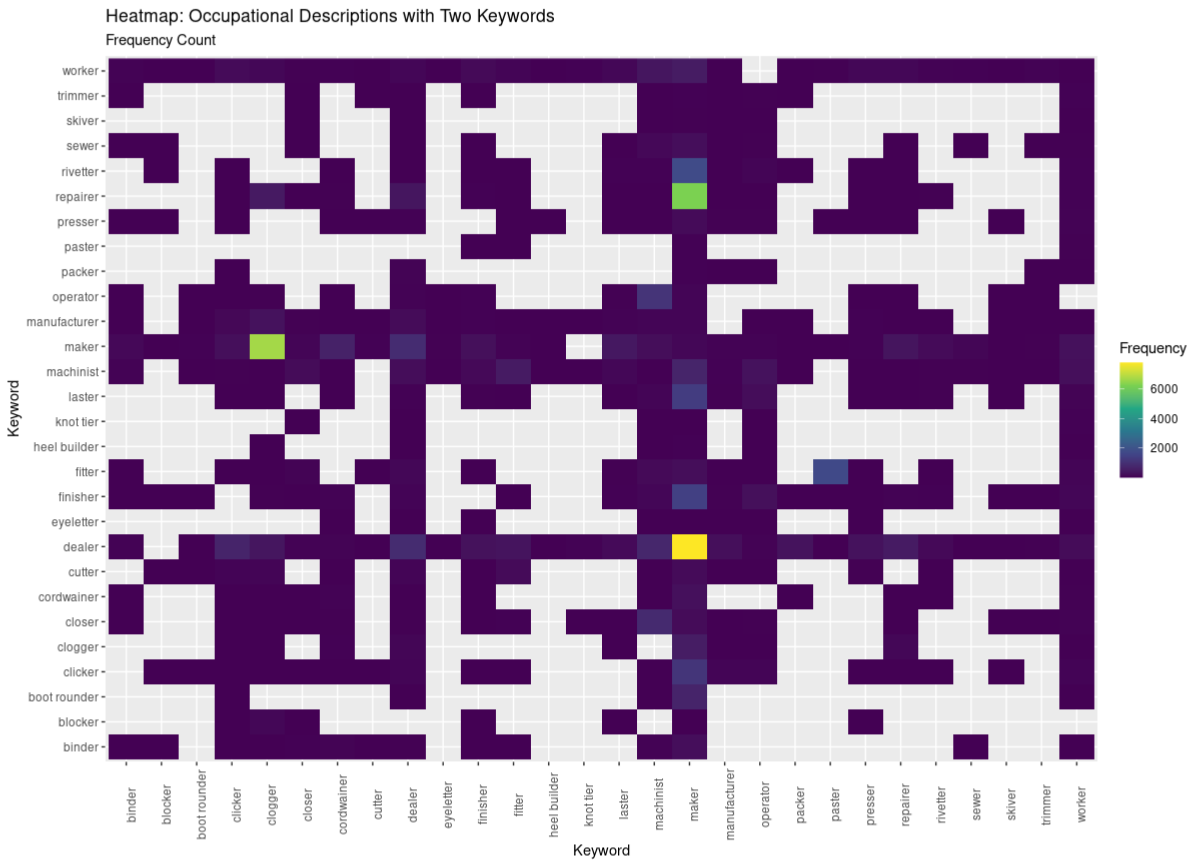


Figure 7: Heatmap of Dyads

As there are only a relatively few number of entries which could potentially be coded to two or more types of task in the bootmaking industry the choice of the hierarchy does not make a substantial impact to the results. See Table 5, below for an example of the difference it makes to place machinist first versus last in the hierarchy.

Table 5: Bootmakers identified as "Machinists" by hierarchy order

	1851	**1861**	**1881**	**1891**	**1901**	**1911**
Machinist: if first in hierarchy	0	272	11167	16471	24345	19428
Machinist: if last in hierarchy	0	183	10325	15266	21524	16115
Difference	0	89	842	1205	2821	3313
Difference in percent	0	32%	7.50%	7.30%	11.60%	17.10%

Note: Difference in number of Bootmakers identified as "Machinists" by changes to the order of the hierarchy which manages descriptions of tasks in which there is more than one keyword. Source: Task data derived by author from ICeM data.

There are four types of keywords which emerge in the "tasks" category. The first group of keywords is those which provide the greatest precision in describing occupation. For bootmakers, this includes nomenclature such as: clicker, fitter, repairer, dealer. This group most closely aligns with the standard meaning of "task". The second group refers to occupational titles which are a bit more generic: for example "foreman", "factory worker", "employer". These are terms which emerge as technological change alters the structure of work, and production becomes increasingly based in factories. The third group refers to the materials being used: for example, a slipper maker vs a bootmaker. Finally, there is a set of "catch-all" terms, including "makers, workers". The hierarchy of keywords places the specific keywords highest, then the supervisory type roles, then those with information regarding material, and then the most general terms. This ensures that the greatest amount of information is extracted from the strings describing occupation.

7.3 Appendix C: Pace of Change

The technological shock of mechanization did not unfold uniformly across the six decades between 1851-1911. The sewing machine was not introduced until 1858. In the first decade, between 1851-1861, prior to mechanization, there is no clear sign of job loss and job creation. See Figure 8. However, between 1851-1881, a clear pattern starts to emerge. The old jobs are now in decline in nearly every single English county, while the new jobs are emerging in Northamptonshire, Leicestershire, and London. See Figure 9. This pattern simply becomes more entrenched over time, see Figures 10, 11, 12.

Please see Figures 13 and 14 for the tables showing the exact pace of change at the regional level. Figure 13 shows the absolute change in the number of "Old" tasks in each time period. Figure 14 shows the absolute change in the number of "New" tasks, by county, in each of the census years.

Figure 8: Change in Number of Bootmakers Employed: 1851-1861

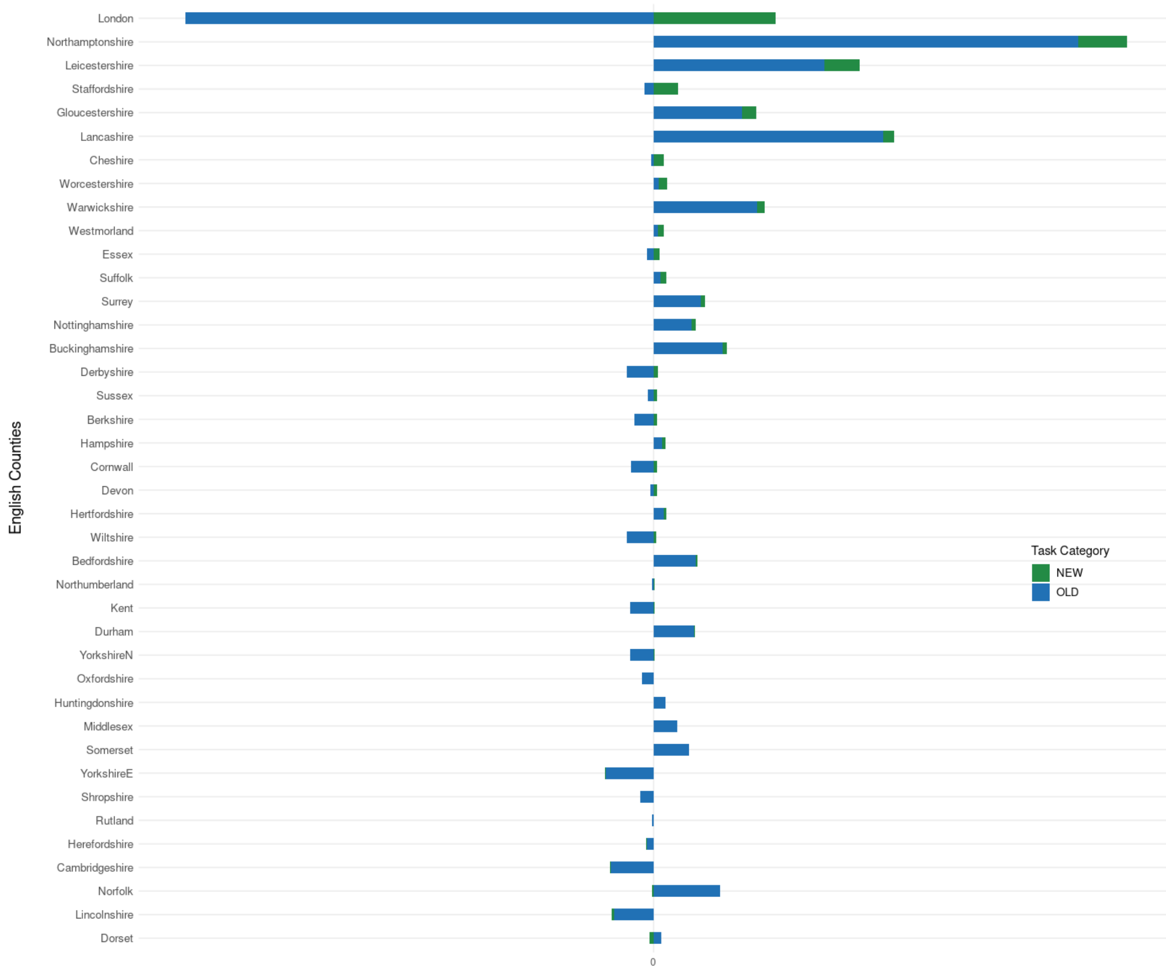


Figure 9: Change in Number of Bootmakers Employed: 1861-1881

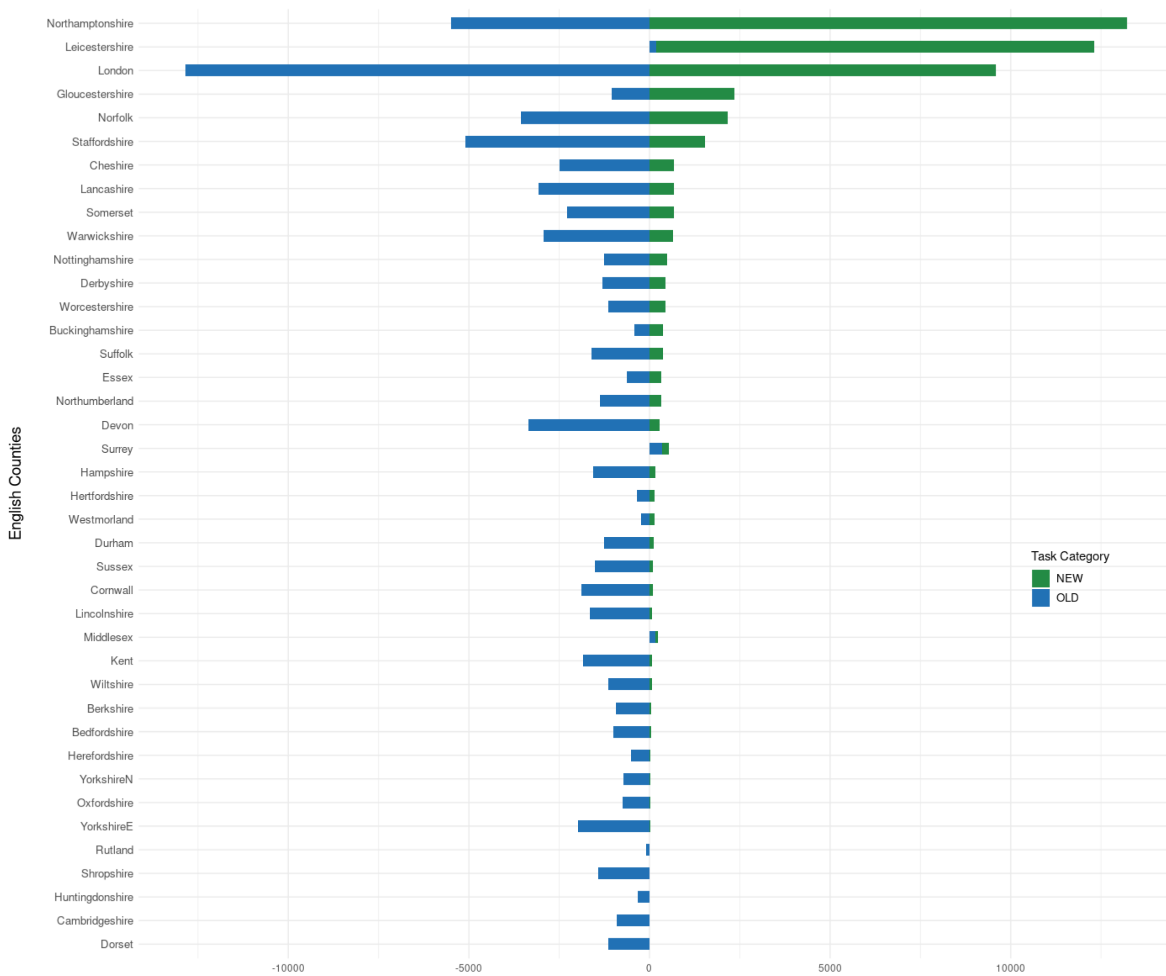


Figure 10: Change in Number of Bootmakers Employed: 1881-1891

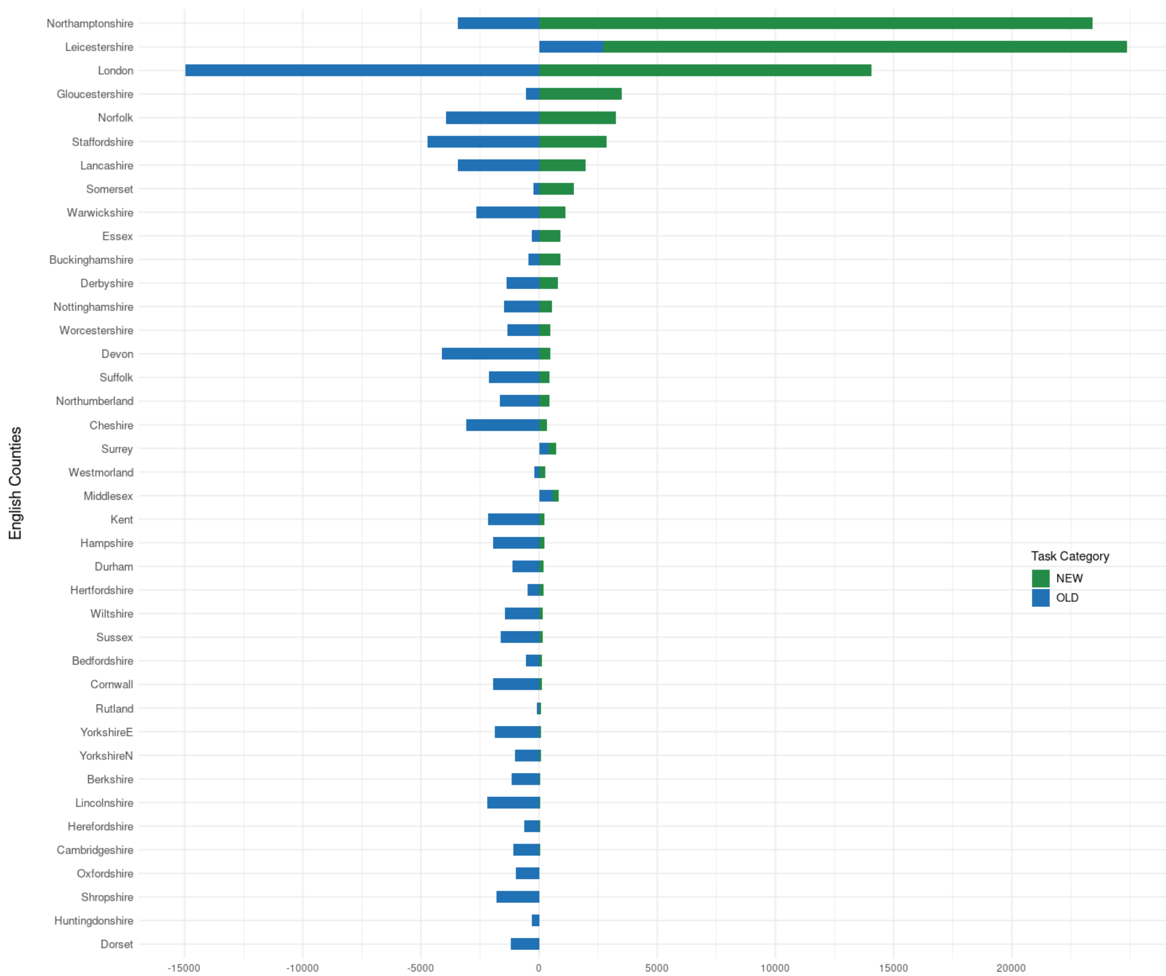


Figure 11: Change in Number of Bootmakers Employed: 1891-1801

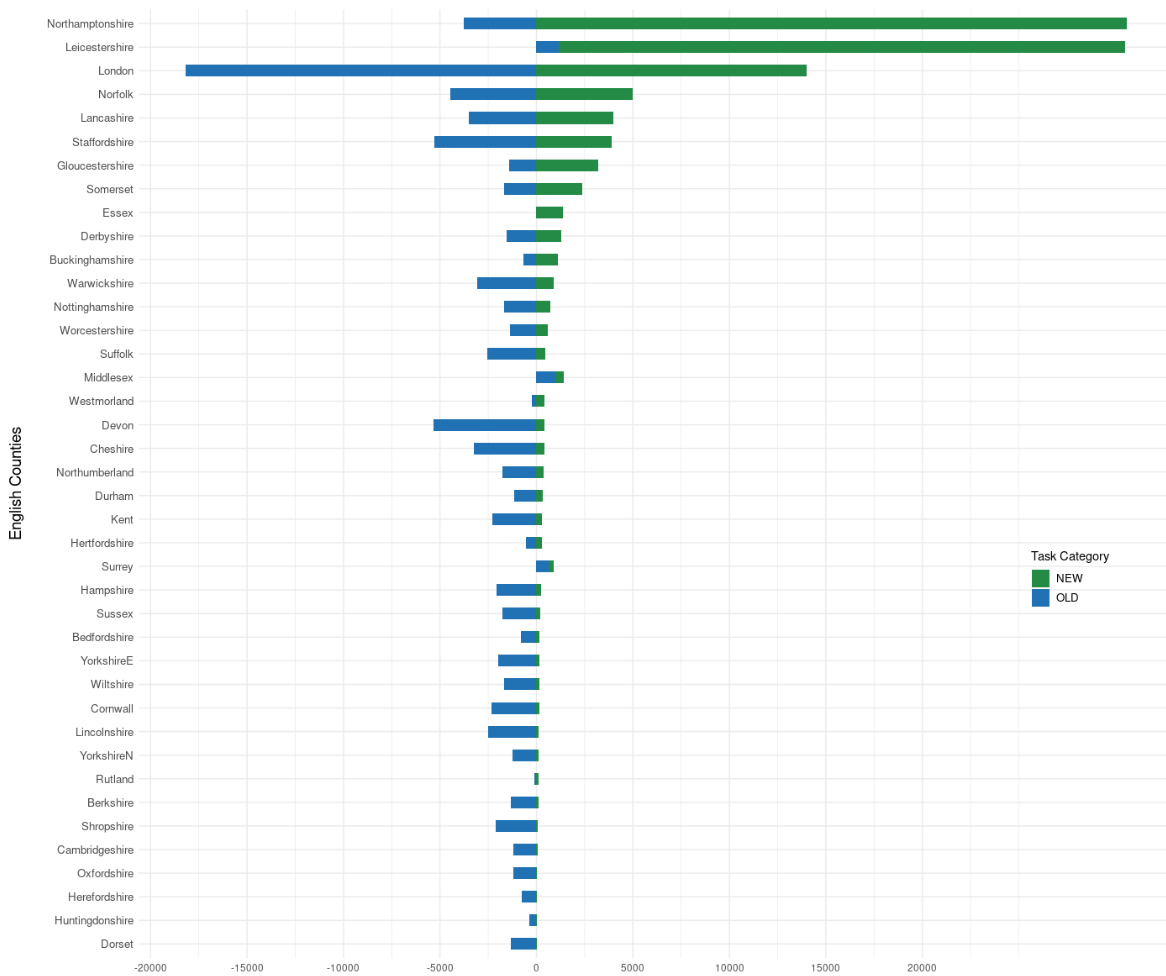


Figure 12: Change in Number of Bootmakers Employed: 1901-1911

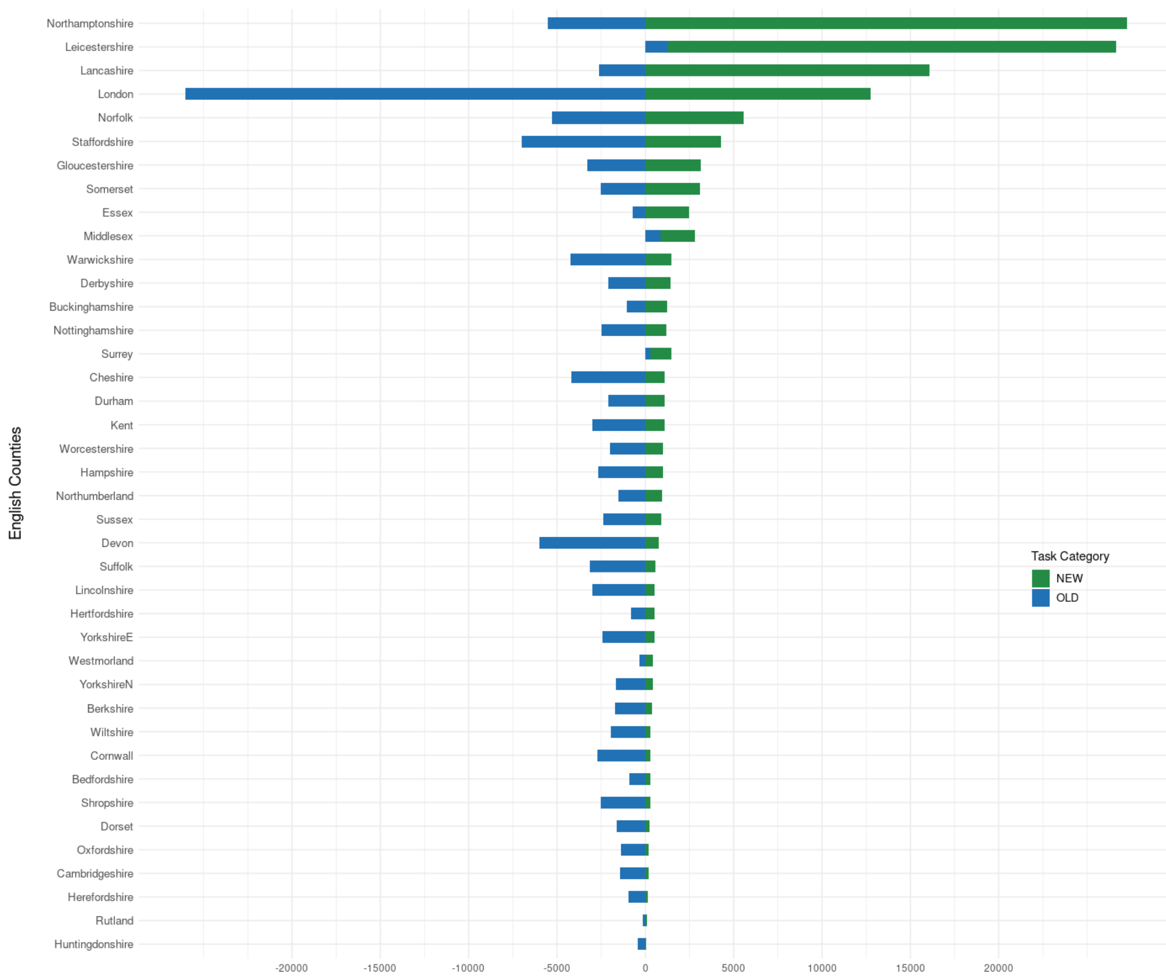


Figure 13: Pace of Change, "Old" Tasks, English Bootmakers

English County	**Number: 1851**	**Change: 1851-1861**	**Change: 1851-1881**	**Change: 1851-1891**	**Change: 1851-1901**	**Change: 1851-1911**
Bedfordshire	1428	291	-1000	-571	-812	-906
Berkshire	2234	-133	-930	-1178	-1344	-1697
Buckinghamshire	1803	473	-419	-453	-678	-1065
Cambridgeshire	1955	-289	-903	-1081	-1217	-1431
Cheshire	6221	-17	-2496	-3066	-3232	-4169
Cornwall	3713	-156	-1886	-1930	-2331	-2718
Cumberland	2205	-361	-672	-916	-1019	-2205
Derbyshire	3095	-180	-1303	-1374	-1538	-2119
Devon	8015	-20	-3358	-4132	-5339	-6004
Dorset	2082	54	-1143	-1205	-1345	-1632
Durham	3863	275	-1267	-1121	-1149	-2091
Essex	3207	-43	-626	-296	-6	-697
Gloucestershire	5853	601	-1053	-547	-1393	-3299
Hampshire	4419	58	-1557	-1954	-2082	-2672
Herefordshire	1197	-45	-522	-624	-756	-947
Hertfordshire	1441	70	-343	-496	-552	-799
Huntingdonshire	570	80	-324	-305	-364	-455
Kent	4870	-160	-1844	-2173	-2267	-3003
Lancashire	19116	1570	-3078	-3443	-3496	-2609
Leicestershire	3165	1167	194	2699	1146	1303
Lincolnshire	4130	-270	-1654	-2202	-2489	-2996
London	37507	-3191	-12837	-14949	-18166	-26010
Middlesex	1323	162	167	590	1000	838
Norfolk	8413	455	-3558	-3943	-4443	-5296
Northamptonshire	12915	2897	-5487	-3432	-3787	-5507
Northumberland	3473	-12	-1375	-1648	-1758	-1521
Nottinghamshire	3642	260	-1254	-1477	-1681	-2458
Oxfordshire	1829	-78	-733	-995	-1178	-1365
Rutland	225	-8	-91	-108	-126	-160
Shropshire	3169	-90	-1425	-1787	-2099	-2542
Somerset	5908	241	-2275	-244	-1676	-2538
Staffordshire	9915	-63	-5087	-4719	-5281	-6978
Suffolk	4271	48	-1613	-2116	-2544	-3156
Surrey	1632	321	353	415	617	280
Sussex	3687	-37	-1509	-1642	-1780	-2369
Warwickshire	6033	705	-2932	-2670	-3091	-4224
Westmorland	628	31	-233	-201	-237	-354
Wiltshire	2507	-185	-1133	-1450	-1666	-1964
Worcestershire	3128	35	-1136	-1352	-1363	-2010
Yorkshire East	3551	-328	-1968	-1858	-1975	-2435
Yorkshire North	2721	-159	-732	-1034	-1253	-1693
Yorkshire West	14878	-326	-3738	-4170	-5222	-14878

Figure 14: Pace of Change, "New" Tasks, English Bootmakers

English County	1851	Change: 1851-1861	Change: 1851-1881	Change: 1851-1891	Change: 1851-1901	Change: 1851-1911
Bedfordshire	15	11	56	125	161	275
Berkshire	17	25	58	45	91	380
Buckinghamshire	10	29	384	908	1107	1228
Cambridgeshire	27	-8	1	33	54	185
Cheshire	101	71	672	338	396	1105
Cornwall	24	24	86	104	138	283
Cumberland	11	12	2	15	26	-11
Derbyshire	27	28	453	812	1266	1429
Devon	58	22	280	475	407	759
Dorset	42	-27	-5	-6	17	220
Durham	21	9	116	202	309	1087
Essex	11	39	332	918	1393	2451
Gloucestershire	58	101	2350	3492	3208	3134
Hampshire	37	24	157	213	253	974
Herefordshire	11	-4	24	37	34	123
Hertfordshire	9	19	143	176	267	521
Huntingdonshire	4	2	2	17	18	52
Kent	55	9	74	231	271	1069
Lancashire	401	74	671	1970	3992	16079
Leicestershire	73	240	12125	22167	29349	25320
Lincolnshire	50	-14	78	44	114	540
London	1105	832	9597	14075	14014	12739
Middlesex	25	1	77	239	437	1955
Norfolk	241	-11	2165	3236	4981	5542
Northamptonshire	794	332	13213	23420	30588	27245
Northumberland	32	10	331	431	359	941
Nottinghamshire	44	29	485	562	714	1184
Oxfordshire	20	3	22	29	44	201
Rutland	8	-4	10	93	93	87
Shropshire	37	-2	2	18	54	274
Somerset	80	-1	669	1479	2388	3082
Staffordshire	221	166	1541	2852	3889	4276
Suffolk	36	37	378	435	466	552
Surrey	11	31	183	320	266	1183
Sussex	28	26	92	145	218	917
Warwickshire	148	55	644	1110	891	1478
Westmorland	2	40	129	275	409	427
Wiltshire	12	17	66	164	150	302
Worcestershire	32	58	435	478	602	1013
Yorkshire East	48	-2	13	84	155	509
Yorkshire North	11	8	22	66	95	403
Yorkshire West	203	88	3995	5926	7048	-203

7.4 Appendix D: Gender by Task

Occupations were gendered through the 19th century. Within the bootmaking industry there were a small number of tasks which fell to women. The majority of tasks were men's work, and a few tasks were undertaken by both men and women. See Figure 15 below.

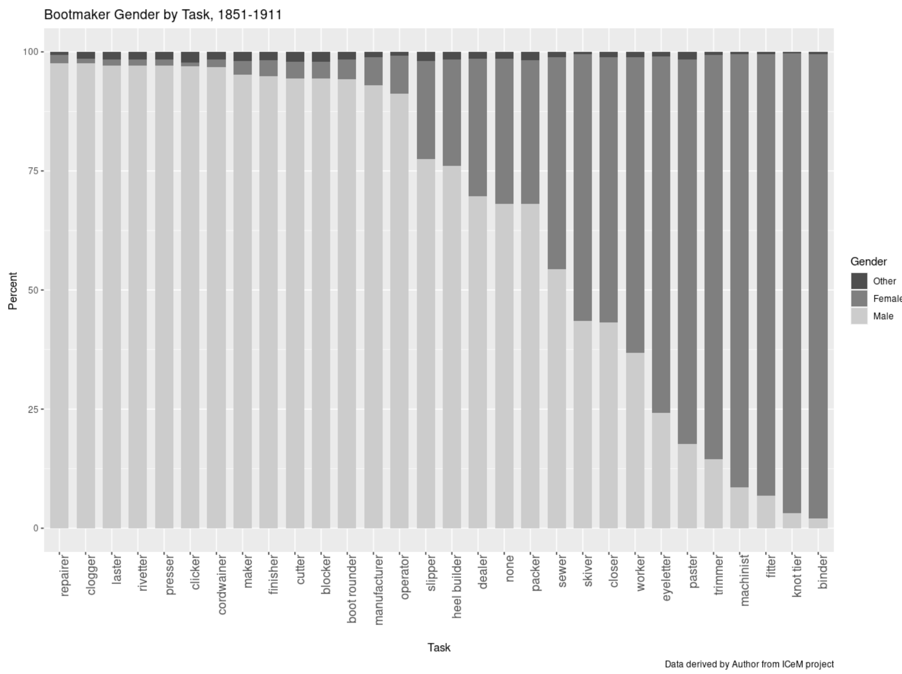


Figure 15: Task by Age, English Bootmakers

7.5 Appendix E: Advertisements

This data is based on a small dataset of approximately 100 advertisements, from London papers running between 1855-1885, digitized by the British Newspaper Archives project. Each advertisement provides information on the cost of training on the bootmaking and regular sewing machine. The adverts first emerged in 1860. Figures shown in the tables communicate average prices for each five year period. Prices for the training declined over the twenty year period, and then the adverts disappeared entirely. In all periods tuition on the use of the heavier "bootmaking" sewing machine was more costly. See Table 6, below

Table 6: Cost of Lessons, in London, to Learn the Sewing Machine

Year	Price for Lessons
1860 - 1864	6s for the sewing machine, 10s 6d for bootwork
1865 - 1869	5.6s for the sewing machine, 10s 4d for bootwork
1870 - 1874	3.1s for the sewing machine, 8s 7d for bootwork
1875 - 1879	2.3s for the sewing machine

Note: Data from British Newspaper Archives project

7.6 Appendix F: Consistency Argument, Census Linking

To test whether bootmakers tended to refer to themselves as doing the same kinds of "task" level work over time I must observe the individuals over multiple time periods. I therefore use an automated linking algorithm based on ABE (Abramitzky, Boustan, and Eriksson,2014; Ager, Boustan, and Eriksson, 2021; Long and Ferrie, 2013b), with my own modifications.

Linking is done on three variables: name, age, and place of birth. Name consists of both first and last name, but not the middle name or the middle initial, as this is given very sporadically. Names can be matched in various ways: on an exact spelling, a phonetic spelling, and on a range of different measures of string distance. I match on phonetic spelling, for three reasons. Firstly, exact matching on name is highly restrictive, and makes no allowance for the routine variations in spelling which occurred in Victorian times. Secondly, measures of string distance are often plagued by considerably weakness, and yield highly misleading results. Finally, phonetic matching retains a large portion of possible matches in the Cartesian mix. This can lead to false positives if there is no further way of tie-breaking. However, there is sufficient additional tie-breakers in this case that the wide net cast by the phonetic matching is advantageous.

The second variable in the matching is age. As is standard, I allow for some fuzziness of matching – a date of birth which is ± 2 years is permitted. The two year range is fairly standard, and seems to be a reasonable compromise. See robustness tests for matches when three year and one year ranges are used.

Finally, the third variable used in the matching process is place of birth. At present I use both county of birth and parish of birth. Making use of both variables is quite conservative – American data tends to have only State of birth, which makes false matches likely, and which results in dropping large numbers of common names from the dataset. The parish level place of birth available in the British census data means that comparatively few people share the same birthplace: there are 42 counties in England in 1851, but 15 000 parishes. The corollary here is that x% in 1851, and y% in 1861, do not identify their parish of birth. When this is made a requirement of the matching process it therefore returns a false match.

I proceed by creating cartesian matches and then filtering. All names are matched with all names, blocking on the full names matching phonetically. The potential matches in this set are then filtered by the date of birth requirement. They are then filtered by the place of birth requirement. The last step, in keeping with most ABE type deterministic linking algorithms, is to drop names with more than one potential match. In practice this means that more common names are dropped from the dataset.

Finally, I split the group by gender. I filter women to retain three groups: married women who stay married or become widowed This leaves me with a total of 4916 matches. The "mar" variable may be an improvement, and can be included in the algorithm next time I run the census matching.

I then require that the two following conditions are met. Firstly, I require that the head of household surname remain the same in both years. This is somewhat forced, and excludes matches in which a married woman happens to be staying with a male relative, a single woman is boarding or in service, or a widow is staying with any other household. Secondly, I require that the age of the head of household is either the same as the woman's age (this person is their own head of household), or that the head of household has the same birthdate in both datasets (with a ± 3 years range on age). For the first match I finish keeping 3062 observations. My female sample is biased, since it does not include women who are single in the first time period, and then marry and change their name in the second period .

This matching process yields a match rate as in the figure below. For the first match, I census link English bootmakers between 1851-1861, with a match rate of 28% for men and 9% for women. For the second match I link English bootmakers between 1861-1881, with a match rate of 22% for men and 6% for women.

Once matching has been completed I have two panel datasets: one for 1851-1861, and one for 1861-1881. For both, approximately 70% of individuals describe themselves as having the same task they did in the previous period. That is, people who describe themselves as cordwainers in the first period describe themselves as cordwainers in the second period. I have now done this with three

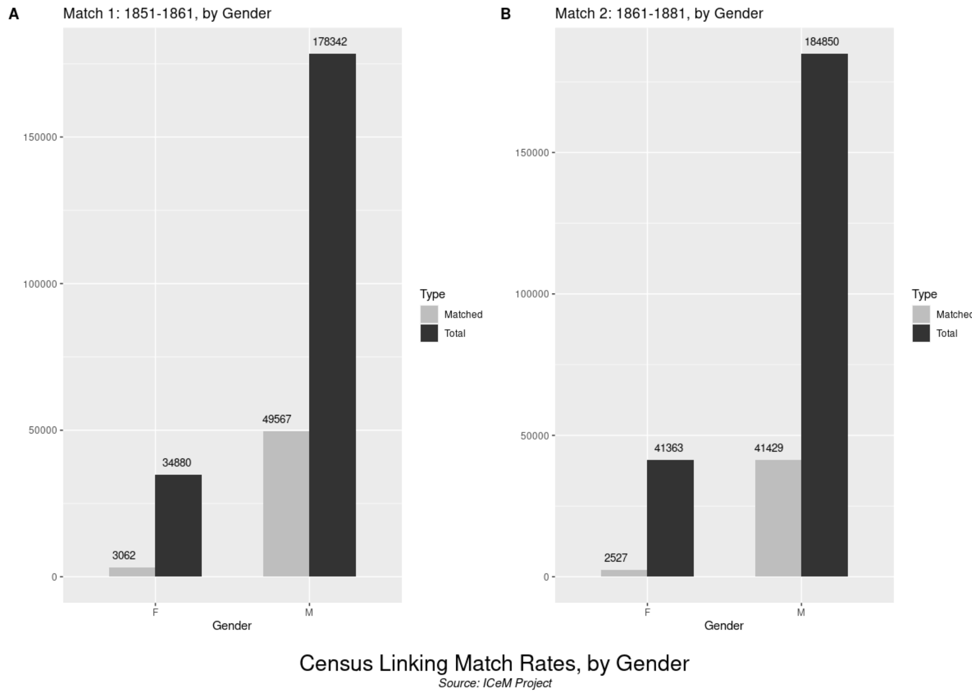


Figure 16: Task by Age, English Bootmakers

different matches, and each time I'm getting around 68.3% for TP1 and around 67.5% for TP2. TP2 is lower because there are some people switching into the new tasks, just not very many.

Note: In both matches there are approximately 2% of the observations which have no entry for occupation in one of the years. If we assume that 68% of these missing observations have the same task in both years then that would bring both up to a total of 70%.

7.7 Appendix G: Age by Task

Please see figures below for additional information on the distribution of age in bootmaking tasks over this period.

Figure 17: Task by Age, English Bootmakers in 1881

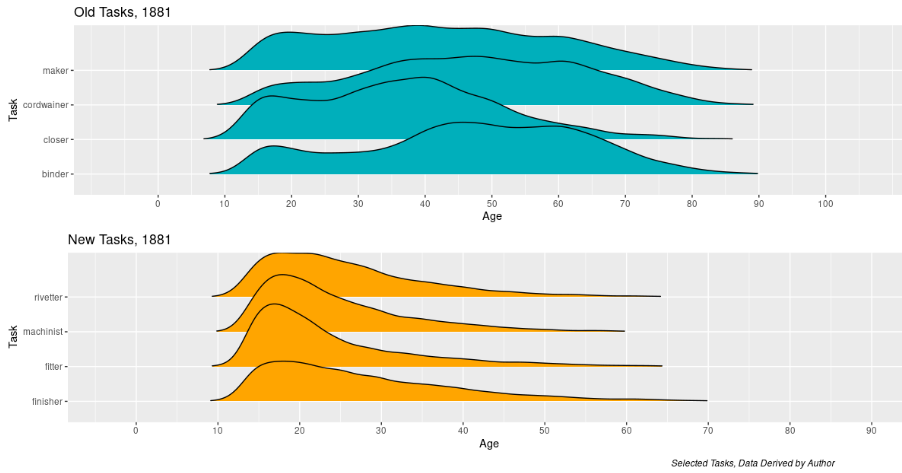


Figure 18: Task by Age, English Bootmakers in 1891

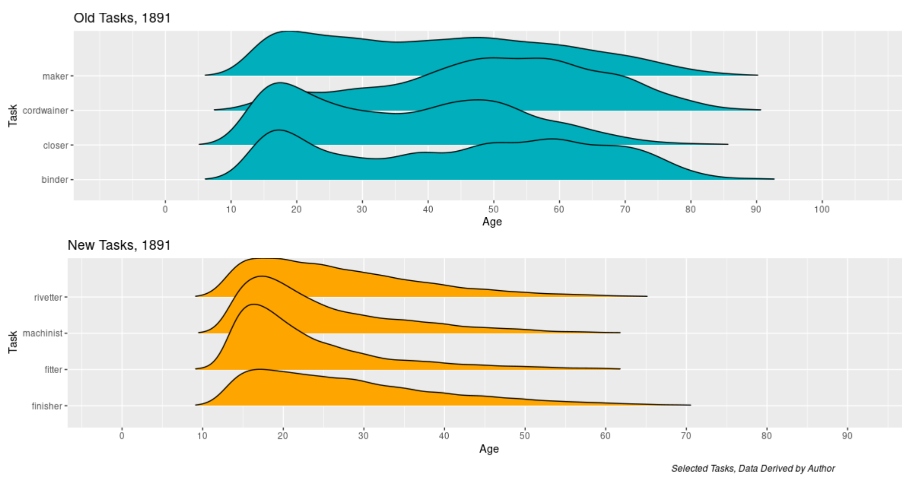
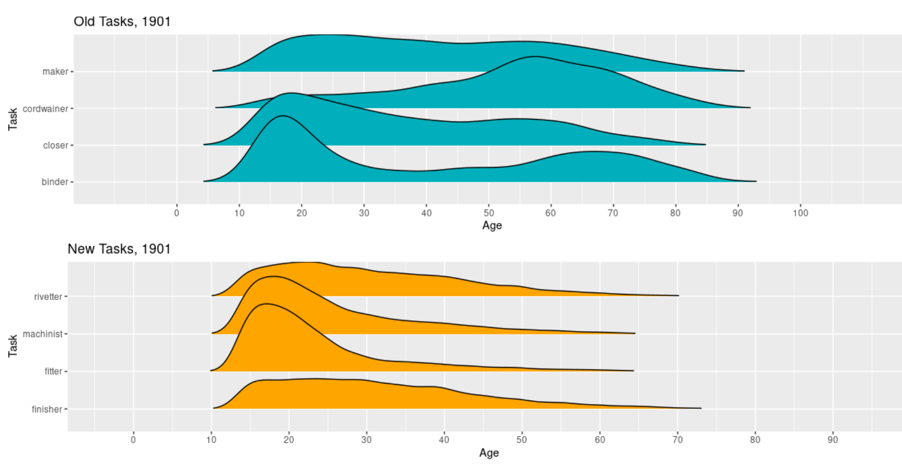


Figure 19: Task by Age, English Bootmakers in 1901



7.8 Appendix H: Number and Share of People Employed in Bootmaking Tasks Over Time

For a disaggregated view of Bootmaker Tasks over time please see the tables below.

Table 7: Bootmaking Tasks Over Time

Task	1851	1861	1881	1891	1901	1911
Binder	27160	28759	2999	1488	624	216
Blocker	150	NA	128	113	74	46
Clicker	462	925	5367	10169	12076	11875
Clogger	2107	2921	5816	5723	5355	4913
Closer	4983	8674	3417	2997	2485	2030
Cobbler	NA	NA	40	158	251	145
Cordwainer	41655	35731	11315	3507	1733	688
Employer	401	NA	691	NA	NA	84
Factory	NA	NA	154	176	1565	1614
Finisher	NA	NA	11028	19660	19109	14465
Fitter	NA	174	6095	8203	9918	4539
Foreman	NA	NA	NA	100	731	675
Knot Tier	NA	NA	52	83	310	228
Laster	NA	NA	885	4007	8346	6243
Machinist	NA	NA	10129	14910	22779	18203
Maker	120449	124955	103487	111775	90380	55771
Manufacturer	319	480	1606	3169	2574	2380
Mender	80	NA	242	1128	4364	28710
Nailer	NA	NA	124	NA	NA	31
Operator	NA	NA	17	NA	752	1811
Presser	NA	NA	450	1069	2044	1646
Rivetter	NA	NA	9038	10543	8881	5607
Seller	147	211	2790	5998	14185	16939
Sewer	NA	NA	181	355	431	595
Trimmer	NA	NA	124	274	528	557

Table 8: Note: number and share of bootmakers not allocated to one of the task categories. Source: ICeM Census Data

Year	**N: Not Assigned**	**N: Assigned**	**Percent of Observations Not Assigned**
1851	2049	220137	0.93%
1861	2549	226220	1.13%
1881	3457	197510	1.75%
1891	6671	232732	2.87%
1901	8389	240897	3.48%
1911	13909	213150	6.53%
All	37024	1330646	2.78%

7.9 Appendix I: Reporting on Female Labour Force Participation

Modern definitions of FLFP focus on women being "economically active" (Ortiz-Ospina, Tzvetkova & Roser, 2018). This includes self-employment, and in practice translates into the sale of goods or services in exchange for an income. In 19th century England the most comprehensive record of FLFP emerges from the decennial census records. Census enumerators in 1851 were instructed: "The occupations of women who are regularly employed from home, or at home, in any but domestic duties, to be distinctly recorded instructions given to the census takers" (Shaw-Taylor & Wrigley, 2007, p.4). These instructions can form the basis of a definition of FLFP for the period. The census likely under-records part-time employment, given the emphasis on "regular employment". In practice this may impact more on the accounting of female labour force participation

Can we trust the recording of women's LFP in the English census data of the 19th century? The controversy over whether the Victorian census records reliably report female employment is long standing. In a recent article, Edward Higgs revisits the historiography of the debate (Higgs & Wilkinson 2016). Several scholars have argued that the census records cannot be trusted (Higgs 1987; Hill 1993; Horrell & Humphries 1995; Sharpe 1995; Davidoff & Hall, 2002; Kay 2006). Higgs traces the origin of this argument to his own 1987 paper, and points out that subsequent papers espousing the position either cited his work or did not provide evidence to back up the claim: "In summary, it seems that the assumption that the work of Victorian women in the British censuses is under enumerated relies to a worrying extent on the comments made by me some thirty years ago, which I subsequently repeated in my guide to the census records, Making Sense of the Census in 1989" (Higgs & Wilkinson 2016).

The paper then summarizes a few of the arguments put forward in support of the reliability of the census records. Both John McKay and Michael Anderson note that the census records show higher employment for married women in Lancashire than in other counties (McKay 1998; Anderson 1999). Leigh Shaw-Taylor has argued that, if married women were well recorded it is unlikely that unmarried women would have been less well recorded.

In revisiting the debate Higgs notes both his original views and counter-arguments. Firstly, he had claimed that women occupied in part-time work were likely to have been excluded from the census records, and that this would have impacted particularly on women working in agriculture.

He now notes that the seasonal labour done in agriculture is likely to have been under-reported for both men and women. Secondly, he points out that he relied heavily on ideological grounds, the Victorian views on "separate spheres", to suggest that census enumerators may have systematically undercounted women in employment. Finally, his original paper relied on a set of very local studies of the CEBs. These often made use of the records of a small employer, or those held in a local community. He feels now that these are likely not representative, and presents case studies which explore the limitations of these datasets.

He asserts that he has now changed his views, and considers the Victorian census records a reliable account of female employment. He then presents new empirical work by his co-author, Amanda Wilkinson, in support of the new view. Wilkinson makes use of occupation data given in asylum records from the towns of East Anglia. She matches individuals, and then compares occupation given in both sets of records. By 1871 the occupations have high match rates, ranging from 70%-100%, with match rates increasing over time.

Another two defences of the value of the census records of female employment have been put forward elsewhere. Leigh Shaw-Taylor points out that many of the papers arguing that women's work is not well recorded are in fact concerned with women's part-time and irregular work. This is clearly under-recorded. However, that does not imply that full time employment has been under-reported. A close study of the CEB records in one county, Herefordshire, provides evidence that women's work was not under-recorded (McGeevor, 2014). Textile work, in both the factories and in the cottage industries, was well recorded (Shaw-Taylor & Wrigley, 2007).

It is worth noting that the entire debate on these questions has taken place prior to the digitized version of the Victorian census data becoming available. Researchers often made use of the tables published in the 1851 census report. This provides summary tables of female occupation. There are 196 categories , recorded in 5 year age intervals. 21 of these are not linked to market-oriented work. Higgs and Wilkinson note that as ICeM becomes available it will become possible, for the first time, to examine women's work at the national level.