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Contents

APPENDIX **94**

List of Figures

List of Tables

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Abstract

This study investigates three distinct examples of technological innovation during the 19th century United States. I first examine the long-run impacts of a deskilling technology on workers and their children. The McKay stitcher dramatically changed shoe production in the late 19th century by replacing skilled artisans with machines and less-skilled workers. It was licensed in only a few counties and impacted workers across counties unevenly through the transportation network. More-exposed shoemakers and their children faced long-run losses in the face of this displacement. During the same era, the railroad network of the US expanded rapidly, changing the organization of firms in manufacturing. Expanding market access pushed establishments to specialize production on fewer products. Manufacturing plants specialized on specific steps in the production process, shortening the production chain within establishments. Together these imply that the ingredients for Smithian growth arose in response to technologically driven market integration. Towards the end of the century, a new method of market integration began to take hold. The introduction of the first telephone exchange in Chicago in 1878 enabled faster communication between businesses throughout the city. This study connects the increase in communication speed to prices in Chicago commodity markets. The telephone lowered dispersion in both spot and futures markets at the Chicago Board of Trade.

Chapter 1

MACHINES EATING MEN: SHOEMAKERS AND THEIR CHILDREN AFTER THE MCKAY STITCHER

There have long been concerns of technological advances displacing workers. In 1931, Keynes (1931) predicted automation would lead to "technological unemployment." Technologies can shift labor demand away from the skills of incumbent workers in favor of different skills. Recent evidence documents many examples of lower-skill workers being displaced by new technologies (Humlum, 2019; Acemoglu and Restrepo, 2019, 2020). Less is known about the long-run effects of new technologies and the different types of innovation that replace high-skill workers. Historical evidence can help us examine both. Many de-skilling technologies in the late 19th century replaced skilled artisans with lower-skill workers and machines. This historical setting provides an opportunity to understand the long-run and intergenerational consequences of "machines eating men" and to document the effects of a deskilling technology.[1]

I study one such example, the McKay stitcher, that enabled a low-skill worker to replace traditional shoemakers, a type of high-skilled artisan at the time. This led to a dramatic shift from hand to machine labor in the 19th century United States shoe industry. In 1860, there were over 130,000 shoemakers in the United States (about 2% of the workers in 1860), with shoemakers living in the majority of US counties. In 1861, the McKay stitcher was

[1] These episodes recall Sir Thomas More's concerns in 1516 about "sheep eating men" as growing sheep populations drove agricultural workers off land in England. Though the phrase "sheep eating men" never actually appears in the text of the book, the phrase has become proverbial. More describes wealthy individuals creating enclosures for pasture where poor farmers previously planted and harvested, leading to the displacement of farmers. He wrote: "your sheep that were wont to be so meek and tame..., become great devourers... that they eat up, and swallow down the very men themselves" (More, 1516).

first used in production and enabled key shoemaking tasks that previously required hours of a skilled shoemaker's time to be completed in minutes.[2] This new technology meant a less skilled worker with one McKay stitcher could sew the soles of shoes 60 times faster than the traditional artisan shoemakers without the machine (U.S. Bureau of Labor, 1886). The new machine created demand for different skills, decreased the price of shoes, and boosted shoe production dramatically.

In my analysis, I leverage the spatial variation of shoemaker competition with the McKay stitcher. The owner of the patent, Gordon McKay, instituted a first of its kind restrictive licensing agreement, charging royalties on each shoe produced in a limited number of chosen counties. As a result, there were approximately 700 McKay stitchers in only 15 counties in 1870.[3] I refer to those 15 counties as McKay counties. The concentration of the McKay stitcher combined with the existing railroad network in the late 19th century resulted in some shoemakers being more exposed to this technology shock than others. Consumers could purchase McKay shoes produced across the United States rather than from local shoemakers. This increased competition in the product market and caused downward pressure on the wages of shoemakers, but the degree of this pressure varied across counties depending on the cost of shipping shoes from a McKay producer.[4] Formally, I follow the existing literature to define a county's exposure as the market access to shoes from McKay producers (Redding and Venables, 2004; Donaldson and Hornbeck, 2016; Adao, Arkolakis and Esposito, 2019).

I study workers across generations using a panel of individual level data from the US

[2] As discussed further in section I, the McKay stitcher was actually invented in 1858 by Lyman Blake who then sold the patent to Gordon McKay, an astute businessman. Historians in the UK refer to this machine as the Blake stitcher after the inventor rather than the patent owner. It was used experimentally prior to 1861.

[3] For comparison, the 1860 Census of Manufacturers reports 1,208 counties producing shoes, with almost 12,500 establishments.

[4] In studying trade liberalization in India, Topalova (2010) showed that more exposed places saw slower improvements in consumption and wages relative to places that were more insulated. Regarding trade liberalization in Brazil, Dix-Carneiro and Kovak (2017) showed adaptations in labor markets impacted by the liberalization took decades. I similarly demonstrate that within-country transportation costs are sufficient to cause dramatic variation in adjustment paths.

Census of Population and the US Census of Manufacturers (Ruggles et al., 2021; Hornbeck and Rotemberg, 2024). My strategy is to compare shoemakers with other occupations in more and less exposed counties, creating a triple-difference. My analysis of this data will be focused on: (1) how did incumbent shoemakers adjust to competition from the McKay stitcher, (2) how were the children of shoemakers affected, and (3) who benefited from the shift in demand for skills?

Within ten years of the introduction of the McKay stitcher, incumbent shoemakers in high-exposure counties (top decile of exposure) left traditional shoemaking 23 percentage points more than shoemakers in the bottom decile (low-exposure counties), which equates to a 52% increase in exit rates. Shoemakers in high-exposure counties continued to switch occupations into the next decade. Though migration is a method for seeking better opportunities, it was not a quantitatively significant source of adjustment. Within McKay counties, displaced shoemakers turned to shoe factory work, which paid lower wages than traditional shoemaking.[5] These positions were largely temporary. More generally, shoemakers in high-exposure counties were more likely to enter low-skill occupations through 1870 and 1880.

Despite exiting shoemaking, shoemakers in high-exposure counties were less likely to report property values of more than $100.[6] Conditional on reporting greater than $100, shoemakers in high-exposure counties had 16% lower property values in 1870 which equates to 1.3 years of shoemaker wages.

Though substantial effects have been documented with technological displacement, these results are particularly striking given that the 19th century United States is considered

[5] This conclusion comes from occupation level data from Weeks (1886) and US Department of Labor (1899). High skill opportunities from the McKay stitcher were quantitatively small compared with the displacement. Only 22 machinists are reported in the shoe industry in 1870, and McKay's company for repairing shoemaking machinery only reported 58 employees, while shoe industry employment dropped by more than 35,000.

[6] Census takers only recorded property values when values were over $100. Thus, this does not mean they had no property, only that their property was valued less than $100 (about 4 months of shoemaker wages).

a time of high mobility, both in terms of occupations and geographies (Long and Ferrie, 2013). Though shoemakers did change occupations to adjust to this technology, their ability to mitigate the negative consequences was limited. These findings echo those of recent studies documenting local adjustment to labor market shocks (Enrico, 2011; Autor, Dorn and Hanson, 2013*a*,*b*; Acemoglu and Restrepo, 2020).

In this historical context, I examine consequences beyond the impact on incumbents to analyze the long-run impact of the technology on their children and uncover the intergenerational transmission of the displacement effects. I document high correlations between occupation and industry choices of fathers and sons in this setting. This phenomenon, which I refer to as occupation continuance, has been demonstrated in modern settings as well (Dal Bó, Dal Bó and Snyder, 2009; Hvide and Oyer, 2019; Staiger, 2022). The persistence of occupation is related to the well-documented transfer of wealth and income across generations both historically and more recently (Chetty et al., 2014; Ager, Boustan and Eriksson, 2021). Occupation continuance provides an additional channel through which the McKay stitcher impacted the labor market. From 1850 to 1860, prior to the McKay stitcher, 29% of the children of shoemakers were themselves shoemakers ten years later, while between 1860 and 1870 occupation continuance was only 15%.[7] Though this trend was initially driven by the children of shoemakers in high-exposure counties, by 1900 these trends were consistent nationwide.

The children of shoemakers did not pursue other skilled occupations. In high-exposure counties, they entered lower wage occupations and were less likely to continue their education as students. In McKay counties, the children of shoemakers turned to shoe factory work, implying high industry continuance in McKay counties despite plummeting occupation continuance. As was true for their fathers, shoe factory work was temporary, and the children of shoemakers continued in other lower-wage occupations through 1880 and even 1900. The

[7]These statistics are conditional on reporting an occupation.

children of shoemakers had limited migration responses, similar to their fathers.

Finally, I turn to the job opportunities created by the new technology. Though costs to incumbent workers and their children were high, the McKay stitcher also created new opportunities for workers from less literate and lower wealth fathers. This highlights the deskilling effect of the McKay stitcher. Workers entering the shoe industry prior to the McKay stitcher came from above average wealth fathers with above average rates of literacy, while new entrants after the McKay stitcher came from below average wealth fathers with below average rates of literacy.

To quantify the losses to incumbent shoemakers and their children during this period, I connect the switching decisions of shoemakers and their children to a model of occupation selection from Artuç, Chaudhuri and McLaren (2010). I first estimate the cost of migration and the cost of occupation switching. Estimation of this model relies on wages which are not generally available in this time period. To supplement existing wage estimates, I hand-match census occupations with manufacturing wage data from Weeks (1886). With switching rates from the linked population census and the improved data on wages, I estimate smaller occupation and migration switching costs than observed in modern data and a slightly greater wage sensitivity.

I use a revealed preference approach to infer changes in the value of traditional shoemaking based on the occupation exit decisions of incumbent shoemakers and their children. The model-estimated losses to shoemakers are highly correlated with exposure. Exposure predicts losses of 0.89 years of wages per standard deviation increase in exposure, totalling as much as 2.2 years of losses in the top decile of exposure. Similarly, the children of shoemakers lost 0.98 years per unit of exposure, totalling 2.5 years of losses in the top decile of exposure. Summing across all impacted individuals, incumbent workers lost a total of $39 million dollars and the children of shoemakers lost $27 million dollars. This $66 million dollar loss to shoemakers is similar in magnitude to back-of-the-envelope estimates for production cost savings from the McKay stitcher, demonstrating that the losses to shoemakers and their children were indeed substantial.

This article contributes to the economic literature by documenting a historical episode of substantial technological displacement and the adjustment choices of displaced workers. Modern automation technologies have shown similar displacement effects through shifting skill demand (Acemoglu and Restrepo, 2018; Feigenbaum and Gross, 2023).[8] The displacement in this context led to lower earnings, consistent with episodes of job loss more generally, and lower property values which are not often observed (Jacobson, LaLonde and Sullivan, 1993; Couch and Placzek, 2010; Davis and Von Wachter, 2011; Walker, 2013). This paper provides new evidence of similar displacement effects in a different era in history.

Additionally, this paper provides new evidence that parent to child occupation continuance is a mechanism through which employment displacement effects can persist. The direct transfer of human capital from parents to children is partially responsible for the persistent losses from this technology.[9] This complements the work of French (2022) by documenting additional channels through which shocks to parents can affect their children.

The decline in children's student status connects to the literature on the determinants of education. This reduction appears driven by declining household income. Lower or more volatile household income is associated with lower school attendance across the age distribution in modern data (Gennetian et al., 2018). Separately, Goldin and Katz (2009) and Atkin (2016) show school enrollment fell in response to rising manufacturing opportunities in both the historical US and modern Mexico, respectively.[10] The McKay stitcher created

[8]Braxton and Taska (2023) document that the shift in skill demand can make adaptation harder for incumbent workers. This study connects well with Vipond (2023) that documents detailed occupation and task changes in the shoe industry during this same time period in the United Kingdom.

[9]Becker et al. (2018) provide a model of the direct transfer of human capital from parents to children. The long-run effects of the McKay stitcher emphasize that when labor saving technology reduces the returns to an occupation, some of the human capital transferred from parent to child has also become less valuable.

[10]Relatedly, Charles, Hurst and Notowidigdo (2018) show decreased educational attainment in response to improving investment opportunities during housing booms.

many entry-level opportunities for the children of shoemakers in McKay counties, potentially increasing the opportunity cost of school. However, the estimated effect of the McKay stitcher on children's education is unaffected by splitting the analysis between non-McKay and McKay counties.

The empirical evidence on entrants to the shoe industry is an example of the theoretical implication that deskilling technologies can open industries to new participants and benefit lower-skill workers (Griliches, 1969; Goldin and Katz, 1998; Atack, Bateman and Margo, 2004). It adds to the literature on mechanization during the industrial revolutions by providing worker level evidence to complement previous studies on deskilling technologies and characterize the individuals that benefited in the labor market (Hounshell, 1984; Sokoloff, 1984; James and Skinner, 1985; Brown and Philips, 1986; Atack, Margo and Rhode, 2023). My findings are consistent with the idea in Adao, Beraja and Pandalai-Nayar (2021) that technologies are rapidly adopted when they augment skills in wide supply in the economy. The McKay stitcher displaced specialized workers and opened the industry to a broad supply of labor.

I Historical Context

The McKay stitcher displaced traditional skilled-labor intensive production methods. Given the dramatic productivity increases from the McKay stitcher after 1861, documenting where it was used in production will lay the groundwork for estimating its impact across counties in the US.

I.A Shoemaking before 1860

During the 19th century, the shoemaking industry saw a dramatic shift from artisanal handicraft to large factory style production. At the start of the century, shoemaking was a small shop craft. Master shoemakers could hire apprentices who could become journeymen and support the work of the master shoemaker. In parts of Massachusetts, New York, and Pennsylvania, shoemakers adopted a division of labor that boosted production and turned from custom shoemaking into separate wholesale and retail markets (Hazard, 1913). Standardized shoe sizes were increasingly adopted and created a market for ready-made shoes. In Massachusetts, wholesalers began shipping shoes to other regions of the US, particularly the antebellum South. By 1850, Massachusetts accounted for 44.7% of national shoe output.

As the production process was divided into tasks, task-specific machinery was invented, productivity in various tasks increased, and new styles of production developed. In 1852, the invention of the Singer sewing machine and its ease of use led to the widespread adoption of sewing machines nationally. By 1859, some types of sewing machines were affordable for an individual craftsman.[11] Machine sewing became a critical input in shoe production to remain competitive in the shoe market. The sewing machine brought work into a factory setting.

The introduction of the sewing machine dramatically increased the productivity of some portions of the manufacturing process but left the more difficult and time consuming portions to the shoemaker: sewing the soles of shoes and lasting the shoes.[12] Recognizing a bottleneck in production, Lyman Reed Blake created a new type of shoe where the sole could be attached by a unique machine design.

I.B The Introduction of the McKay Stitcher

Lyman Blake's design involved stitching the upper, inner sole, and outer sole together in a single waxed-thread seam as shown in Panel A of figure A1. The sewing had to be done inside the shoe, which was too difficult to do by hand.[13] These shoes were somewhat less

[11]Some types of sewing machines sold for as little as $50 in 1859. The average salary for shoemakers was $304 in 1860.

[12]Lasting the shoes is the process of forming the top of the shoe around the "last" or mold of a foot. The invention of wood-pegged shoes in 1815 and the subsequent sole pegging machine in the 1850s meant that there were some firms that produced wood-pegged shoes rather than sewing as referenced here. Wood-pegged shoes were less comfortable and less favorable to consumers. In 1860, pegged shoes accounted for between 2 and 3 percent of all US shoe production (Thomson, 1989).

[13]This is true for the majority of shoes, but some lighter shoes and slippers could be sewn inside out.

comfortable than hand sewn shoes, but only initially. With steam power, Blake's machine could produce 300 shoes a day in 1860 and continued to see productivity improvements over the next half century.[14] The speed of the stitcher meant that even the largest firms in 1870 with 50 sewing machines only needed three McKay stitchers.

Soon after developing his machine, Blake sold his patent and future patents to businessman Gordon McKay in 1859 for $70,000.[15] The machine and the corresponding shoes were soon named after McKay in the US.[16] Together, McKay and Blake worked to improve the McKay stitcher before selling it publicly. The Civil War provided high demand for shoes which prompted many improvements in the machine. McKay and Blake produced 150,000 pairs for the Northern army (Thomson, 1989).[17] Gannon (1912) documents: "Shoemakers at the front, who had deserted their benches before the McKay machine appeared, used to study the shoes, and wonder how in the world any sort of a machine could be made to sew shoes."

Soon, the McKay shoe was competitive in quality with hand sewn shoes and unmatched in terms of prices. Shoe and Leather Reporter (1871), a frequent industry publication stated:

> For some time it was doubted whether boots and shoes made upon this machine could compete, either in quality or price, with those made by hand. But the experience of the past year or two has forever set this question at rest, and goods made upon this machine are now regarded quite equal, if not superior, to any that can be made by hand.

This feat of technology was impressive to workers in the trade and prompted a rapid increase in sales and production.

[14] By 1880, it could produce 600 pairs a day, and in 1900 it could produce 1,260 pairs of shoes a day (Thomson, 1989).

[15] $8,000 was paid in cash, with the remainder paid from royalties from machine use.

[16] Shoemakers in the UK referred to this as the Blake machine after the inventor.

[17] Figure (A2) shows a later variation of the McKay stitcher in Museum L-A in Lewiston, Maine.

McKay retained control of the machine through a first-of-its-kind leasing system. After charging a modest $400 set up fee, he charged royalties per shoe produced: 3 cents for men's shoes, 2 cents for women's and boys' shoes, and 1 cent for slippers and girls' shoes.[18] He supplied supporting machinery (like bobbin winders and channelers) at cost with no additional royalties. As a result of this system, machines were first leased to Blake and McKay's personal contacts.[19] After raising over $100,000 in royalties in 1864, McKay expanded the leasing system and established branches for sales and servicing in Massachusetts, New York, and Philadelphia (Thomson, 1989). Almost half of the McKay machines used in the United States between 1867 and 1873 were in Massachusetts. In the 1870 manufacturing census, the vast majority of establishments using the McKay stitcher were in Massachusetts, New York, Pennsylvania, New Hampshire, New Jersey, and Maine.[20] In 1871, the McKay Machine Association received over $400,000 in royalties from leasing the McKay stitcher, corresponding to 32 million pairs of shoes, or 40% of American-made shoes.

To estimate the effect of the McKay stitcher throughout the US, I identify which counties were using the machine in 1870. The 1870 Census of Manufacturers reports what kinds of machines were used in production. Using these reports combined with the *Shoe and Leather Reporter* and biographical information, I identify 15 counties using the McKay stitcher in 1870 and approximately how many stitchers each county was using. Details on this process are discussed in appendix section AI.D.

In the counties identified, firms using the McKay stitcher were larger than most firms.

[18]The royalty was collected through sale of a stamp that was sewn into the shoes by the McKay stitcher. Scans of 1-cent and 2-cent stamps are pictured in appendix figure **??**.

[19]Various histories can help to identify a few of the early adopters. For instance, George W. Keene was claimed to be the first shoemaker to use Singer sewing machines to manufacturing uppers as well as the McKay Sole Sewing Machine in Lynn, Massachusetts (Shoe and Leather Reporter, 1893). Keene left his business to his sons in 1869.

[20]Thomson (1989) provides additional evidence confirming these states as places utilizing the McKay stitcher. There is a report of George Stribley acquiring a few McKay stitchers during the Civil War. Additionally, a shoemaking firm in Salt Lake City acquired one McKay stitcher around this time as well. It less likely that these few machines were leased for royalties. Estimates in the paper are not be sensitive to including or excluding these machines.

Of the 12 firms producing over $250,000 worth of shoes in Essex, MA, at least 9 were using the McKay stitcher (U.S. Census, 1870*b*).[21] Table A2 reports summary statistics for establishments in Essex, MA from the Census of Manufacturers in 1870. It reports 55 establishments using the McKay machine, 22 firms using pegging machines, and 996 establishments that do not report using a machine for attaching the soles of shoes to the uppers. The median McKay shoe producer made $85,000 in revenue, while the median firm without machinery produced $500 in revenue.[22] Table A2 further shows that the median McKay shoe producer hired 51 workers, while non-machine firms had a median size of 1 worker. Firms using wood pegging machines were similar in size, but their products were both inferior and more expensive than the McKay stitcher. Sales of pegged shoes grew much more slowly during this period.

The production of shoes transformed to use less labor, produce lower cost products, and expand production quantities. Panel A of table 1.1 documents a 7% increase in revenue, while panel B shows an aggregate employment decline of 29%. In contrast, other manufacturing saw an 92% increase in employment with an 83% increase in revenue. Since there is limited data on national quantities produced, I use more detailed data from the state of Massachusetts only. Table A3 shows statewide revenue increased by 21%, employment declined by 25%, and the quantity of shoes rose by 93%. This corresponds to a 37% decrease in factory gate prices in Massachusetts.[23] With physical productivity skyrocketing, the need for shoemakers was dropping, and where it was dropping is important for understanding the full impact of the McKay stitcher.

[21] One of the remaining establishments used a shoe pegging machine, and the other two do not have sufficient machine use data to be certain about their production process.

[22] In 1870, census takers were instructed not to count establishments with less than $500 in yearly revenue (U.S. Census, 1870*a*). Many firms are reported at this lower bound.

[23] Shoe and Leather Reporter (1893) claimed that the McKay stitcher "placed sewed shoes within the means of all, which was not true of hand-made shoes." Thus, along with price decreases, the quality of shoes increased.

Table 1.1: Aggregate Industry Values by Decade (Nominal Values)

	(1)	(2)	(3)	(4)
	Boots & Shoes		Other Manufacturing	
	Value	% Change	Value	% Change
Panel A. Revenue (millions)				
1860	92		3,418	
1870	98	6.8%	6,261	83.2%
1880	165	68.0%	10,832	73.0%
Panel B. Employment (thousands)				
1860	123		2,226	
1870	87	-29.1%	4,269	91.7%
1880	115	32.8%	5,865	37.4%
Panel C. Wagebill (millions)				
1860	31		629	
1870	27	-13.2%	1,156	83.8%
1880	42	55.3%	1,883	62.9%
Panel D. Wagebill / Employment				
1860	251		283	
1870	308	22.3%	271	-4.1%
1880	360	17.0%	321	18.5%

Notes: Aggregate values for revenue (Panel A), employment (Panel B), and the wagebill (Panel C) are summed across county-industry totals. Panel D is the entries from panel C divided by panel D.

Percents reported in columns 2 and 4 are 1 year changes. For example, the percent change in revenue in 1870 is equal to revenue in 1870 minus revenue in 1860 divided by revenue in 1860.

Figure 1.1: Counties using the McKay Stitcher in 1870

Notes: The boundaries represented are 1890 county boundaries matching the transportation network. The 15 counties in dark gray report using the McKay stitcher in 1870.

I.C The Spatial Distribution of Shoemaking

As productivity skyrocketed in select counties, the geographic distribution of shoemaking activity shifted and provides the variation I leverage to estimate the impact on shoemakers. The branches McKay established in Massachusetts, New York, and Philadelphia were important for the adoption of the McKay stitcher and were the locations where the majority of McKay stitchers were in use in 1870.[24] Figure 1.1 shows the 15 counties using the McKay stitcher in 1870, with over half of the machines leased in Massachusetts. These 15 counties represent only 0.7% of the 2,194 counties reporting manufacturing activity in 1870.

Figure 1.2 shows that employment in boots and shoes manufacturing concentrated ge-

[24]The name of this company was the "McKay Sewing Machine Association." Though often the machine was referred to as the McKay stitcher, it was indeed a variation on a sewing machine. It is this naming convention that limits the number of observable McKay stitchers in the Census of Manufacturers. Many of those machines are reported alongside other kinds of sewing machines despite their different capabilities.

ographically through 1860 and 1870.[25] The most obvious trend in the figure is the exit of counties from the manufacture of shoes. From 1860 to 1870, 71.9% of shoe manufacturing counties exited the shoemaking industry. From 1870 to 1880, another 16.9% of the original 1860 counties stopped manufacturing shoes, leaving only 11.2% of counties remaining. As discussed earlier, however, this dramatic concentration was associated with larger quantities of production and expanding revenue at the national level.

In observing the transforming distribution of shoe production, it's important to recognize that there are still individuals in the shoemaking profession, but their shops either earn less than $500, or they primarily repair shoes rather than make new ones.

Atack, Margo and Rhode (2019) and Vipond (2023) document that the mechanization of the shoemaking industry was associated with a proliferation and separation of many tasks in the shoemaking process. In a study of the labor market consequences in 19th century Britain, Vipond (2023) finds the titles and tasks of workers within the industry changed rapidly. This division of labor masks great variation in shoemaking employment during this period, as I also demonstrate in the US.

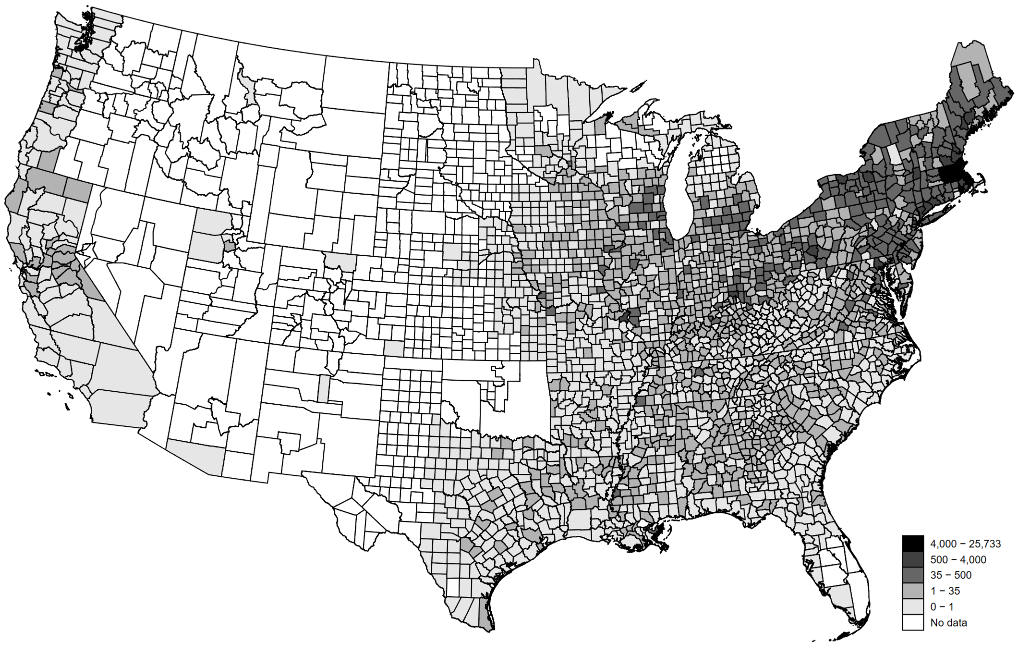
II Data Description

In this section, I describe the collection of biographies, periodicals, and federal reports used to characterize the shoemaking industry, the transportation and manufacturing data from Hornbeck and Rotemberg (2024), and the longitudinally linked sample of individuals across the complete count decennial census from 1860 to 1900. In the final subsection, I present the merging of multiple data sources to create improved estimates of wages for the late 19th century.

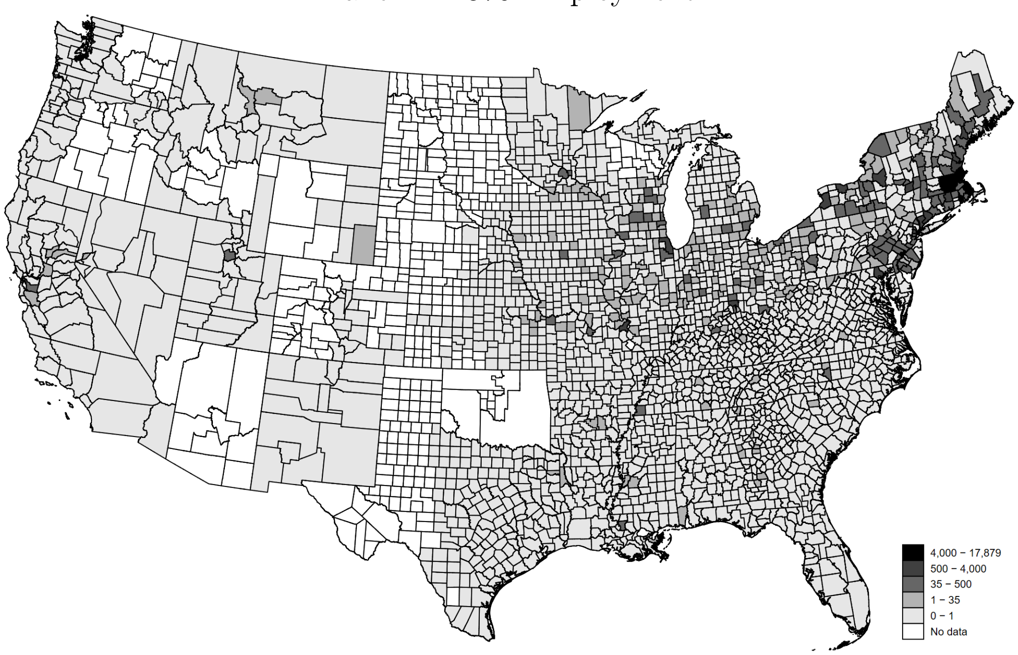
[25] Appendix figure A3 shows shoe industry employment in 1880.

Figure 1.2: Spatial Distribution of Shoe Manufacturing Employment

Panel A. 1860 Employment



Panel B. 1870 Employment



Notes: Shoe manufacturing employment is tabulated at the county level for each decade and then reapportioned in 1890 county borders as shown above. Panel A and B report quantities for 1860 and 1870, respectively. Bins are divided at time consistent cutoff values forming 5 groups. Darker shades reflect higher employment levels.

II.A Data on Shoemaking Production

The McKay stitcher was a dramatic improvement in productivity that enabled export of shoes throughout the country. Though the McKay stitcher only replaced one step in production, it saved anywhere from 25% to 50% of shoemaker time. From county-by-industry data digitized by Hornbeck and Rotemberg (2024), the shoemaking industry reported a doubling in revenue per worker from 1860 to 1880. Using data I digitized from annual reports on shoemaking in this period in Massachusetts, I document that industry employment declined by 25% between 1860 and 1870 and the quantity of shoes produced skyrocketed 93% (Shoe and Leather Reporter, 1871, 1876). The expansion of production was not for local sale–Massachusetts shoemakers were producing shoes for sale in the entire US.[26] By 1875, Massachusetts shipped more shoes outside of New England than the state's total production in 1870. I provide further details in appendix section AI.A.

To estimate the level of competition faced in each county, my analysis benefits from data on transportation costs and machine use during this period. The railroad network played a major role in connecting markets throughout the US and made shipping to regional markets more cost effective (Donaldson and Hornbeck, 2016; Hornbeck and Rotemberg, 2024). Using estimates of railroad costs in Fogel (1964), Hornbeck and Rotemberg (2024) construct a matrix of transportation costs during this period, including 1860. These transportation costs serve to limit the level of competition from the McKay stitcher in places that have high shipping costs.

Not every county with a McKay stitcher has equal access to the McKay stitcher, and this variation is part of determining the level of exposure shoemakers faced. In the first decade, over half of McKay stitchers were in Massachusetts. This concentration of use further enhances the importance of the spatial distribution of these machines. Combining

[26]International exports were a very small portion of production. In 1875, New York reports shipping only 2,647 cases internationally compared with hundreds of thousands shipped domestically (Shoe and Leather Reporter, 1876).

establishment level reports from the Census of Manufacturers in 1870 and various issues of the *Shoe and Leather Reporter*, I infer the approximate number of machines by county (Hornbeck et al., 2024; Shoe and Leather Reporter, 1867, 1871). Further details are discussed in appendix section AI.D.

II.B Linking Across Census Waves

Shoemakers in 1860 were the incumbent workers exposed to the McKay stitcher. Linking these individuals across censuses is a difficult task. The main estimates reported in this paper use links from Helgertz et al. (2023), which are produced with a probabilistic model relying on names and ages as well as household characteristics. Linking individuals from 1860 to 1870 and 1880 produces a sample of 30,126 shoemakers representing 23% of shoemakers in 1860. A separate sample linked from 1850 to 1860 is used to evaluate shoemakers prior to the McKay stitcher.

Linking across census waves is subject to non-classical measurement error that could also be correlated with the outcomes of interest. I consider two other sets of links that vary in the information used in the linking process. Abramitzky et al. (2022) restricts the set of information to first names, last names, places of birth, and ages. They identify unique matches only and discard other potential links. Though this produces a smaller set of links, excluding family information can decrease the potential for some kinds of measurement error.

Alternatively, the Census Tree Project constructs links across census waves combining family history methods with machine learning techniques (Price et al., 2021; Buckles et al., 2023; Price et al., 2023*a*,*b*,*c*,*d*). The family history data comes from FamilySearch, a wiki style family tree. Rather than limit the information used in linking, these links combine any information available about the individual, including other documents that can corroborate matches. This linking procedure could be biased in favor of individuals that married, had children, and potentially have surviving descendants. Such individuals have more records created about them and therefore are more likely to be matched by genealogists. Combining these methods with machine learning can produce a large set of high quality links.

Each set of links provides distinct samples with different potential biases. I discuss these samples further in appendix section AI.C. The main estimates are robust to using any of these samples, and results are discussed in section IV.

To document the effects of the McKay stitcher on the children of shoemakers, I create two samples of children: those living in the home of a shoemaker in 1860 and those born after 1860 and living in the home in 1870. Limiting my focus to the children of craftsmen in my sample of incumbents, I link 52,136 children from the 1860 households, 46,505 children from the 1870 households, and 27,614 children from the 1880 households. Of the children at home in 1860, 37% have occupations in 1870 and 93% have occupations in 1880. By 1900, 88% of the 1860 sample and 89% of the 1870 sample have occupations.

II.C Outcomes for Incumbent Shoemakers

My main outcomes will be indicators of job switching, indicators for migration, 1870 property values, occupation codes, and estimated wages for occupations. Each of these are included in the complete-count decennial census data provided by Ruggles et al. (2021).

Census takers recorded written occupations as reported by the individuals that were later sorted into occupation codes and industry codes. Combining occupations with industries provides insight into the actual work completed by individuals. "Shoemakers and repairers, excluding factory work" is one of 253 coded occupations. The shoemaking industry is one of 150 coded industries. In 1860, 90% of individuals in the shoemaking industry report being shoemakers and repairers, while the majority of the other 10% were shoe factory workers and were subsequently coded as operatives in the shoemaking industry. I utilize this distinction to examine individuals that move into shoe factory occupations as factories replace the shoemaker shops. It is important to note that individuals may remain shoemakers even when they are cobblers, only repairing shoes.

Job switching and migration are treated as binary indicators of changes between any two decades. Job switching is defined as when the self reported occupation in one decade differs from the previous decade.[27] Migration is defined as when the county of residence in one decade differs from the previous. Berkes, Karger and Nencka (2023), referred to as the Census Place Project, addresses the issue of inconsistent boundaries etc. over time. They generate consistent latitude and longitude coordinates for places reported in the historical US censuses. My default specifications consider movements of over 100 miles to be candidates for migration, though the results are robust to shorter and longer distance cutoffs.

Individual wealth is a novel outcome to consider in the context of technological displacement. It is self reported in 1860 and 1870 in two parts: personal property values and real estate values. Census takers only recorded these values when they were greater than $100, or four months of shoemaker annual wages in 1860. This data on wealth is helpful both as a control and as an outcome. Baseline wealth is correlated with the outcomes of interest and controlling for it produces more accurate estimates for the effect of the McKay stitcher. Examining the effect of the McKay stitcher on wealth provides new insights about the effects on incumbent workers.

Ruggles et al. (2021) includes an occupational wage score for each occupation in the census. These values are generated based on the occupation status in 1950 and do not vary by location. Given the very large discrepancy in years from my data to the classification of relative wages, this measure is not ideal. Saavedra and Twinam (2020) use a machine learning method to estimate occupation scores that vary by age, sex, race, and location. Estimates using these scores are quite similar, however.

[27] Details on potential measurement error are provided in appendix section AI.B.

II.D Outcomes for the Children of Shoemakers

The children of shoemakers report geographic locations and occupations in 1880 and 1900. Similar to their parents, I define migration from their childhood locations and characterize the kinds of occupations they selected. I define occupation continuance to be an indicator of whether a son's reported occupation is the same as their father's. I define industry continuance to be an indicator of whether a son's reported industry is the same as their father's.

In 1900, the census also reports whether individuals owned a home and whether or not the mortgage had been paid off. The definition of home was quite broad, per the census instructions. Having an unpaid mortgage did not depend on the size of the loan or lien. Though this provides no indication into the value of the home, I assume that owning a home and having paid off a mortgage are both indicators of greater wealth.

II.E Wages in the 19th Century

Wages by occupation are of first order interest in discussing the economic consequences of individuals switching jobs or migrating to new opportunities. Comprehensive wage data are difficult to come by in the 19th century, and many studies use occupation scores based on median incomes in 1940 or 1950. Though these estimates are between 60 to 90 years after the period of interest, they are frequently the primary options available.

A notable exception to the limited data is in the manufacturing industries, which are of particular interest in this project. I use two sources of wage data to improve wages for the manufacturing sector, and I defer to typical wage scores otherwise.

The first set of wages are derived from a report in 1886 by Joseph D. Weeks (Weeks, 1886). Weeks collected wage information from "typical establishments" in 53 of the most prominent manufacturing, mechanical, and mining industries across various regions of the US. These establishment specific wage tables were cleaned and are now maintained by Meyer

(2004). This data features specific occupations within each of these industries for a variety of cities over the years 1850 to 1880 (with a few hundred additional observations outside of these years).

I use a hand generated crosswalk to connect occupations, industries, and cities in the Weeks Report to occupation codes, industry codes, and counties in the IPUMS dataset. The vast majority of wages in this report are for operatives and laborers in a variety of industries. These were very common codes used for occupations in this time. The report does not include a large portion of individual craftsmen and unfortunately does not include traditional shoemakers.

I next use industry average wages from the Census of Manufacturers (Hornbeck and Rotemberg, 2024). I match manufacturing industries in the Census of Manufacturers with the industry codes in the IPUMS census data and use the average wage for all occupations within an industry when the Weeks Report does not provide occupation specific wages. Together, these provide 75% coverage of craftsmen occupations but only 28% of individuals generally. These data imply the average salary of shoemakers in 1860 was $304.

For the remaining occupations, I merge manufacturing wages with the LIDO scores estimated in Saavedra and Twinam (2020). Details on the process of generating the crosswalks, scaling each source of wages for comparability, and the coverage of occupations by state are discussed in appendix section AI.E.

These new and updated wage score data provide an improved measure of occupation quality for shoemakers that is beneficial in estimating the model of occupation choice in section VI.

III Estimation Framework

In this section, I introduce a definition of exposure to the McKay stitcher and discuss the identification assumptions required to establish a causal relationship between exposure to the McKay stitcher and the observable outcomes for incumbent shoemakers. I compare shoemakers who were more or less exposed to the technology and introduce an estimating equation designed to capture this comparison.

III.A Defining Exposure to the McKay Stitcher

Since the McKay stitcher was used in only 15 counties in 1870, the effect of the McKay stitcher is unequal across the US. Traditional shoemakers faced increased competition in the product market by shoe factory producers. In this way, transportation costs served to insulate traditional shoemakers from McKay factories purely by increasing the price at which McKay factories can sell shoes in the same markets. As the majority of shoemakers produced custom shoes locally, traditional shoemakers face competition to the extent that their consumers have access to McKay shoes. Following the literature on market access style measures, I define exposure to be a county's market access to McKay stitchers (Redding and Venables, 2004; Donaldson and Hornbeck, 2016; Adao, Arkolakis and Esposito, 2019). Using iceberg transportation costs for shipping goods from county c to county d (τ_{cd}), the trade elasticity (θ), and the number of McKay stitchers in county d (M_d), I define exposure as follows:

$$\text{Exposure}_c \equiv \sum_{d \in \mathcal{C}/\{c\}} \tau_{dc}^{-\theta} M_d. \tag{1.1}$$

This mirrors the reduced form definition of market access in Donaldson and Hornbeck (2016), but replaces access to populations with access to machines. It is increasing in the number of machines and decreasing in the transportation cost to those machines. It excludes the number of machines within the county, as the number of available machines in the county may be endogenous to some shoemaker decisions within the county.[28]

[28]Estimates are robust to including own county access.

In a general equilibrium model, this expression arises if all traditional shoemakers only sold shoes locally. Selling only locally is equivalent to an infinite trade elasticity for shoes produced by traditional shoemakers. If I assume traditional shoemakers ship to various locations, exposure would instead be a summation of equation (1.1) across all target markets and weighted by the size of those markets. These measures are typically highly correlated, and since only a small portion of shoemakers shipped shoes prior to the McKay stitcher, my baseline definition includes only local competition. Further discussion on this topic is included in appendix section AII.A.

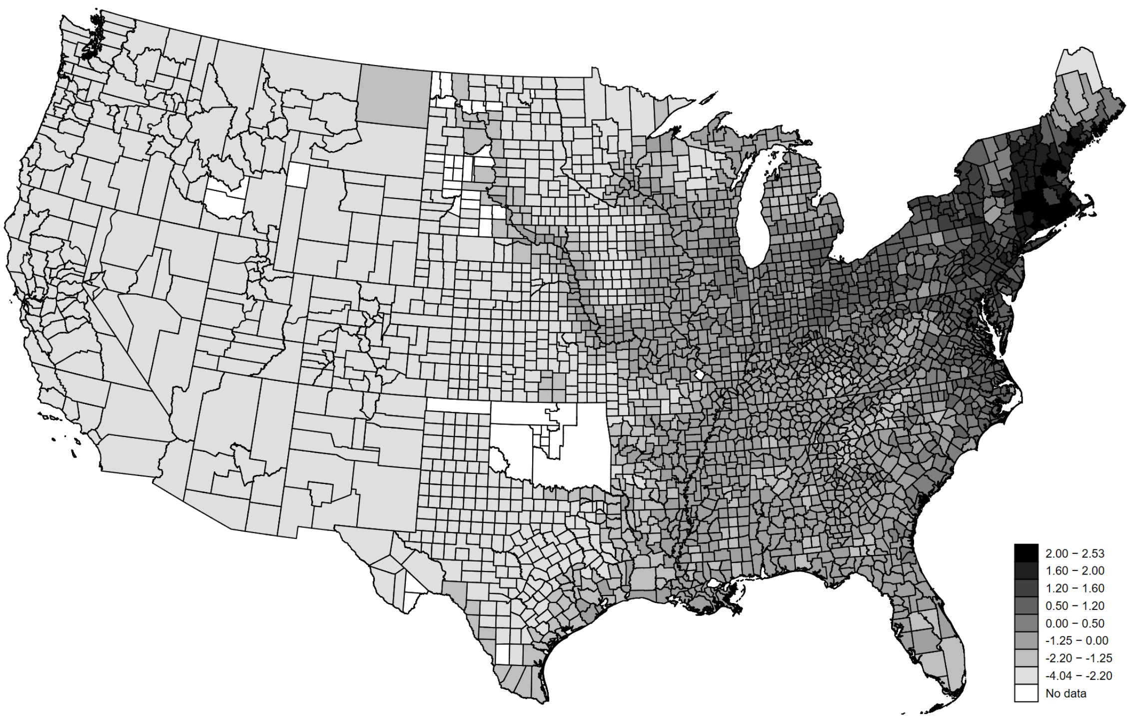
Transportation costs and the trade elasticity are directly from Hornbeck and Rotemberg (2024), though I consider robustness to other elasticities and assumptions on transportation costs. Hornbeck and Rotemberg (2024) estimate the trade elasticity using data on all shipments. The trade elasticity θ governs the relationship between absolute advantage and comparative advantage–a relationship which, for my purposes, may vary between shoes and other products. I assume the trade elasticity for factory produced shoes is the same as other transported products. To emphasize that shoes became a widely traded commodity, appendix table A4 shows the number of cases shipped to various counties throughout the US from Boston in 1875. Very large quantities of shoes were sent as far inland as St. Louis, MO and even across the continent to San Francisco, CA.[29] Massachusetts shoe manufacturers were selling shoes almost everywhere in the US.

Figure 1.3 maps the distribution of exposure. Exposure is highest in New England relative to the rest of the US. Though a few McKay stitchers were used in both Salt Lake and Cincinnati, the small number of machines means traditional shoemakers faced a far smaller change in competition relative to producers in New England.

Exposure to the McKay stitchers is not random. The New England area was growing as

[29]Shoes sent to San Francisco were likely sent via boat, although the transcontinental railroad was completed in 1869.

Figure 1.3: Map of Exposure



Notes: This map depicts 8 bins of exposure, where exposure is defined in equation 1.1 as the consumer market access to McKay stitchers. Darker shades are higher exposure with lighter shades reflecting less exposure. The measure is scaled such that a unit increase in exposure is a standard deviation and the 10th percentile of shoemakers have exposure equal to 0.

a manufacturing center more generally, and the Civil War caused many changes in the labor market that are unrelated to the McKay stitcher but were highly correlated with exposure. Additionally, the expanding network of railroads was shifting economic activity throughout the US (Donaldson and Hornbeck, 2016; Hornbeck and Rotemberg, 2024). These and other spatially important reasons mean that the trends of shoemakers would not be orthogonal to exposure in the absence of the McKay stitcher.[30] A standard difference-in-differences approach would be biased. To address this bias, I compare shoemakers across levels of exposure with comparable occupations in the same counties that were similarly affected by these other factors, but not by the McKay stitcher.

I use a triple difference specification comparing shoemakers (1) pre- and post-technology, (2) with comparable occupations K, and (3) across varying levels of exposure. The following estimating equation relates changes in outcome $Y_{c,i}^{j}$ for individuals i in location-occupation c, j with location fixed effects α_c, occupation fixed effects α^j, individual observables X_i (quadratic of age, indicator of literacy, and property values), exposure interacted with an indicator for shoemakers, and an error term $\epsilon_{c,i}^{j}$:[31]

$$\Delta Y_{c,i}^{j} = \alpha_c + \alpha^j + \beta_X X_i + \beta \text{Exposure}_c \mathbb{1}\{j = S\} + \epsilon_{c,i}^{j}. \tag{1.2}$$

Unbiased estimation of β requires that any location-shoemaker specific effects are orthogonal to exposure. This is certainly violated for some choices of the comparison group K. For instance, the increased urbanization of the New England area likely affected shoemakers differently than farmers. I discuss the appropriate choice of K in the next section.

[30] This is a violation of the parallel trends assumption (Angrist and Pischke, 2009).

[31] The individual characteristics: an indicator of literacy, quadratic of age, baseline inverse hyperbolic sine (IHS) of personal property value, and baseline IHS real estate value.

III.B Comparable Occupations

I propose all other craftsmen as my baseline comparison group. All craftsmen is a category containing 54 distinct occupations generally in the construction or manufacturing sector.[32] Craftsmen, including shoemakers, accounted for 15% of the labor force in 1860. Using 1860 reported occupations, summary statistics for shoemakers and other craftsmen are given in appendix table A5. On average, shoemakers were more exposed to the McKay stitcher, had less wealth, had similar dispersion in wealth, and were the same age as other craftsmen. These characteristics are informative about the sample, but they do not ensure the necessary assumptions for identification are satisfied.

The triple difference specification requires parallel trends in the absence of the McKay stitcher in order to get unbiased estimates. That is, differences in outcomes between craftsmen and shoemakers must be orthogonal to exposure. I evaluate several important considerations before assuming parallel trends in this context.

A common method to evaluate this assumption is to show parallel pre-trends which could imply parallel trends in the absence of the McKay stitcher. As discussed in section I, places in New England began producing shoes with a division of labor and sewing machines, but key shoemaking tasks were still a bottleneck in production. The increased productivity for some firms caused shoemakers in those areas to exit traditional shoemaking. There was no effect on migration or property values.

Whether elevated occupation exit in the pre-period biases the main estimates depends on whether those trends would have continued in the ensuing decade. I consider two potential solutions to this issue. First, the trend in occupation exit is driven by Massachusetts. Excluding Massachusetts from the estimation removes the pre-trends entirely, as reported in table A6 panel B. To accommodate concerns that the pre-period division of labor biases

[32]Craftsmen are defined as individuals with 1950 occupation code between 500 and 600. Including shoemakers makes 55 distinct occupations.

the estimates of the impact of the McKay stitcher, specifications dropping Massachusetts counties are discussed in section IV.

Second, the expansion of shoe production from the division of labor was constrained without further innovation. Therefore, the effect of the division of labor was limited by the available technology (e.g. without the McKay stitcher) and by the ability of these firms to compete outside of Massachusetts. As the railroad network expanded, these more productive firms could have exported shoes more readily and the main estimates would overstate the effect of the McKay stitcher. To address this potential confounder, I control for the change in transportation costs from Boston, the shoemaking center of Massachusetts. The baseline estimates are robust to this control, suggesting that exposure to the McKay stitcher is driving effects in the next decade rather than the expanding railroad network. This is consistent with the historical record. The productivity gains from the division of labor without the McKay stitcher are much smaller than the sixty fold increase from the McKay stitcher.

An alternative evaluation of the parallel trends assumption is to consider indicators of socioeconomic status of each group at the time. Prior to the McKay stitcher, craftsmen lived in the same places as shoemakers. The 1850 census data records include the page of the census manuscripts where individuals were documented.[33] Following Feigenbaum and Gross (2023), I use these pages as indicators of which occupations clump together in "neighborhoods" as defined by the same census page. Though craftsmen represent 16% of the population in 1850, 35% of people on pages with shoemakers are craftsmen. Thus, craftsmen are represented over twice as often in places where shoemakers live. Locations of homes are moderately indicative of similar wealth and income as well as the potential outside options of both groups.

If the other craftsmen experienced technology advances themselves, the estimates would capture differences between the McKay stitcher and the effects of other technologies. In

[33] Page numbers are missing from the available census data for 1860.

section IV, I compare shoemakers with carpenters, which are known to have had limited technological improvements, and find robust results.

Shoes are very tradeable goods and experienced increased demand during the Civil War. In section IV, I discuss comparisons with tailors, who faced similar increases in demand and produce similarly tradeable goods.

There are other potential concerns that are quantitatively less significant. As shoes became cheaper, consumers could spend more on other products. This could potentially affect the occupation and migration decisions of other workers, though I suggest that these effects are quantitatively small. As shoe production increased, demand for shoe inputs would have increased. Leather was the largest share of input expenditure, and leather workers are not included in the set of craftsmen.[34] Displaced shoemakers may have indirect labor market effects on their target occupations, which would bias the estimates down. However, only 4% of shoemakers in 1860 became craftsmen in 1870 compared with the random uniform allocation of 15%. This suggests that shoemakers were a small source of new craftsmen during this period.

The Civil War is a large confounder in terms of the loss of human life and the general destruction of property. There is little reason to suspect the loss of life and destruction of property affected shoemakers differently than other craftsmen. However, the consequences of the Civil War were quite different across the North and South, suggesting that the southern states may not provide an appropriate counterfactual more generally. The results are robust to excluding states in the South from the estimation.[35]

In summary, craftsmen provide a robust comparison group for traditional shoemakers

[34]Leather tanners or curriers would certainly be impacted as an upstream industry, but are generally not included in the sample. Due to the occupation code structure used by IPUMS, workers in the leather industry account for less than 0.1% of craftsmen in the 1860 census. The majority belong to other occupation categories.

[35]Additionally, Hacker (2013) notes significant under-counting in the South in the 1870 US population census. Robustness to excluding the South similarly suggests this under-counting does not bias the results substantively.

during this time period.

IV The Effect of the McKay Stitcher on Incumbent Shoemakers

Using equation 1.2, I estimate the effect of the McKay stitcher on occupation exit, migration, personal property values, and the occupation choices of incumbent shoemakers. Exposure is scaled to have a unit standard deviation across shoemakers. Exposure equal to zero corresponds to the 10th percentile of shoemakers by exposure.[36] Estimates for β imply that the difference in the specified outcomes between shoemakers and craftsmen increase by β for each standard deviation increase in exposure.

Shoemakers in high-exposure counties were more likely to leave shoemaking. Table 1.2 panel A column 2 reports that shoemakers with one standard deviation greater exposure changed occupations 7.6 percentage points more in the first decade after the McKay stitcher. While about 54% of shoemakers in low-exposure counties exited traditional shoemaking during this decade, almost 70% of shoemakers in the highest exposure counties switched occupations. Looking at switching in the longer run from 1860 to 1880, the trends in exposure remain relatively similar, but with moderately higher rates of switching nationally reported in column 2. Column 3 reports that more-exposed shoemakers were more likely to continue switching in the next decade, with increased switching of 2.3 percentage points per standard deviation of exposure. Occupations in 1870 were more temporary for shoemakers in high-exposure counties. Panel B of table 1.2 similarly reports elevated industry exit in high-exposure counties.

The McKay stitcher pushed shoemakers to adapt close to home. Panel C documents that shoemakers did not migrate in response to the McKay stitcher. There are no significant trends by exposure between any two decades for incumbent shoemakers. Appendix table A7

[36]For geographic context, the majority of the state of Iowa has exposure approximately equal to zero. The 90th percentile of exposure is approximately equal to 2. The highest exposure county is Suffolk County, Massachusetts with exposure equal to 2.5.

Table 1.2: Incumbent Shoemakers: Occupation Exit, Industry Exit, and Migration

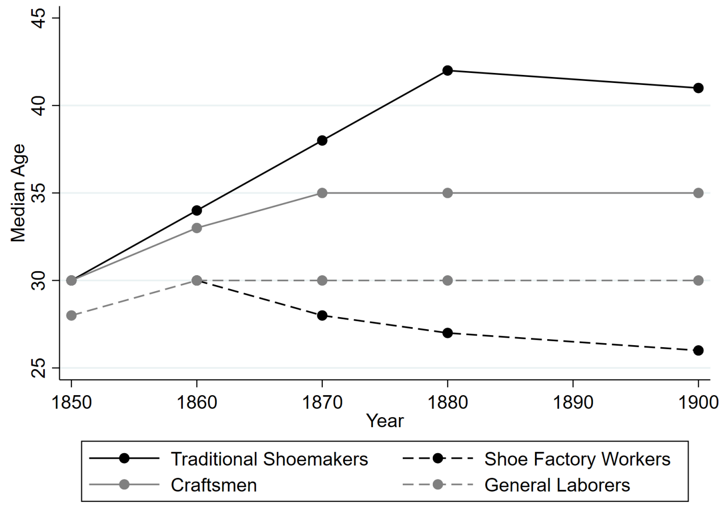
	Pretrend 1850-1860 (1)	Short Run 1860-1870 (2)	Long Run 1860-1880 (3)	Continuing Effects 1870-1880 (4)
Panel A. Occupation Exit				
Exposure × Shoemaker	0.022	0.076	0.068	0.023
	(0.007)	(0.011)	(0.010)	(0.006)
Shoemaker	-0.084	-0.035	-0.014	0.001
	(0.010)	(0.010)	(0.012)	(0.008)
Control Mean	.55	.51	.560	.45
R-squared	0.096	0.107	0.098	0.073
Observations	215,404	200,330	200,330	200,330
Number of FE Groups	7,453	9,831	9,831	9,831
Panel B. Industry Exit				
Exposure × Shoemaker	0.012	0.025	0.025	0.016
	(0.006)	(0.006)	(0.006)	(0.005)
Shoemaker	-0.059	-0.038	-0.004	-0.009
	(0.008)	(0.006)	(0.007)	(0.006)
Control Mean	.53	.5	.54	.44
R-squared	0.086	0.096	0.088	0.069
Observations	215,404	200,330	200,330	200,330
Number of FE Groups	7,453	9,831	9,831	9,831
Panel C. Migration (>100 miles)				
Exposure × Shoemaker	-0.002	0.003	0.004	0.003
	(0.002)	(0.002)	(0.003)	(0.002)
Shoemaker	-0.002	-0.008	-0.012	-0.009
	(0.004)	(0.003)	(0.004)	(0.003)
Control Mean	.16	.09	.13	.07
R-squared	0.119	0.145	0.184	0.222
Observations	215,404	200,330	200,330	200,330
Number of FE Groups	7,453	9,831	9,831	9,831

Notes: All columns are regressions on the exposure measure, an indicator for McKay counties interacted with being a shoemaker, shoemaker fixed effects, and county-town fixed effects. Column 1 additionally includes an indicator of literacy and a quadratic of age in 1850. Columns 2, 3, and 4 additionally include individual observables in 1860: indicator of literacy, quadratic of age, inverse hyperbolic sine (IHS) of log personal property, and IHS of real estate property. All panels report comparisons between shoemakers and all other craftsmen.

The outcome variables are: indicators of whether reported occupation in the later year is different than the reported occupation in the earlier year (Panel A), whether industry in the later year is different than earlier year industry, and whether the later year county is over 100 miles away from the individual's earlier year county (Panel C). Column 1 compares outcomes prior to the McKay stitcher from 1850 to 1860. Column 2 looks at incumbent worker outcomes by 1870. Column 3 looks at 1880, and Column 4 looks at continuing adjustments between 1870 and 1880.

Robust standard errors clustered by county-occupation are reported in parentheses.

Figure 1.4: Median Ages by Occupation



Notes: For each census, the median age is reported across all individuals reporting each occupation. Shoe factory workers are shown beginning in 1860.

reports robust results when considering migration of over 50 miles or migration of over 200 miles.

The primary occupations for shoemakers after displacement were the newly formed shoe factory occupations. Table A8 panel A column 1 reports that only 0.2% of other craftsmen entered shoe factory work and 5% of shoemakers in non-McKay counties entered shoe factory work in 1870. Shoemakers in McKay counties were an additional 13.8 percentage points more likely to enter shoe factory work, equating to 19% of incumbent shoemakers in McKay counties. These occupations were lower paying than traditional shoemaking. Panel B reports that by 1880, the rates diminish, but remain elevated with about 15% of incumbent shoemakers in McKay counties working in shoe factories.

Exit from shoe factory work aligns with a shift towards younger workers in the shoe factory. Figure 1.4 shows that shoe factory workers were, on average, much younger than other craftsmen, shoemakers, and even general laborers. The age gap increased through the decades, solidifying shoe factory work as an occupation of opportunity for the young.

Table 1.3: Incumbent Shoemakers: Target Occupations

	Shoe Factory Worker (1)	Factory Worker (2)	Craftsmen (3)	Laborer (4)	Manager (5)	Farmer (6)	Other Occupation (7)	Non-Occupation (8)
Panel A. Target Occupations in 1870								
Exposure × Shoemaker		0.001	-0.030	0.011	-0.003	0.011	0.004	0.001
		(0.002)	(0.005)	(0.002)	(0.003)	(0.003)	(0.002)	(0.001)
McKay County × Shoemaker	0.138							
	(0.030)							
Shoemaker	0.047	-0.024	-0.509	0.001	0.024	-0.007	-0.011	-0.002
	(0.005)	(0.002)	(0.007)	(0.002)	(0.003)	(0.004)	(0.002)	(0.002)
Control Mean	.002	.06	.57	.04	.06	.15	.07	.04
R-squared	0.309	0.074	0.226	0.077	0.054	0.208	0.050	0.277
Observations	202,327	200,330	200,330	200,330	200,330	200,330	200,330	200,330
Number of FE Groups	9,851	9,831	9,831	9,831	9,831	9,831	9,831	9,831
Panel B. Target Occupations in 1880								
Exposure × Shoemaker		-0.002	-0.025	0.008	-0.005	0.018	0.005	-0.002
		(0.002)	(0.005)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)
McKay County × Shoemaker	0.117							
	(0.023)							
Shoemaker	0.039	-0.016	-0.469	0.009	0.027	-0.008	-0.007	-0.001
	(0.004)	(0.002)	(0.006)	(0.002)	(0.003)	(0.005)	(0.003)	(0.002)
Control Mean	.001	.05	.52	.04	.07	.19	.07	.05
R-squared	0.256	0.061	0.196	0.068	0.057	0.207	0.052	0.139
Observations	202,327	200,330	200,330	200,330	200,330	200,330	200,330	200,330
Number of FE Groups	9,851	9,831	9,831	9,831	9,831	9,831	9,831	9,831

Notes: All columns are regressions on shoemaker fixed effects, county-town fixed effects, and individual observables in 1860: indicator of literacy, quadratic of age, IHS personal property, and IHS real estate property. Column 1 additionally includes an indicator for 1860 shoemakers in McKay counties. Columns 2 through 8 include exposure. All columns are comparing shoemakers with other craftsmen. Panels A and B report estimates for 1870 and 1880, respectively.

The outcome variables are: indicators for whether an individual reports being a shoe factory worker (column 1), a general factory worker (column 2), a craftsman (column 3), a laborer (column 4), a manager (column 5), a farmer (column 6), any other occupation (column 7), or a non-occupation response (column 8).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Table 1.3 columns 2 through 8 show that more exposed shoemakers were less likely to become craftsmen, more likely to become laborers, and more likely to become farmers. Laborers were one of the lowest paid occupations in this period, defined as any kind of manufacturing or farming labor. In 1870, a standard deviation greater exposure equated to a 1.1 percentage point increase in the probability of becoming a laborer. This effect increases to 2.5 percentage points in 1880. This implies that the most exposed shoemakers, with 2.5 standard deviations greater exposure, were 6.25 percentage points more likely to be laborers in 1880 than those with zero exposure. Estimating the value of becoming a farmer is much more difficult to quantify, as farming could be lucrative for individuals with a lot of land. Given the modest property values in 1860, however, it seems unlikely that many shoemakers became wealthy farmers as opposed to poorer farmers. Appendix table A8 lists the other main target occupations for shoemakers in both 1870 (panel A) and 1880 (panel B).

Occupation level wages confirm that shoemakers in high-exposure counties were more likely to have lower wage occupations in each decade. Appendix table A9 reports estimates on occupation wage scores from IPUMS and LIDO scores. Columns 1 and 2 show a small but statistically significant decline in wages relative to low-exposure counties in 1870. By 1880, the trends are somewhat stronger. These estimates suggest that shoemakers in the highest exposure counties worked in occupations with between 2.5% and 4.5% lower wages than low-exposure shoemakers.

Further, more-exposed shoemakers lost wealth equal to 1.3 years of wages by 1870. For a standard deviation increase in exposure, table 1.4 column 1 reports that shoemakers were 1.3% less likely to report greater than $100 of property value in 1870. This suggests only 75% of shoemakers in high-exposure counties reported property values as opposed to 79% in zero exposure counties. Table 1.4 Panel A column 2 further reports that, conditional on reporting wealth, shoemakers had 5.8% lower property values per unit of exposure. This corresponds to the most exposed shoemakers reporting 15% lower property values in 1870.

Table 1.4: Incumbent Shoemakers: Property Values in 1870

	Has > $100 (1)	Log Total Property (2)	Log Personal Property (3)	Log Real Estate Property (4)
Exposure × Shoemaker	-0.013	-0.058	-0.078	-0.046
	(0.003)	(0.012)	(0.015)	(0.010)
Shoemaker	-0.019	-0.022	-0.009	-0.044
	(0.004)	(0.016)	(0.018)	(0.014)
Control Mean	.81	7.87	6.48	7.74
R-squared	0.145	0.426	0.372	0.501
Observations	200,330	77,467	71,019	69,788
Number of FE Groups	9,831	7,531	7,348	7,179

Notes: All columns are regressions on the exposure measure, shoemaker fixed effects, county-town fixed effects, and individual observables in 1860: indicator of literacy, quadratic of age. Column 1 includes an indicator for reporting greater than $100 of property in 1860. Columns 2, 3, and 4 include the log of personal property and the log of real estate property. All estimates compare shoemakers with all other craftsmen.

The outcome variables are: an indicator of reporting greater than $100 in 1870 (column 1), the log of the sum of personal property and real estate property (columns 2), the log of self-reported personal property values (column 3), and the log of self-reported real estate property value (column 4).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Using the average shoemaker wage in 1860 of $304, this 15% loss in property values equates to 1.3 years of wages during that ten year period.[37] Shoemakers lost substantial wealth in addition to the lower future earnings.

Appendix table A11 reports robustness to various definitions of exposure. Each of these specifications will have updated normalizations such that a unit increase is a standard deviation and zero exposure is the 10th percentile of shoemakers. The results are robust to including own-county machines in the calculation (row 2), using the 1870 railroad network (row 5), using only the distance to the closest McKay stitcher (row 7), and using a model motivated firm market access measure of exposure (row 8). The baseline estimates assume an average price per ton of goods transported to be 38.7, following Hornbeck and Rotemberg (2024). Row 4 supposes that the average price per ton of transported shoes is $100,

[37] Appendix table A10 reports estimates using the inverse hyperbolic sine of property values.

since shoes have a much higher price per ton.[38] This assumption makes the relative cost of shipping shoes very low, and thereby reduces the estimated effect by a third. This is unsurprising, as the identification strategy depends on unequal treatment across the United States. Row 5 assumes a trade elasticity of 8, the estimated θ from Donaldson and Hornbeck (2016). They estimate θ using data on land prices and the cost of transporting agricultural goods. This estimate is similar in magnitude to the baseline estimate.

Appendix table A12 documents robustness to altering the estimating equation (equation 1.2). The results are robust to controlling for the expanding railroad network (row 2), excluding individual controls (row 3), using county fixed effects rather than county-town fixed effects (row 4), excluding all county fixed effects (row 5), clustering standard errors by state-occupation (row 6), and clustering standard errors by county and by occupation separately (row 7).

Appendix table A13 examines the effect of changing the sample used in estimation. Panels B through C consider different comparison groups than all craftsmen. Panel B compares with carpenters, who did not face substantial changes from technology during this period. Panel C reports comparisons with tailors who faced similar changes in demand from the Union army. Additionally, clothing was similarly tradeable and therefore may have been impacted by the expanding network. The comparison is imperfect, however, as tailors also faced substantial technological competition during this period. It is likely for this reason that estimates on occupation exit are muted relative to the other comparisons. Both carpenters and tailors are included in the baseline estimates. Alternatively, laborers are generally lower skill workers across a variety of industries that are separate from the set of craftsmen. Panel D reports that the estimates are remarkably similar, but with smaller effects on property values.

Panels E, F, and G examine subsets of the baseline sample. Panel E drops McKay

[38]Shoes were generally shipped in cases ranging from 40 to 70 pairs of shoes. Though the exact weight of shoes is not known, the price per pound is much higher than the $0.02 per pound implied by assuming 38.7. There is limited historical evidence on how the transportation of shoes was priced.

counties and reports similar estimates. Panel F drops Massachusetts counties and the effect on occupation switching decreases to 5.0 percentage points. The effect on property values remains the same. This specification shows no pre-trends, as discussed in section III.B, and may be an encouraging comparison due to that. However, it also excludes the most affected individuals. Since the Civil War had heterogeneous consequences across the North and South, Panel G drops all counties in the southern region of the United States and reports estimates quite comparable to the baseline estimates.

Panels H and I of appendix table A13 document very similar effects when using two different linking methods, as discussed in section II.B and appendix section AI.C.

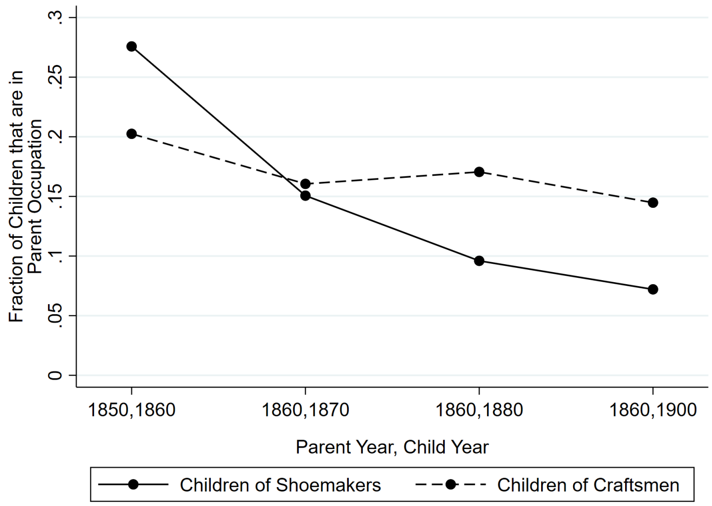
In summary, shoemakers in high-exposure counties left traditional shoemaking for lower paying occupations which resulted in wealth losses over the next decade. Shoemakers did not move to new opportunities. Shoemakers continued occupation switching into the next decade resulting in even lower wage occupations relative to less exposed shoemakers. Shoemakers in less exposed counties were generally poorer than other craftsmen, but ended up in similar wage occupations by 1880, in stark contrast with shoemakers in high-exposure counties. Even as the McKay stitcher created new opportunities for work, these benefits for traditional shoemakers were temporary and provided inferior income.

IV.A The Effect of the McKay Stitcher on the Children of Shoemakers

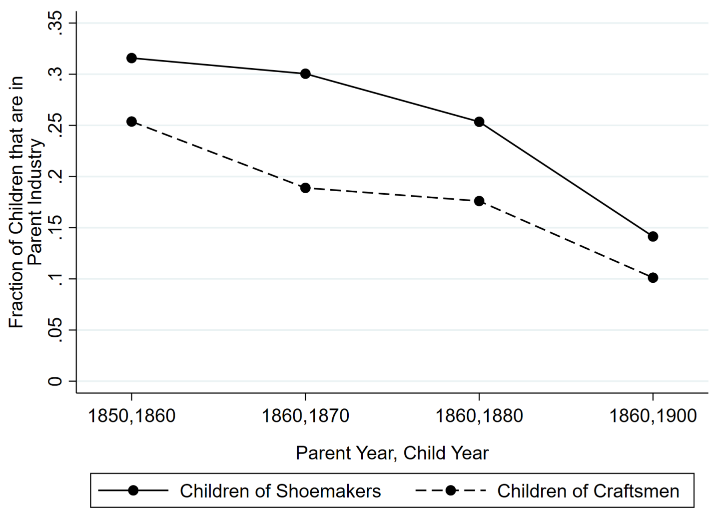
The children of craftsmen initially had high rates of occupation and industry continuance, but the McKay stitcher disrupted this transfer for shoemakers. Figure 1.5 panel A shows that 29% of the children of shoemakers in 1850 were shoemakers in 1860 compared with 21% of the children of other craftsmen. For shoemaker children in 1860, only 12% became shoemakers in 1870, compared with 17% for other craftsmen. The gap between the children of shoemakers and the children of craftsmen grows as the decades go on. These statistics are national trends.

Figure 1.5: Intergenerational Occupation and Industry Continuance

Panel A. Occupation Continuance



Panel B. Industry Continuance



Notes: Occupation (industry) continuance is defined as when a child's occupation matches a parent's occupation (industry). The x-axis is labelling first the parent year observance and then, after the comma, the year of the child's observation. Panel A reports occupation continuance, and panel B reports industry continuance. These plots only consider father to son continuance.

Table 1.5 documents the spatial distribution of these disruptive effects. Panel A column 1 shows that high-exposure places had lower rates of occupation continuance in 1880, driving only some of the decline in occupation continuance, though national rates also dropped precipitously. Column 2 reports that by 1900 the decline in occupation continuance was national with a slightly larger decrease in high-exposure counties.

Panel B reports the effect on industry continuance in McKay counties. Individuals that did not enter traditional shoemaking may have entered new shoe factory occupations. I limit the focus on McKay counties, because machine use in 1880 has not been well documented. Exposure is defined based on 1870 machine use, but afterwards use continued to expand geographically. However, even in 1880, McKay counties accounted for 62% of shoe production. Thus, these counties still constitute the majority of shoe production.

Though industry continuance was around 12% for shoemakers generally, industry continuance averaged 40% in McKay counties. Industry continuance in 1900 drops to 6% in non-McKay counties and 29% in McKay counties compared with a 16% rate for craftsmen.

Similar to their parents, the children of shoemakers did not migrate in response to the McKay stitcher. Table 1.5 panel C reports that the children of shoemakers did not have a significant migration response by 1880 or 1900.

Shoe factory occupations also became a major source of employment for the children of shoemakers in 1880 and 1900, similar to their parents. Table 1.6 panel A column 1 reports that the children of shoemakers in McKay counties were shoe factory workers in 1880 18 percentage points more often than other craftsmen in the same counties. The children of shoemakers were still far more likely to be shoe factory workers in 1900 than other craftsmen.

Columns 2 through 7 of table 1.6 report estimates of exposure on the same potential occupations as examined for their parents. Similarly, the children of shoemakers were less likely to be craftsmen and more likely to be laborers and farmers (columns 3, 4, and 6). The children of shoemakers in high-exposure counties were also less likely to be managers relative

Table 1.5: Children of Shoemakers: Continuance and Migration

	Long-Run	
	1880	1900
	(1)	(2)
Panel A. Occupation Continuance		
Exposure × Shoemaker	-0.021	-0.007
	(0.004)	(0.003)
Shoemaker, Parent	-0.056	-0.083
	(0.006)	(0.004)
Control Mean	.14	.13
R-squared	0.030	0.027
Observations	71,902	89,887
Number of FE Groups	1,199	1,216
Panel B. Industry Continuance		
Exposure × Shoemaker		
McKay County × Shoemaker	0.227	0.126
	(0.046)	(0.028)
Shoemaker, Parent	-0.051	-0.096
	(0.007)	(0.005)
Control Mean	.17	.16
R-squared	0.055	0.033
Observations	75,526	94,065
Number of FE Groups	1,599	1,617
Panel C. Migration (>100 Miles)		
Exposure × Shoemaker	0.006	0.000
	(0.006)	(0.005)
Shoemaker, Parent	0.004	-0.000
	(0.008)	(0.007)
Control Mean	.51	.53
R-squared	0.056	0.035
Observations	71,902	89,887
Number of FE Groups	1,199	1,216

Notes: Panels A and C report regressions on the parents' exposure in 1860, indicators of a father being a shoemaker, and county-town fixed effects. Panel B reports regressions on an indicator for being in a McKay county interacted with an indicator for a father being a shoemaker.

The outcome variables are: indicators for the child's occupation in 1880 or 1900 matching their parent's occupation in 1860 (panel A columns 1 and 2) and the child's industry in 1880 or 1900 matching the parent's industry in 1860 (panel B columns 1 and 2), and an indicator for whether a child moves more than 100 miles between their first year of observation and 1880 or 1900 (panel C columns 1 and 2).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Table 1.6: Children of Shoemakers: Target Occupations in 1880 and 1900

	Shoe Factory Worker (1)	Factory Worker (2)	Craftsmen (3)	Laborer (4)	Manager (5)	Farmer (6)	Other Occupation (7)	Full-Time Student (8)
Panel A. Target Occupations in 1880								
Exposure × Shoemaker		0.001	-0.015	0.016	-0.006	0.001	-0.022	-0.013
		(0.004)	(0.004)	(0.005)	(0.002)	(0.004)	(0.005)	(0.004)
McKay County × Shoemaker	0.141							
	(0.027)							
Shoemaker, Parent	0.040	-0.005	-0.111	0.014	0.004	-0.006	0.007	-0.000
	(0.005)	(0.005)	(0.006)	(0.007)	(0.003)	(0.005)	(0.006)	(0.005)
Control Mean	.005	.08	.18	.18	.02	.08	.15	.13
R-squared	0.194	0.036	0.040	0.108	0.015	0.111	0.045	0.031
Observations	89,258	85,382	85,382	85,382	85,382	85,382	85,382	85,382
Number of FE Groups	1,608	1,207	1,207	1,207	1,207	1,207	1,207	1,207
Panel B. Target Occupations in 1900								
Exposure × Shoemaker		0.004	-0.016	0.007	-0.013	0.011	-0.020	0.000
		(0.002)	(0.005)	(0.005)	(0.004)	(0.005)	(0.006)	(0.001)
McKay County × Shoemaker	0.074							
	(0.015)							
Shoemaker, Parent	0.016	0.004	-0.112	0.023	0.019	0.003	0.016	-0.002
	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)	(0.007)	(0.007)	(0.001)
Control Mean	.004	.04	.27	.1	.08	.17	.22	0
R-squared	0.121	0.022	0.038	0.032	0.018	0.142	0.038	0.017
Observations	94,260	90,067	90,067	90,067	90,067	90,067	90,067	90,067
Number of FE Groups	1,618	1,216	1,216	1,216	1,216	1,216	1,216	1,216

Notes: All columns are regressions on an indicator for whether a son's father was a shoemaker in 1860. Column 1 includes an indicator for whether the shoemaker parent was in a McKay county. All other columns include the shoemaker parents' exposure in 1860. Panel A reports estimates on 1880 occupations and panel B reports estimates on 1900 occupations. Panel B column 8 is not included since so few children by 1870 were students thirty years later.

The outcome variables are: indicators for whether an individual reports being a shoe factory worker (column 1), a general factory worker (column 2), a craftsman (column 3), a laborer (column 4), a manager (column 5), a farmer (column 6), any other occupation (column 7), or a full-time student (column 8).

Robust standard errors are reported in parentheses.

to low-exposure shoemakers (column 5).

Though many new occupations were created at the lower end of the skill distribution, there were relatively few new opportunities at the top, and very few children of shoemakers benefited from these occupations. In line with Goldin and Katz (1998), the McKay stitcher did create managerial and machinist occupations in the upper end of the skill distribution along with the new occupations in the lower end. There were only 26 machinists employed at shoemaking establishments in 1870 compared with 166,435 workers in the industry in total. Gordon McKay's firm responsible for producing and repairing the stitchers employed 58 machinists. These 84 new machinist jobs are a small number relative to the size of affected individuals. Only 0.3% of the children of shoemakers become machinists in 1870, and none of those are in the shoe industry, nor are any of them machinists in later decades.[39]

Though the number of managerial positions expanded, the children of shoemakers did not benefit from these new occupations. In 1860, there were 2,700 managers or foremen in the shoemaking industry, or 1.8% of industry employment. In 1870, there were 4,300 managers or foremen representing 2.6% of occupations in the shoe industry. In 1880, there were 5,000 managers or foremen, or 2.5% of the industry. By 1900, managers or foremen totaled 5,400 individuals, or 2.9% of the industry. In relative terms, the number of managers grew, but table 1.6 columns 4 and 5 document that the children of shoemakers in high-exposure areas were less likely to become managers in any industry both in 1880 and 1900.

The children of shoemakers were also less likely to be full-time students. Table 1.6 panel A column 8 shows that each unit increase in exposure corresponds to a 1.2 percentage point decrease in the fraction of shoemaker children being full-time students in 1880. This is in comparison to the average rate of 14% for other craftsmen. Children in the highest exposure counties were as much as 3 percentage points less likely to be students which corresponds to

[39] Of the 164,740 children linked to craftsmen parents, only 1 is a machinist in the shoemaking industry, in 1880. That individual is the child of a blacksmith.

a 21% lower rate than other craftsmen.

The decline in full-time student status is likely jointly driven by a need to work and the creation of new, low-skill occupations. Atkin (2016) showed how rising opportunities could lead to lower educational attainment by raising the opportunity cost of school. Though the McKay stitcher created many entry-level opportunities for the children of shoemakers, the trends are consistent even when splitting the analysis between non-Mckay and McKay counties. These results are documented in appendix table A14. Separating the sample of children into those that were born before 1860 and those that were born between 1860 and 1870 emphasizes that this trend is consistent across samples both in and out of McKay counties. It is not only the presence of new low skill jobs in McKay counties that pushed down the fraction of full-time students, instead it is also the declining value of their father's occupation that inhibits full-time student status.

More generally, the children of shoemakers turned to lower wage occupations. Table A15 documents declining wages across OCC scores and LIDO scores. A unit greater exposure corresponds to between a 2.7 and a 3.0 percentage decrease in wages in 1880 and 1900, or as much as 7.6% lower wages in the highest exposure counties.

With lower wage occupations and declining parental wealth, the children of shoemakers show some evidence of lower wealth even 40 years after the introduction of the McKay stitcher. Appendix table A16 columns 1 and 2 report estimates on the fraction of shoemakers owning a home and paying it off. I interpret each of these as indicators of wealth. Owning a home was expensive, and only 58% of the children of craftsmen owned homes in 1900 with only 32% of them having paid off their mortgage by 1900.[40] In 1900, the children of shoemakers in McKay counties were 2.4% less likely to own a home. Estimates on the probability of having paid off the mortgage is too noisy to draw conclusions. Though there

[40]Mortgages in this time period were not like mortgages today. They had terms between 3 and 6 years depending on the region Frederiksen (1894). Mortgage companies accounted for less than 2% of all the mortgages in the US between 1879 and 1890, while 55% were from local investors.

is no data on the wealth of these individuals, there is suggestive evidence that the children of shoemakers in McKay counties were at a financial disadvantage relative to the children of other craftsmen.

The children of shoemakers were the primary source of labor for the new occupations created by the McKay stitcher, yet these occupations proved to be an insufficient replacement as the losses to income and wealth persisted for 40 years following the introduction of the McKay stitcher.

IV.B Entrants to the Shoe Industry

Though the children of shoemakers were the single largest source of new workers in the factory, there is more to be said about who benefited from the new opportunities created by the McKay stitcher. The primary occupation created by the McKay stitcher was the shoe factory worker. Though there are many subcategories of workers within the factory, they most often reported their own occupations more generally in the census.[41]

Since I observe wealth in 1860, prior to the McKay stitcher, I rank employed heads of households by their 1860 wealth. Linking these workers across time, I can identify household wealth rankings of children for each decade. For example, the set of children in 1850 that enter shoemaking in 1860 have fathers in 1850 that link to their property values in 1860. Taking this median and comparing it to the median wealth of all other children in 1850 that entered other industries in 1860 provides a relative comparison of familial wealth.

By this measure, the McKay stitcher provided employment opportunities for children from less wealthy families over time. For children entering shoemaking in 1860, figure 1.6 shows their fathers reported a median property value 40% higher than the median for other children's fathers. This drops to 33% lower than other children's fathers in 1870 before settling at 50% lower in 1880 and 1900. While workers in occupations created by the McKay

[41] See Vipond (2023) for details on the composition of occupations within factories.

stitcher became younger, these new occupations also provided opportunities for individuals from financially disadvantaged backgrounds.

Using a similar method, I document that new entrants to the shoe industry after the McKay stitcher came from less literate fathers on average. For shoe industry entrants in 1860, fathers had a 7% higher literacy rate. Entrants to the shoe industry in 1870 had fathers with .6% lower literacy rate, which declined further by 1880 and 1900 with some rebound in 1900.

The deskilling changes from the McKay stitcher displaced incumbent workers in favor of new opportunities for individuals with worse economic backgrounds.

V Quantifying the Costs to Shoemakers

The reduced form estimates document strong displacement effects on shoemakers without quantifying the cost of that displacement. Switching probabilities are based on workers maximizing value, so these revealed preferences can imply information about the value lost by those workers as indicated by their occupation exit decisions. Adapting Artuç, Chaudhuri and McLaren (2010) to this setting, I define each county-occupation pair as distinct choices, treating traditional shoemaking and shoe factory work as distinctly different occupations with different productivity, wages, and switching costs.

V.A The Worker's Decision Problem

Let the value of county-occupation pair (c, j) be defined by the wage, continuation value, and the option value of switching into other occupations. Let continuation values and option values vary by type $\omega \in \{\text{Adult,Child}\}$.[42] Adults have no costs to stay in their occupation. Children are treated as inheriting their parent's county-occupation and similarly benefit from

[42] I do not allow wages to vary by type due to data restrictions.

Figure 1.6: Shoe Industry Entrants: Wealth and Literacy

Panel A. Relative Property Values of Fathers

Panel B. Relative Literacy Rate of Fathers

Notes: Panel A reports the median property values of the fathers of entrants to the shoe industry divided by the median property values of the fathers of all workers in the given year. Panel B reports the literacy rate of the fathers of shoe industry entrants relative to other fathers of other workers in that year. The sample is limited to McKay counties.

no switching cost to enter their parent's occupation. Then, both values can be defined as:

$$v_c^j(\omega,t) \equiv \underbrace{w_c^j(t)}_{\text{Wage}} + \underbrace{\beta\mathbb{E}[v_c^j(\omega,t+1)]}_{\text{Continuation Value}} + \tag{1.3}$$
$$\underbrace{\max_{d,k}\left\{\epsilon_d^k(\omega,t) - \psi_{cd}^{jk}(\omega) + \beta\mathbb{E}[v_d^k(\omega,t+1)] - \beta\mathbb{E}[v_c^j(\omega,t+1)]\right\}}_{\text{Option Value of Switching}}$$

where I have defined $w_c^j(t)$ to be the wage of county-occupation (c, j), β as the time discount factor, $\psi_{cd}^{jk}(\omega)$ as the utility cost of switching from county-occupation c, j to d, k, and $\epsilon_d^k(\omega,t)$ as an idiosyncratic shock to the value of county-occupation d, k. High wages, high future wages, or easy access to other valuable occupations correspond to high occupation value.[43]

I make the standard assumption that $\epsilon_d^k(\omega,t)$ is independently and identically distributed as a type 1 extreme value distribution with parameters $-\gamma\nu_\omega$ and ν_ω, where ν_ω sets the variance of $\epsilon_d^k(\omega,t)$ and γ is a constant.[44] This assumption delivers a simple linear regression equation relating current county-occupation flows $(m_{cd}^{jk}(\omega,t))$, next period wages, and next period county-occupation flows $(m_{cd}^{jk}(\omega,t+1))$.[45]

(1.4)

$$\ln(m_{cd}^{jk}(\omega,t)) - \ln(m_{cc}^{jj}(\omega,t)) = \frac{-(1-\beta)}{\nu_\omega}(\psi^{jk}(\omega) + \phi_{cd}(\omega)) + \frac{\beta}{\nu_\omega}\left(w_d^k(t+1) - w_c^j(t+1)\right) +$$
$$\beta\left(\ln(m_{cd}^{jk}(\omega,t+1)) - \ln(m_{dd}^{kk}(\omega,t+1))\right) + \mu_{cd}^{jk}(t+1)$$

[43]The model can be adapted to include a bequest motive by adults. This bequest could be in the form of money or the value of passing skills to their children. With no specific data on this, I cannot separate this motive from other expectations for the future. Thus, as long as the bequest is additively separable from the continuation value, the updated problem is equivalent to the model defined here. While the results remain unchanged, the interpretation then implies that any gains or losses include changes in the value of the bequest for their children.

[44]This assumes the same scale parameter across all county-occupation pairs, rather than varying across occupations and locations separately. Though this may be quantitatively significant in other settings, migration was not a substantial form of adjustment for shoemakers. The constant γ is the Euler-Mascheroni constant, which is approximately 0.523.

[45]This is derived following Artuç, Chaudhuri and McLaren (2010) in section AII.B.

This estimating equation nets out continuation values, leaving only the relationship between switching probabilities and wages across multiple time periods. It leverages the assumption that, after switching costs, the expected value of an occupation does not vary by origin occupation. Additionally, it requires that $\epsilon_d^k(\omega,t)$ is independent across time.[46]

Wages and switching probabilities are generally correlated with $\mu(\omega,t+1)$, and estimation of switching costs and ν by ordinary least squares may be biased. Artuç, Chaudhuri and McLaren (2010) propose using lagged wages as instruments. In addition, I use exposure to the McKay stitcher as an alternative instrument for next period wages and switching rates. Estimation of these parameters is discussed in section VI.

With estimated parameters, I propose a method to use observed occupation exit rates to reveal the changes in the value of traditional shoemaking. This method leverages the assumptions of the model and the estimation approach of the reduced form estimates to identify the relative changes in the value of traditional shoemaking caused by exposure to the McKay stitcher.

V.B From Switching Rates to the Value of Traditional Shoemaking

For notational ease, I define the optimal outside option for an adult or child in c,j: $\bar{V}_c^j(\omega,t) \equiv \max_{d,k\neq c,j}\left(v_d^k(\omega,t) - \psi_{cd}^{jk}(\omega)\right)$. I additionally define $\delta_c^j(\omega,t)$ to be the option value of occupation c,j as follows:

$$\delta_c^j(\omega,t) \equiv \max_{d,k}\left\{\epsilon_d^k(\omega,t) - \psi_{cd}^{jk}(\omega) + \beta\mathbb{E}[v_d^k(\omega,t+1)] - \beta\mathbb{E}[v_c^j(\omega,t+1)]\right\}$$

Since $\epsilon_d^k(\omega,t)$ is type 1 extreme value distributed, $\delta_c^j(\omega,t)$ is type 1 extreme value distributed with mean $\bar{\delta}_c^j(\omega,t)$ which is derived in appendix AII. I further demonstrate that $\bar{V}_c^j(\omega,t)$ also has a type 1 extreme value distribution. The difference between $\bar{V}_c^j(\omega,t)$ and

[46] It is possible that $\epsilon_d^k(\omega,t)$ is correlated over time. By assuming time independence, I overstate the costs of switching (Abaluck, Compiani and Zhang, 2023).

$(\delta_c^j(\omega,t) - \bar{\delta}_c^j(\omega,t))$ therefore has a logistic distribution (a known property of type 1 extreme value distributions) with a mean equal to $\mathbb{E}[\bar{V}_c^j(\omega,t)]$ and variance ν_ω. Let $F_\omega(\cdot)$ be the CDF of a Logistic distribution with mean zero and variance ν_ω. I relate the data on switching rates, $\Pr[\text{Exit}_c^j(\omega,t)]$, with the theoretical switching rates implied by the occupation values using the distributional relationships:

$$\begin{aligned}
\Pr[\text{Exit}_c^j(\omega,t)] &= \Pr[\bar{V}_c^j(\omega,t) - v_c^j(\omega,t) \geq 0] \\
&= \Pr[\mathbb{E}[v_c^j(\omega,t)] + \delta_c^j(\omega,t) - \bar{\delta}_c^j(\omega,t) \leq \bar{V}_c^j(\omega,t)] \\
&= \Pr[\mathbb{E}[v_c^j(\omega,t)] \leq \bar{V}_c^j(\omega,t) - (\delta_c^j(\omega,t) - \bar{\delta}_c^j(\omega,t))] \\
\Pr[\text{Exit}_c^j(\omega,t)] &= 1 - F_\omega(\mathbb{E}[v_c^j(\omega,t)]). \qquad (1.5)
\end{aligned}$$

Equation 1.5 simply states that the observed exit rates must equal the exit rate implied by the expected value of county-occupation c, j.[47] Inverting the logistic distribution in equation 1.5 gives:

$$\mathbb{E}[v_c^j(\omega,t)] = \mathbb{E}\left[\bar{V}_c^j(\omega,t)\right] + \nu \ln\left(\frac{1 - \Pr[\text{Exit}_c^j(\omega,t)]}{\Pr[\text{Exit}_c^j(\omega,t)]}\right) \qquad (1.6)$$

This is the direct relationship between the value of traditional shoemaking and the data on occupation exit rates. All else equal, increases in exit rates imply that the value of the occupation declined. This relationship depends, however, on the unobserved $\mathbb{E}[\bar{V}_c^S(\omega,t)]$. Similar to the reduced form estimates, I leverage the spatial variation of exposure and comparable occupations to net out changes in the outside option that could confound estimates on the impact of the McKay stitcher.

The potential confounders are the same concerns discussed in section III.B, and I use the same identification strategy to account for these. I assume that the mean differences in

[47]Note, $F_\omega(\mathbb{E}[v_c^j(\omega,t)])$ is the probability of an individual in c, j staying in c, j.

outside options for shoemakers S and craftsmen K in a county c are orthogonal to exposure. That is,

$$\mathbb{E}[\bar{V}_c^S(\omega,t)] - \mathbb{E}[\bar{V}_c^K(\omega,t)] = \rho_c \perp \text{Exposure}_c. \tag{1.7}$$

This assumption is quite similar to the parallel trends assumption when occupation exit is the dependent variable. Similar to the reduced form estimates, this assumption enables craftsmen to represent a counterfactual average switching rate for shoemakers. Subtracting the value of each occupation gives:

$$\mathbb{E}[v_c^S(\omega,t)] - \mathbb{E}[v_c^K(\omega,t)] = \rho_c + \nu\left(\ln\left(\frac{1-\Pr[\text{Exit}_c^S(\omega,t)]}{\Pr[\text{Exit}_c^S(\omega,t)]}\right) - \ln\left(\frac{1-\Pr[\text{Exit}_c^K(\omega,t)]}{\Pr[\text{Exit}_c^K(\omega,t)]}\right)\right). \tag{1.8}$$

This equation represents the difference between the value of traditional shoemaking relative to the value of other craftsmen occupations within a county. Comparing these values across levels of exposure delivers the triple difference used in the reduced form estimates.

VI Estimating the Model

There are two separate steps in estimating the model. The first step is to estimate switching costs and ν for each type ω. Since the universe of possible migration and occupation switching decisions is broad and wage data is too sparse at the county level, I make assumptions to reduce the dimensionality in the next section. Second, I use equation 1.8 to compute the change in shoemaker value in every county and document the effect of exposure on these values. Finally, I use these estimates to quantify the relative costs of the McKay stitcher on more-exposed versus less-exposed shoemakers.

VI.A Estimation: Model Parameters

I aggregate the 258 occupations into 11 categories of particular interest to shoemakers. The categories are: shoemaker, carpenters, tailors, general factory workers, other craftsmen, laborers, managers, farm laborers, farmers, mine operatives, and other occupations. This simplification masks a lot of variation in occupation switching, but it captures what is most directly relevant for shoemakers. The other category only accounts for 11% of target occupations for shoemakers between 1860 and 1870.

I reduce geographic variation to the state-level, rather than county or town. Migration in this simplified setting is defined only by changing states rather than counties.[48]

Finally, I reduce dimensionality with restrictions on the set of switching costs. I assume switching costs are additively separable across occupations and counties $\psi_{cd}^{jk} = \psi^{jk} + \phi_{cd}$. I further assume occupation switching costs are either constant for all occupation pairs (ψ) or constant by source occupation (ψ^j). When costs are constant by source occupation, they represent an exit cost to leaving an occupation. I assume that any migration between states has the same cost ϕ regardless of distance.

With these assumptions, I estimate equation 1.4 by the Generalized Method of Moments using links across census waves (Hansen, 1982; Helgertz et al., 2023). Switching rates m_{cd}^{jk} are the fraction of individuals in c, j that report d, k in the next census. Wages are from the wage data discussed in section II.E. Estimation can be completed using the set of adults with incumbent occupations and separately with children, where children have no switching cost to enter their father's occupation.

Table 1.7 reports estimates for three estimation procedures for each type: ordinary least squares in columns 1 and 4, lagged variables as instruments in columns 2 and 5, and exposure as an instrument in columns 3 and 6. Panel A reports estimates using constant switching

[48]This assumption only covers 55% of county-level migration over 100 miles, but since migration was not a significant form of adjustment, little is lost in the parameter estimation.

costs while panel B uses occupation exit costs.

Panel A of table 1.7 documents occupation switching costs between 1.0 and 2.4 times shoemaker annual wage in 1860 and migration costs between 2.9 and 6.4 times shoemaker wage. The parameter ν_ω, which governs the sensitivity of workers to wage changes, is between 0.8 and 1.9 times shoemaker annual wage. The estimates of switching costs and ν are smaller than modern estimates.[49] The smaller estimate for ν_ω suggests that workers were more sensitive to wages in this historical setting. Low switching costs are low barriers to mobility. These are consistent with the long held belief that the second industrial revolution was more mobile than the modern era (Long and Ferrie, 2013). Yet, despite this, I show that large shocks can cause persistent losses to incumbent workers and their children.

Panel B of table 1.7 expands the parameter set to include occupation-specific exit costs. This is frequently done with occupation entry and used to represent the difficulty of entering an occupation. In the setting of labor displacement, however, the utility cost to leave an occupation is fitting. Occupation specific exit costs show that there is substantial variation in the estimated barriers to switching occupations, with exiting the shoemaking industry being between 1.2 and 2.3 times the annual wage of shoemakers in 1860. The occupations that are easiest to exit show either no cost to exit or even a utility *gain* from exiting: factory workers, laborers, farm laborers, and mine operatives.

The parameter ν_ω has a large impact on the dollar loss to shoemakers and their children. In the next section, I use the average estimated ν_ω across all 5 specifications for adults and children to get 1.61 for adults and 1.40 for children. These values imply that the children of workers are somewhat more sensitive to wage changes than their parents.

[49] See Artuç, Chaudhuri and McLaren (2010) and Traiberman (2019) for details on modern estimates. Artuç, Chaudhuri and McLaren (2010) find occupation switching costs to be 4 to 13 times average wages with a standard deviation between 1.5 and 4 times average wages.

Table 1.7: Estimated Switching Costs

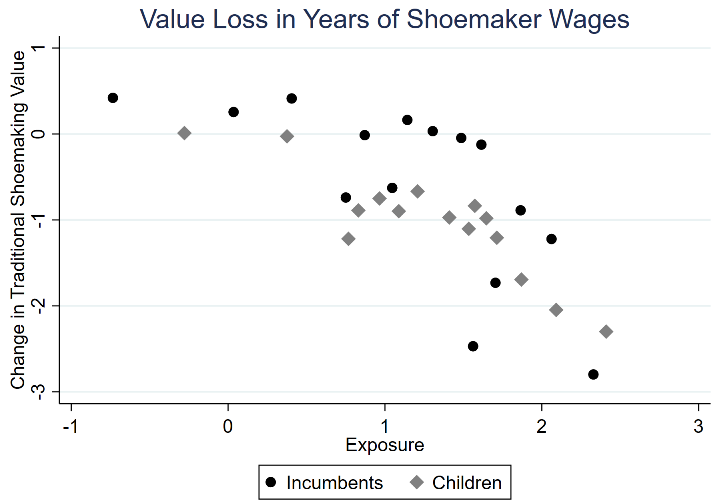
	Adults			Children		
		Lag	Exposure		Lag	Exposure
	OLS	IV	IV	OLS	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Constant Switching Costs						
ν_ω	1.88	1.63	0.79	1.59	1.51	0.86
	(0.16)	(0.23)	(0.05)	(0.14)	(0.26)	(0.06)
$\psi(\omega)$	2.37	2.18	0.96	3.22	2.67	1.62
	(0.21)	(0.32)	(0.07)	(0.29)	(0.45)	(0.13)
$\phi(\omega)$	6.37	4.96	2.87	3.48	3.65	2.18
	(0.54)	(0.70)	(0.17)	(0.33)	(0.64)	(0.17)
Kleibergen-Paap χ^2 Test Statistic		1,052	4,833		786	4,077
Panel B. Occupation Exit Costs						
ν_ω	2.36		1.37	1.86		1.22
	(0.23)		(0.23)	(0.18)		(0.22)
$\psi(\omega)$: Shoemakers	2.28		1.19	2.65		1.79
	(0.41)		(0.27)	(0.38)		(0.34)
$\psi(\omega)$: Carpenters	2.39		1.24	3.21		2.20
	(0.43)		(0.38)	(0.44)		(0.53)
$\psi(\omega)$: Tailors	1.86		1.35	3.09		2.27
	(0.43)		(0.25)	(0.42)		(0.36)
$\psi(\omega)$: General Factory Workers	-0.77		0.04	-0.11		0.28
	(0.31)		(0.18)	(0.26)		(0.17)
$\psi(\omega)$: Other Craftsmen	3.04		1.69	3.84		2.49
	(0.41)		(0.37)	(0.46)		(0.51)
$\psi(\omega)$: Laborers	-2.77		-0.84	-0.65		0.26
	(0.44)		(0.30)	(0.30)		(0.18)
$\psi(\omega)$: Managers	2.32		1.45	2.71		1.92
	(0.33)		(0.28)	(0.33)		(0.35)
$\psi(\omega)$: Farm Laborers	-5.20		-2.56	-4.71		-3.03
	(0.57)		(0.36)	(0.54)		(0.45)
$\psi(\omega)$: Farmers	12.14		7.20	10.78		6.92
	(1.18)		(1.21)	(1.06)		(1.23)
$\psi(\omega)$: Mine Operatives	-4.44		-1.85	-2.12		-1.03
	(0.82)		(0.51)	(0.64)		(0.44)
$\psi(\omega)$: Other Occupations	9.90		5.94	11.82		7.56
	(0.98)		(1.00)	(1.19)		(1.34)
$\phi(\omega)$	6.90		4.13	2.69		1.96
	(0.68)		(0.69)	(0.29)		(0.34)
Kleibergen-Paap χ^2 Test Statistic			2,236			1,686

Notes: Panel A reports the estimated parameters ν and ψ for type: Adults or Children. Panel A assumes all occupation switches have the same cost. Panel B assumes occupation exit costs vary by original occupation. Columns 1 and 4 report estimates using OLS, columns 2 and 5 use lagged wages and switching rates as instruments, and columns 3 and 6 use exposure interacted with occupations as instruments.

All estimates reported assume $\beta = 0.97$ for a one year interval, equating to a discount of 0.7 for decade by decade estimates.

All estimates are computed using the Generalized Method of Moments (GMM).

Figure 1.7: Model Implied Loss to Traditional Shoemakers and their Children



Notes: Using 15 equally sized sample population bins, this plots the change in the value of traditional shoemaking relative to the value of other craftsmen occupations by county sorted by exposure. Circles reflect the loss to incumbent workers while diamonds reflect the losses to the children of shoemakers. The y-axis is a per-person coefficient for ν as defined in equation 1.2.

VI.B Estimation: The Value of Traditional Shoemaking

Using equation 1.8, I estimate the relative loss to traditional shoemakers in terms of years of shoemaker wages. Figure 1.7 plots the losses by county as a function of exposure, using 15 equally sized population bins for parents and children. There is a visibly strong negative relationship between exposure and the losses accrued to shoemakers and their children.

Consider the following linear relationship:

$$\mathbb{E}[v_c^S - v_c^K] = \rho_0 + \rho_1 \text{Exposure}_c + \tilde{\rho} \tag{1.9}$$

Given the assumption in expression 1.7 that $\rho_c \perp \text{Exposure}_c$, estimating the relationship between the value loss and exposure produces unbiased estimates of ρ_1, and this equation matches the triple difference specification used in the reduced form estimates. Table 1.8

Table 1.8: Losses to the Value of Traditional Shoemaking

	Change in Shoemaker Value	
	Incumbents	Children
Exposure	-0.88	-0.75
	(0.19)	(0.13)
Constant	0.25	-0.13
	(0.20)	(0.23)

Notes: All columns are regressions of the model estimated change in shoemaker value on exposure. Value loss is scaled to be the number of years of shoemaker salary (at 1860 wage level).

reports estimates on these regressions by type. For each standard deviation of exposure, incumbent shoemakers lost an additional 0.88 years of shoemaker wages, while the children of shoemakers lost 0.75 years of wages per unit of exposure.

It's striking that the losses to children are similar in magnitude to the parents. It is theoretically possible for the costs to be higher or lower. Since the parents of shoemakers have already invested in human capital, the loss to their personal earnings capacity is large. On the other hand, the children have a much greater time horizon and therefore lose more in terms of lifetime income than incumbent shoemakers. Data limitations prevent precise separation of the potential mechanisms in this setting.

To aggregate these costs across exposure levels, I integrate across the regression estimates and weight each level of exposure by the number of individuals affected. Incumbent shoemakers in counties with greater than zero exposure lost a total of \$37 million dollars relative to shoemakers in zero exposure counties. Their children lost a total of \$28 million dollars in excess of the losses in zero exposure counties.

To conceptualize the size of \$65 million dollars in losses, I consider back-of-the-envelope estimates of the production cost savings from the McKay stitcher. Production of McKay shoes expanded from 5 million shoes produced by McKay machines in 1864, 25 million in

1870, 55 million in 1883, and reaching 100 million per year in 1893 (Thomson, 1989; Shoe and Leather Reporter, 1893). In a filing to extend their patent, Lyman Blake claimed an $0.18 savings on the production cost of McKay shoes from the McKay stitcher itself (Blake, 1874). Taking these generalized facts, I assume an $0.18 savings in production costs for each McKay shoe during this period to arrive at an estimated present discounted value of $95 million dollars in cost savings.

The $65 million dollar loss to shoemakers is similar in magnitude to the estimated $95 million dollars in cost savings, demonstrating that the losses to shoemakers and their children were substantial.

VII Conclusion

The historical setting is an opportunity to study the long-run impacts of deskilling technologies. The introduction of the McKay stitcher led to a rapid shift in the skill composition of the labor force, replacing traditional shoemakers with lower skill workers and a machine. The geographic distribution meant that workers faced unequal pressures on the value of their skills and their opportunities to adapt to the changing economy.

Parent to child occupation and industry continuance provided a mechanism through which displacement events can have impacts stretching decades. The children of shoemakers represent a sample of individuals who would have continued in the occupation in the absence of the technology.

Though new technologies frequently create new opportunities at the lower and upper end of the distribution, the McKay stitcher created an out-sized set of opportunities for low skill workers and minimal opportunities for high skill workers. While skill-biased technologies create higher wage opportunities for the younger generation, here the new opportunities were low-wage occupations.

In connecting with more general economic understanding, my findings do not suggest it would be better if shoes were still made by hand. Rather, my findings suggest that the long-run costs of deskilling technologies may be larger than previously recognized. Further, workers do not adjust as well as we may have expected in an otherwise highly mobile time period. In particular, this study of primary household earners in a skilled occupation shows how technologies can decrease the return on skill investments that would have benefited generations of workers. Future research can build on this and better predict the consequences of a labor saving technology based on the characteristics of the technology itself.

In focusing largely on the labor market effects of the McKay stitcher in the shoe industry, my analysis neglects the future investments of Gordon McKay from his substantial wealth (including a $15 million gift to Harvard University to support engineering and other sciences), the jobs transporting shoes, spillovers to other industries, and direct quantification of the benefits to individuals who entered shoe factory work that were not the children of shoemakers. These benefits are an important part of the equation in evaluating the total impact of the McKay stitcher.

Going forward, researchers can explore what factors enable rapid recoveries and characterize how individual workers can insulate themselves from negative consequences of new technologies. With the advent of generative AI, researchers predict a potential comeback of deskilling technologies in the modern era (Krugman, 2023; Goldman Sachs Global Macro Research, 2023). Navigating the adjustment to these technologies has the potential to mitigate large and persistent negative consequences and maximize the value of new technologies.

Chapter 2

SPECIALIZATION AND THE EXTENT OF MARKET ACCESS: SMITHIAN GROWTH IN PLANT-LEVEL US MANUFACTURING[1]

Adam Smith noted that economic growth can occur even without technological progress in the presence of three coinciding factors: (1) increased population, (2) increased exchange, and (3) a division of labor. Growth derived from the combination of these three sources is called "Smithian Growth." Most of the rise of rich regions in medieval Europe can be attributed to Smithian growth (Mokyr, 2018).[2] The majority of empirical evidence for Smithian growth, however, only examines pre-industrial societies. The effects of Smithian growth in industrial economies are less documented.

The lack of documentation is, in part, due to dramatic technological progress since 1750. Growth from technologies has intertwined with Smithian growth and obscured the relative importance of each effect in economic growth. Some of the most transformative technologies of the last couple centuries produced both direct economic gains as well as integrated and connected markets.[3] Market integration combined with a division of labor are the ingredients that drive Smithian growth. Adam Smith's initial theory claimed that the division of labor was constrained by the extent of the market. Consistent with this proposition, it's plausible

[1]This chapter was coauthored with Richard Hornbeck (University of Chicago), Anders Humlum (University of Chicago), and Martin Rotemberg (New York University). I am extraordinarily grateful that I could collaborate with them on this chapter.

[2]Examples can also be found in pre-industrial China and early Native American settlements (Kelly, 1997; Ortman and Lobo, 2020).

[3]Advances in ship building, automobiles, communication technologies, and other infrastructure improvements are of particular note.

that market integration enables greater specialization and thereby expands productivity.[4]

This study leverages the expanding railroad network during the 19th century US to examine the potential for increased specialization and Smithian growth. Following Donaldson and Hornbeck (2016) and Hornbeck and Rotemberg (2024), we utilize market access as a measure of changing market connectivity during this period. We define market access as the transportation cost access to county populations throughout the US. Therefore, market access increases as county populations increase or as transportation costs decrease.

Using newly digitized plant-level data from the US manufacturing censuses in 1850, 1860, and 1870, this study examines the plant-level response to increased market access. In these data, manufacturing plants self-reported the quantities and values of inputs and outputs in production.

There are many ways that specialization could be realized in an economy, and our data enable us to examine a subset of those ways. We may expect places to specialize in certain industries where they have a comparative advantage (Costinot and Donaldson, 2012). Manufacturing plants may specialize in producing certain products (Bernard, Redding and Schott, 2018). Plants may specialize in performing certain steps along the production chain (Stigler, 1951). The division of labor may occur within the establishment itself (Scott, 1986). By directly observing the inputs and outputs of the plants, we can observe industry specialization, specialization in the number of products, and specialization along the production chain. The within-firm division of labor is not directly observable in this data.

Combining measures of specialization with the geographic variation in market access that comes from the expanding railroad network, we can identify how expanding market access enabled or caused a division of labor.

Increased market access is not associated with specialization at the industry level. We

[4]This result is not a guarantee. Kelly (1997) shows that Smithian growth occurs at a threshold market size, rather than as a gradual response to growing markets. In contrast, this project studies a more incremental increase in productivity in response to incremental increases in specialization.

find no effect on the number of industries nor the concentration of industries in places gaining more market access relative to those with lesser gains. This is consistent with results from Hornbeck and Rotemberg (2024) in studying market access from 1860 to 1880.

Places with larger increases in market access saw a greater reduction in the fraction of multi-product firms. A standard deviation increase in market access is associated with a 9% decrease in the fraction of multi-product plants.

By observing final good producers, we find that increased market access caused firms to perform fewer steps in the production process. The percent of saddle makers producing saddles with pre-processed leather increased by 7.3 percentage points, and the percent of carpenters reporting pre-produced hardware increased by 4.5 percentage points for each standard deviation increase in market access.

These results support the theory of Adam Smith that the division of labor is limited by the extent of the market. With the expansion of the railroads, the extent of markets grew, and places with the largest change in market access saw the greatest changes in specialization.

In the last section of the paper, we consider how this specialization translated into observable Smithian growth. We find no impacts on revenue productivity at the county level, but we do find changes in the distribution of firms. Market access increased the lower percentiles of capital expenditure relative to the higher percentiles, while the opposite was true of labor expenditure. In considering wages at the plant level, we find the highest percentiles increased by as much as 40% per standard deviation of market access, while the lowest percentiles remain unchanged.

We theorize that the gains of specialization appeared in terms of increased labor productivity. These gains were entirely captured by workers. While the evidence supports this theory, further work will need to be completed to quantify the gains of Smithian growth during the expansion of the railroads.

I Empirical Strategy

Following Donaldson and Hornbeck (2016) and Hornbeck and Rotemberg (2024), we define market access as the sum of transportation costs and populations from all counties:

$$\ln(MA_d) = \sum_{o \in \mathcal{C}} \tau_{od}^{-\theta} N_o$$

As discussed previously, increases in population and decreases in transportation costs increase market access. Growing market access is another way to show growth in the extent of the market. Under Adam Smith's theory, this growing extent of the market allows for a greater division of labor. One purpose of this study is to determine whether that division of labor occurs.

I.A Regression Specification

Changes in market access are not independent of other spatially important shocks. The US was changing dramatically during this century. Economic outcomes were impacted by the Civil War, increasing westward expansion, and various technological advances. To separate the effect of market access from other economic shocks, we examine changes in market access, controlling for specific county factors (α_d) as well as specific state-by-year factors ($\alpha_{State,t}$). Thus, identification comes from comparing places that gain more market access with places that gained less market access within the same state. We further control for a polynomial of latitude and longitude coordinates interacted with year ($F(X_d^1, X_d^2, t)$, which captures the effect of being more east or more north compared with more west or more south. The regression specification is as follows:

$$Y_{d,t} = \alpha_d + \alpha_{State,t} + F(X_d^1, X_d^2, t) + \beta \ln(MA_{d,t}) + \epsilon_{d,t}$$

where $Y_{d,t}$ represents any outcome at the county-time level (d, t). Note that most regressions will be conducted at the county-level. When evaluating the distribution of firms, the regression is plant-level. In these cases, the outcome variables are percentiles of plant i outcomes: $Y^i_{d,t}$.

I.B Defining Multi-Product

Products in the Census of Manufacturing are self-reported and recorded by the census taker. There is tremendous variation in products. Figure A4 shows a carpenter's establishment in Franklin, Pennsylvania in 1850. This establishment produced a variety of furniture reported separately, including "Bureaus" and "Tables." The plant also reports the largest revenue in "Other Furniture." This aggregation of products is common but can clearly pose problems in identifying the number of products.. Additionally, some firms report products grouped in the same line, as in: "Boots and Shoes." Identifying the number of products produced by a given firm is not perfect. For the purposes of this study, we consider two distinct definitions of products.

The first definition of multi-product assumes each new line of products is distinct. This treats categories like "Boots and Shoes" and "Other Furniture" as only one product when they are, in fact, more than one. Along with this definition, we consider the Herfindahl-Hirschman Index (HHI) within the plant. Since each line has a reported revenue associated with it, we can calculate the HHI as a sum of the squared shares of revenue. This measures the concentration of revenue among products produced by the plant. If a plant has only one line, the HHI will be 1. A perfect split between two lines of products would be an HHI of 0.5. While this is directly related to the number of lines, it captures the idea that some lines may be of little importance to the plant.

The second definition expands upon the first to treat any entries reporting multiple objects separated by "and" as separate products. While highly correlated with the multi-line definition, it expands the potential for multi-product firms. Conversely, however, this method will miss plants that report "Footwear" rather than reporting boots and shoes separately.

I.C Defining Steps of the Production Process

Manufacturing plants also self-reported material inputs used in production. The reported materials have similarities to the reported products as listed above. We use these inputs to determine how much of the production chain is completed within the establishment, by identifying inputs as raw materials or already manufactured intermediates. We focus on two specific production processes that are straightforward to identify in our data.

The first example product is saddle-making. Saddles are made in a multi-step process that includes tanning, cutting, and shaping leather, sewing firm and soft leather together, and attaching cast-iron stirrups. In particular, we focus on the use of skirting as an input, which is leather already manufactured to be sturdier than other kinds of leather. At times, leather-workers could refine the skirting to have distinct textures and designs. Saddle-makers could purchase hides or partially prepared leather and complete the tanning process themselves, or they could purchase skirting leather from skilled leather-workers and perform the remaining tasks for saddle-making.

The second example is in carpentry for furniture and wood products. Carpenters used various types of lumber and hardware to craft cabinets, beds, coffins, doors, etc. In particular, many pieces of furniture and wood products required iron, tin, or steel hardware to function properly, including hinges, knobs, handles, etc. Carpenters may have initially fashioned their own hardware (potentially out of wood), or they could purchase hardware from other producers.

II Industry Specialization

The very definition of an industry is a grouping of firms that are similar in their type of work. Ricardo's theory of comparative advantage suggests that increased opportunity for trade will push places to shift production to their comparative advantage. This has been well demonstrated in with agriculture, as geographies have large variation in crop suitability (Costinot and Donaldson, 2012). As we turn to manufacturing, Boehm, Dhingra and Morrow (2022) instead document comparative advantage at the firm level.

Table 2.1 documents no evidence for industry specialization in response to market access. Column 1 reports no change in the number of industries, while columns 2 and 3 suggest that the concentration of industries by revenue or by value added did not change significantly in response to market access. These results are consistent with evidence from 1860-1880 (Hornbeck and Rotemberg, 2024).

Table 2.1: Market Access and Industry Specialization

	Number of Industries (1)	Industry Revenue HHI (2)	Industry VA HHI (3)
Log Market Access	-0.011	0.050	0.040
	(0.045)	(0.030)	(0.042)
Observations	1,825	1,825	1,825

Notes: Each column is a regression of the output variable on market access along with county fixed effects, state-year fixed effects, a polynomial of latitude and longitude coordinates interacted with year.

Outcome variables are: number of industries in the county (column 1), the HHI of industry revenue shares (column 2), and the HHI of industry value-added shares (column 3).

Robust standard errors, clustered at the state-level, are reported in parentheses.

III Plant-Level Specialization

While there is no evidence of specialization at the industry level, there is evidence for firm-level specialization. We first observe some specialization in the type of products produced, and then we observe a shortening of the production chain in response to market access. Both types of specialization are an indication of the division of labor outside the firm.

III.A Specialized Goods

Table 2.2 reports the effect of market access on the fraction of firms that produce multiple products as well as the effect on the number of products.

Column 1 of table 2.2 reports that a standard deviation increase in market access causes a 3% decrease in the percent of firms that report multiple lines of products. Nationally, 34.4% of firms report more than one line of products, so this decrease is an 8.4% reduction in multi-line firms. Column 2 reports this is a noisy 1.7% decrease in the average number of lines.

Column 3 of table 2.2 reports the log average within plant HHI. Column 3 reports a 1.2% increase in the average within plant HHI, suggesting production is increasingly concentrated within plants. This confirms that the decrease in the number of products is not simply a decline in small, low revenue product lines. Instead, there is a real shift in the average concentration of production by firms with increasing market access.

Columns 4 and 5 reinforce columns 1 and 2 using the second definition of the number of products, where products in the same line are separated. This measure is much noisier and shows limited results, though there is some evidence that the number of firms reporting multiple products is declining as indicated by column 1.

Table 2.2: Market Access and Multi-Product Firms

	Indicator of Multi-Line (1)	Log Number of Lines (2)	Log Avg Within Plant HHI (3)	Indicator of Multi-Prod (4)	Log Number of Products (5)
Log Market Access	-0.029	-0.017	0.012	-0.026	-0.014
	(0.010)	(0.012)	(0.005)	(0.015)	(0.015)
Observations	1,857	1,857	1,857	1,857	1,857
National Average	.344			.441	

Notes: Each column is a regression of the output variable on market access along with county fixed effects, state-year fixed effects, a polynomial of latitude and longitude coordinates interacted with year.

Outcome variables are: the percent of plants in a county reporting more than one line of output (column 1), the county average number of lines reported by plants (column 2), the county average within-plant HHI (column 3), the percent of plants in a county reporting more than one product name (column 4), and the county average number of product names by establishment (column 5).

Robust standard errors, clustered at the state-level, are reported in parentheses.

III.B Production Line Specialization

Table 2.3 reports evidence on production line specialization for saddle-makers. Saddle-makers saw no change in their use of raw materials in response to market access, as documented in column 1. This is not to say that raw materials did not shrink as a fraction of material cost, but rather that saddle-makers continued to source raw materials. Column 2 reports an increase in the percent of firms using intermediates in production. As market access increased, a larger portion of saddle-makers purchased already processed intermediates.

More specifically, column 3 reports that a standard deviation increase in market access is associated with a 7.3 percentage point increase in the percent of saddle-makers purchasing skirting leather. These results to imply that a larger fraction of saddle-makers previously made skirting themselves, but expanding market access meant the task of producing skirting could be separated from saddle-making.

Table 2.4 documents the response of producers of furniture and other wood products. Columns 1 and 2 show little effect of market access of the fraction of raw materials or

Table 2.3: Market Access and the Production Chain: Saddle-makers

	Percent of Establishments Buying		
	Raw Materials	Intermediates	Skirting
	(1)	(2)	(3)
Log Market Access	0.010	0.118	0.073
	(0.035)	(0.061)	(0.025)
Observations	858	858	858

Notes: Each column is a regression of the output variable on market access along with county fixed effects, state-year fixed effects, a polynomial of latitude and longitude coordinates interacted with year.

Outcome variables are: the percent of plants in a county reporting raw material inputs (column 1), intermediate inputs (column 2), and skirting as an input (column 3).

Robust standard errors, clustered at the state-level, are reported in parentheses.

intermediate materials used by carpenters in these industries. However, column 3 reports that a standard deviation increase in market access is associated with a 4.5 percentage point increase in the percent of firms using hardware as intermediates.

Hardware during this era could be made from a variety of metals or even wood. We interpret the increased used of hardware as evidence that carpenters were outsourcing the production of hardware as they gained market access, rather than making their own. While saddle-makers and furniture makers are a small set of manufacturers relative to the US economy generally, they are indicative of potentially larger trends in response to increasing market access. They are evidence that specialization was indeed occuring as the railroads interconnected counties throughout the US.

IV Connecting Specialization with Productivity

With specialization occurring in response to increased market access, we have the three ingredients for Smithian growth. We now turn to measuring the gains in productivity. At the county level, we find no effect on revenue productivity. Appendix table A17 documents

Table 2.4: Market Access and the Production Chain: Furniture and Other Wood Products

	Percent of Establishments Buying		
	Raw Materials	Intermediates	Hardware
	(1)	(2)	(3)
Log Market Access	0.003	0.031	0.045
	(0.022)	(0.026)	(0.016)
Observations	792	792	792

Notes: Each column is a regression of the output variable on market access along with county fixed effects, state-year fixed effects, a polynomial of latitude and longitude coordinates interacted with year.

Outcome variables are: the percent of plants in a county reporting raw material inputs (column 1), intermediate inputs (column 2), and hardware as an input (column 3).

Robust standard errors, clustered at the state-level, are reported in parentheses.

the response of revenue and input expenditures to market access. While all increase generally, they increase in near lock-step at the county level.

Though the changes in specialization are not showing up as revenue productivity, it may be that plants are becoming more productive in a physical productivity sense. The cases where market access caused the most specialization, however, are cases of final good production with multiple steps in the production process. These products exhibit substantial variation in quality, and changes in quality obscure gains in physical productivity. Instead, we take a more abstract approach and observe changes in the distribution of firms in response to market access.

Using quantile regression with 220,000 plants, figure 2.1 shows how the distribution of firms changed in response to market access. Panel A documents a relatively flat effect on revenues. The railroads increased revenues generally, but evenly across the distribution of firms. Panel B shows that market access increased the lowest percentiles of capital expenditure more than the highest percentiles, decreasing the dispersion of capital expenditure nationally. This result may be driven by exit of low capital firms.

Panel C of figure 2.1 reports a much larger increase in the wagebill for the upper percentiles relative to the lower percentiles. This change increases the variance of wage expenditure across firms. Finally, panel D shows a flat response from materials expenditure, in line with the flat revenue response. This implies little change in the distribution of value-added.

With employment observed at the plant level, we can look at the distribution of wages in figure 2.2. Similar to the wagebill more generally, wages rise for the highest percentile of wages. The lowest percentiles remain largely the same with expanded market access.

These plots are consistent with the theory that labor is specializing and becoming more productive in response to market access. This increased productivity may then drive wages higher and enable workers to capture the returns of specialization rather than manufacturing plants. Smithian growth in this context would then accrue entirely to workers, and it would be measured by the gains in wages enabled by more efficient labor allocation across production processes.

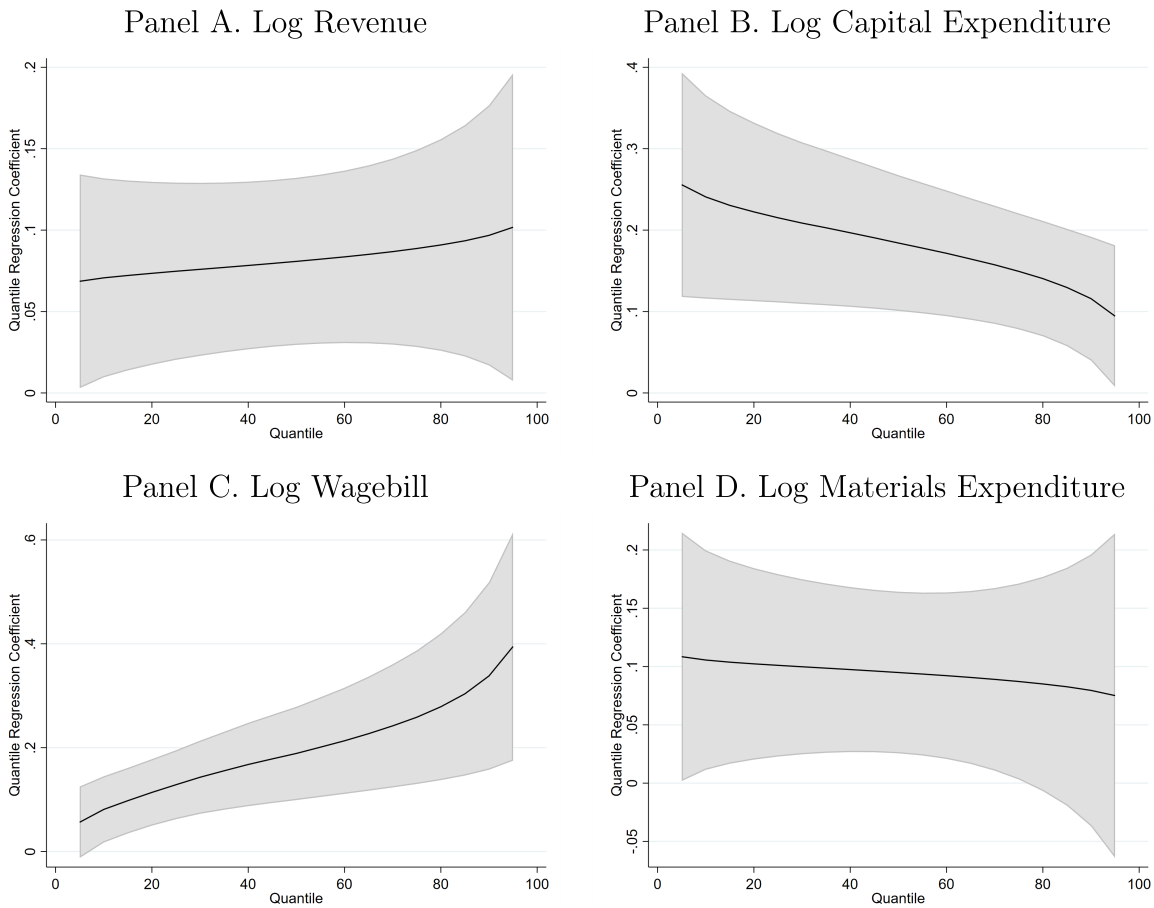
V Conclusion

The expansion of the railroad promoted specialization by manufacturing plants both in terms of the number of products they produced as well as the length of the production chain completed within the same plant. Given the nature of the expanding railroad network, these gains largely materialized in more rural settings.

While there is no evidence of increasing revenue productivity in response to market access, the higher distribution of wages grew dramatically in response to market access. We theorize the gains from Smithian growth accrued directly to workers by increasing wages in lock step with increased labor productivity. Verifying this theory will require further work.

This project suggests that Smithian growth occurs in industrial economies as well as pre-industrial economies. The productivity effects are not necessarily obvious. To the extent that factor markets are competitive, it may be that specialized factors gain the returns of Smithian growth.

Figure 2.1: Market Access and the Distribution of Firms

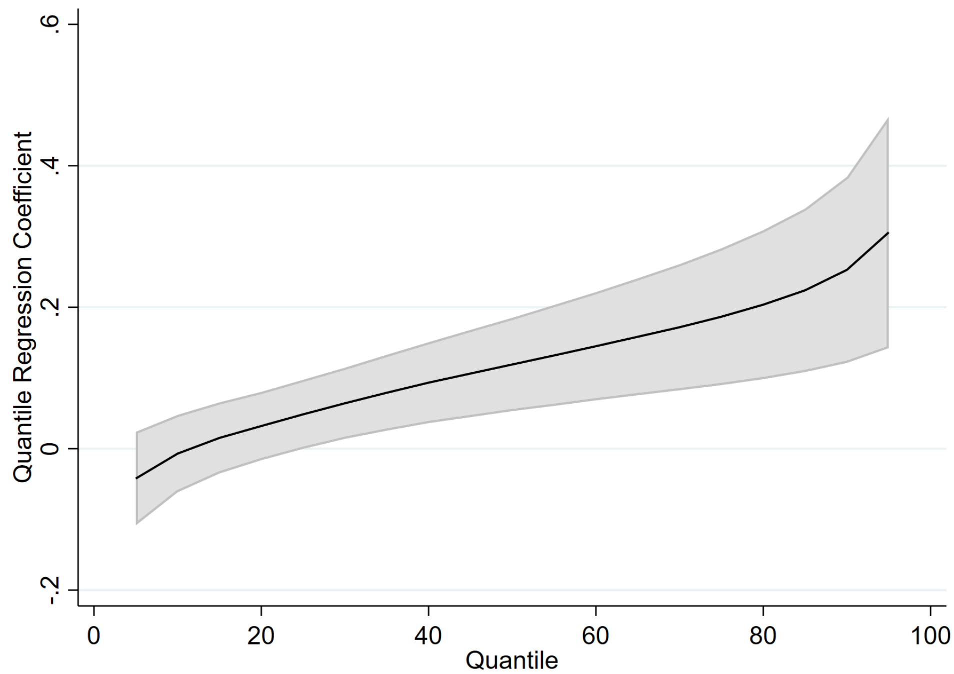


Notes: These figures plot quantile regression coefficients on market access, controlling for county fixed effects, state-year fixed effects, and a polynomial of latitude and longitude coordinates interacted with year.

Outcome variables are: log plant revenue (Panel A), log plant capital expenditure (Panel B), log plant wagebill (Panel C), and log plant materials expenditure (Panel D).

The shaded regions are 95% confidence intervals generated from robust standard errors, clustered at the state-level.

Figure 2.2: Market Access and Wages



Notes: This figure plots quantile regression coefficients on market access, controlling for county fixed effects, state-year fixed effects, and a polynomial of latitude and longitude coordinates interacted with year.

The outcome variables is log wages expenditure minus log employment.

The shaded region is a 95% confidence interval generated from robust standard errors, clustered at the state-level.

Chapter 3

MEDIUM FREQUENCY TRADING: THE TELEPHONE AND THE CHICAGO BOARD OF TRADE[1]

Financial markets are a powerful source of information. Trades reveal the market value of commodities given the information available. As new information arises, the prices of further exchanges adjust to incorporate the news. Over the centuries, innovations have increased participation in financial markets and the information available for traders. The consequences of information on prices depends on the speed and scope of the information. Evidence and theory suggest that more public information decreases price volatility.[2] This has been documented over long distances and with large time savings (Hoag, 2006; Ejrnæs and Persson, 2010; Koudijs, 2016). Similarly, decreases in volatility have resulted from high-speed algorithmic trading in response to changes in price (Hendershott, Jones and Menkveld, 2011). It is not immediately clear how information shared mere minutes faster could affect price volatility in financial markets.

To examine this question, this project studies commodity prices following the introduction of the telephone to Chicago on June 26, 1878. Initially marketed towards businesses, the telephone had the potential to increase the speed of communication with traders and businesses throughout the Chicago area and thereby affect trading behavior (Larson, 1941).

At this time, the Board of Trade in Chicago hosted centralized exchanges for many crops and animal products. This voluntary organization also hosted exchanges for futures contracts

[1]This chapter was coauthored with Martin Rotemberg (New York University). I am grateful to have worked with Martin in preparing this contribution to my dissertation.

[2]Note that in cases where public information is quite complex, Bae et al. (2023) found a short-term increase in volatility before a longer run decline in volatility in response to complicated disclosures.

and formally regulated their fulfillment. The organization reported weekly and sometimes daily high and low prices for each commodity. By comparing the difference between the high and low prices, we can infer some information about the volatility of price during that day or week.

In our analysis, we compare prices immediately following the introduction of the telephone with other years during this period. In the 6-12 weeks after the telephone exchange opened, the difference between weekly high and low prices decreased by approximately 3% relatively to 1877, 1879, and 1880. We have daily data on futures prices throughout this period. The reduction in the difference between high and low prices for futures contracts is approximately 0.4%. When restricting the analysis to animal products, which are potentially less sensitive seasonally in such a small time window, we find larger decreases in the difference between the high and low prices.

We also consider how the telephone affected connected markets. For example, we would expect news about wheat production to affect all wheat products in correlated ways. The difference in price between the one-month and two-month futures contracts actually increased by about 1.5% after the introduction of the telephone relative to other years at this same time. Rather than convergence, we see these two markets separating. We could speculate as to the potential mechanisms for this.

Our results contribute to the literature on the speed of information in financial markets. In modern financial markets, Hendershott, Jones and Menkveld (2011) demonstrated that algorithmic trading led to decreased spreads and adverse selection. Brogaard et al. (2015) note that the proximity of market makers via faster data connections decreased price spreads and increased liquidity for the market more generally. In contrast, the telephone connected individuals within the same city and saved potential minutes of communication lags. However, these effects were sufficient to cause market level convergence in prices. The forces of information speed reflect fundamental forces observed in both modern and historic settings.

This study relates to the literature on information and prices more generally. It is well-known the news affects prices of assets and commodities. In particular, greater public information has been shown to decrease price volatility (Fleming, Kirby and Ostdiek, 2006; Koudijs, 2016). In the case of weather-sensitive products like many agricultural products featured in this study, Fleming, Kirby and Ostdiek (2006) show that public information is even more important. The increased speed of information from telephone had similar effects on prices regardless of the weather sensitivity, and showed a stronger impact on less-weather sensitive products.

Finally, this study contributes to the literature on connected markets. Many historical studies of financial markets focus on connecting previously disconnected markets through increased communication. The effect of the telegraph in a variety of contexts showed rapid integration of previously disconnected markets (Ejrnæs and Persson, 2010; Hoag, 2006). We show that in these already well connected markets–like one-month and two-month futures–the increased speed of information actually pushed prices apart.

I The Board of Trade and the Telephone

The Chicago Board of Trade was founded in 1848 and grew in importance along with the city of Chicago during this period (Taylor, 1917). In 1865, the Board of Trade moved to a new location in Chicago, the Chamber of Commerce Building on the southwest corner of LaSalle and Washington Street (Taylor, 1917). Upon moving to the new building, the Board of Trade established rules for the exchange of futures contracts and began formally regulating them.

On June 26, 1878, the Chicago Telephonic Exchange was established only two blocks north of the Chamber of Commerce Building (Caughlin, 2007).[3] The first telephone book

[3]The original Chamber of Commerce Building was destroyed in the Great Chicago Fire, but a new building was built in the same location within a year and continued to house the operations of the Board of Trade (Taylor, 1917).

for the Chicago area was published in 1878 with 455 subscribers. Among these subscribers were news agencies, railroad company offices, the city messengers office, and a number of members of the board of trade.[4] In October of 1878, these 455 subscribers averaged 1,600 calls per day.

Given that many of the telephone users have the potential to impact commodity trading at the Board of Trade, it is feasible to assume that some phone calls were used to provide information for traders on the exchange floors. Also in 1878, New York City received a telephone exchange. Though no empirical evidence is provided, the New York Stock Exchange claims the introduction of the telephone made markets more efficient than before (Exchange, 2024). With this possibility in mind, we turn to evaluate the impact of the new telephone exchange on market prices in Chicago.

I.A Data

The Board of Trade of the City of Chicago published annual reviews to document prices throughout the year, notable events and information, as well as a list of current members (Board of Trade, 1877, 1878, 1879, 1880). The high and low spot prices of the week for 44 different product-grade combinations were recorded, including even fractions of a cent. Almost exactly half of the products were crops, while the other half were animal products.

The high and low daily prices for futures contracts were recorded for 5 principle products: No. 2 Spring Wheat, No. 2 Corn, No. 2 Oats, Mess Pork, and Prime Steam Lard. Contracts on these products had expiration dates between one month and four months in the future.

II Empirical Framework

The introduction of the telephone was not a temporary change to the Chicago economy, but rather it was a permanent shift with increasing usage. Rather than an immediate, one

[4] See appendix figure A5 for one page of the business directory acquired from Larson (1941).

day impact, we expect a general change in markets in the days and weeks following the introduction of the telephone.

Identifying the impact of the telephone could be confounded by other factors that affect commodity prices directly. To avoid capturing other adjustments in the commodity markets, we limit the scope of our study to between 6, 9, and 12 weeks before and after June 26th. To verify that our estimates are not coincidentally capturing trends that already occur this time of year, we compare this time period in 1878 with the same days in 1877, 1879, and 1880. The results are generally robust to which years used for comparison.

Our estimating equation includes product-year fixed effects ($\alpha_{p,e}(t)$) where e equals the number of months until expiration. We suppress e when considering spot prices. All specifications include the date as a running variable (t) and we allow for a different slope after the introduction of the telephone, and finally an indicator for any date after the introduction of the telephone ($Post_t$). We write outcome variables as $Y_{p,e,t}$, where outcomes can be prices or differences in prices.

$$Y_{p,e,t} = \alpha_{p,e,t} + \beta_{t1} \cdot t + \beta_{t2} \cdot t \cdot Post_t + \beta_{Post} PostJune26_t + \beta_{Tel} PostTel_t + \epsilon_{p,t} \tag{3.1}$$

We restrict t to be within 6 to 12 weeks of the telephone date. The coefficient β_{Tel} is our coefficient of interest, as it documents the difference in the outcome variable after the introduction of the telephone in 1878 relative to the changes after June 26th of other years.

III The Effect on Prices

Table 3.1 reports the effect of the telephone on the variability in spot prices and futures prices. Panel A evaluates the effect on weekly spot prices, while panel B reports results for the daily prices of futures contracts. Columns 1, 2, and 3 report that the log difference between the weekly high and low prices in the spot market decreased by around 3%, relative to other years. Panel B reports an approximate 0.4% effect. Appendix table A18 reports these effects when converting the daily futures prices into weekly highs and lows. These results are similar in magnitude to the effect in the spot market.

Table 3.1: Prices

	Log Difference Between High and Low Prices					
	All Products			Animal Products		
	6 Weeks	9 Weeks	12 Weeks	6 Weeks	9 Weeks	12 Weeks
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Spot Prices						
After the Telephone	-0.028	-0.030	-0.029	-0.036	-0.043	-0.051
	(0.007)	(0.006)	(0.005)	(0.010)	(0.008)	(0.008)
Number of Products	45	45	45	21	21	21
Observations	1,719	2,612	3,523	946	1,425	1,906
Panel B. Futures Prices						
After the Telephone	-0.003	-0.004	-0.004	-0.005	-0.010	-0.012
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Number of Products	16	16	16	7	7	7
Observations	2,833	4,269	5,599	1,282	1,912	2,465

Notes: All columns are regressions on the date, the date interacted with after the June 26th of each year, fixed effects for all product-expiration groups, an indicator for any date after the June 26th, and finally an indicator for after June 26th only in 1878 (the introduction of the telephone). The reported value is the coefficient on this last term. Panel A reports the effect on spot prices, while panel B reports the effect on the prices of futures contracts. The sample for each column varies according to the indicated time window: 6 weeks for Columns 1 and 4, 9 weeks for columns 2 and 5, and 12 weeks for columns 3 and 6. Columns 1-3 use all products, while columns 4-6 consider only animal products.

The outcome variables are the log of the difference between the high and low prices for each product in a given week for spot prices and a given day for futures prices.

Robust standard errors are reported in parentheses.

As discussed previously, there are many factors that could prevent identifying the effects of the telephone. In particular, some crops begin their harvest season in June in the middle of our sample. New information from the harvest and sales on the spot market may bring important information for traders in the futures market. These effects could mask any effect of the telephone. To avoid these factors, Columns 5-8 of table 3.1 consider only animal products.[5]

In both spot prices and futures prices, prices for animal products exhibit larger effects. Columns 4, 5, and 6 document a 3.6% to 5.1% decline in the difference between high and low prices. Futures prices show a 0.5% to 1.2% decline in the daily differences.

Figures 3.1 and 3.2 depict column 2 from panels A and B, respectively.

These negative results are consistent across different comparison groups with varying magnitudes. Appendix tables A19 and A20 document less precise effects when comparing with 1877, 1879, and 1880.

IV The Effect on Relative Prices

While increased speed of information decreased the variation in prices for each product individually, it has the potential to impact correlated prices. Using variation in futures contract expiration dates, we compare the relative high and low prices for different lengths of contracts for the same underlying product. For example, information about wheat generally could affect wheat contracts across all expiration dates.

The majority of contracts expired within one to two months during the summer months. Since June 26th is close to the end of the month, and one month contracts would soon expire, there are mechanical changes in the relative prices unrelated to underlying information.

Table 3.2 reports the log difference between the prices of two-month and one-month futures contracts for all five products. Panel A documents a 1.4-2.3% increase in the difference between the average prices of two-month and one-month contracts. Panels B and C report similar affects across both high and low prices, suggesting this effect is not drive by lower or higher price effects.

Taken altogether, the evidence is suggestive that the introduction of the telephone sep-

[5]In the futures market, this only includes mess pork and prime steam lard, but the varying expiration dates mean 6 product-by-expiration groups.

Table 3.2: Log Difference between Two-month and One-month Futures Contract Prices

	Price Difference between 2-month and 1-month Futures Contracts		
	± 6 Weeks	± 9 Weeks	± 12 Weeks
	(1)	(2)	(3)
Panel A. Log Difference in Average Prices			
After the Telephone	0.014	0.015	0.023
	(0.003)	(0.003)	(0.003)
Number of Products	5	5	5
Observations	1,206	1,830	2,367
Panel B. Log Difference in Low Prices			
After the Telephone	0.015	0.016	0.023
	(0.003)	(0.003)	(0.003)
Number of Products	5	5	5
Observations	1,206	1,830	2,367
Panel C. Log Difference in High Prices			
After the Telephone	0.016	0.017	0.024
	(0.003)	(0.003)	(0.003)
Number of Products	5	5	5
Observations	1,271	1,918	2,505

Notes: All columns are regressions on the date, the date interacted with after June 26th of the same year, fixed effects for 5 distinct products, and an indicator for any date after the counterfactual introduction of the telephone. Panel A reports the effect on the log difference in the average prices of 1 month and 2 months contracts. Panels B and C report the log difference in low and high prices, respectively. Column 1 uses a sample of dates within 6 weeks of June 26th, column 2 within 9 weeks, and column 3 within 12 weeks.

Robust standard errors are reported in parentheses.

arated these markets. Robustness to different years of comparison is reported in table A21. These results are in contrast to potentially anticipated price convergence. We can speculate about the mechanisms, but at the very least, it likely suggests the information gains from the telephone have different effects for products with longer time horizons.

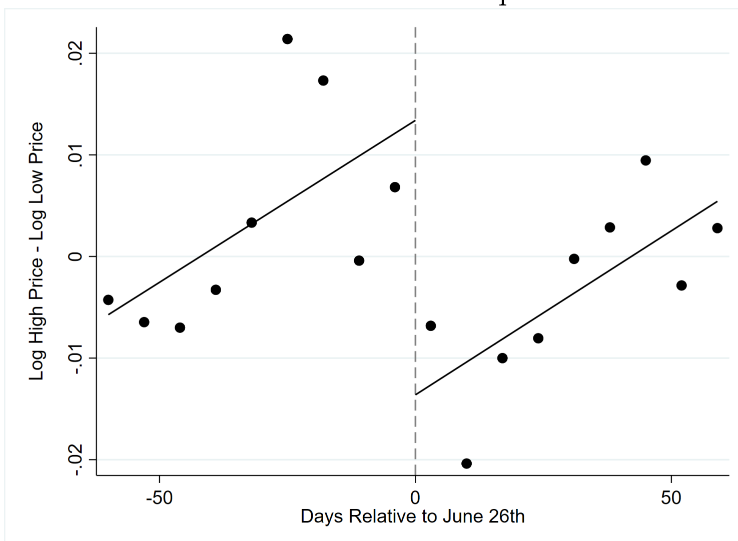
V Conclusion

This historical setting provides an opportunity to study how the speed of information flows affects the volatility of commodity prices, futures prices, and connected markets. The introduction of the telephone in Chicago intended to integrate businesses throughout the Chicago area. Our evidence suggests this integration decreased price volatility for commodities traded at the Board of Trade in Chicago. Further, we show that connected markets saw price divergence in response to the telephone, suggesting the information did not symmetrically affect contracts over different horizons.

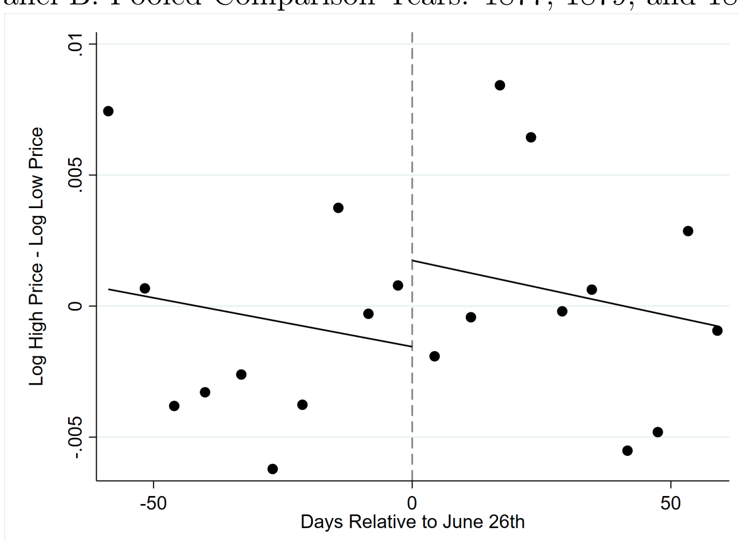
While increased information flows can have the potential to benefit only some individuals, the resulting decrease in volatility suggest that the telephone benefited market participants more broadly. The telephone continued to expand rapidly in the ensuing years, benefiting a larger and larger population. In 1892, Chicago and New York were connected by telephone wire, further integrating Chicago with the global market.

Figure 3.1: Prices and the Telephone

Panel A. The Year of the Telephone: 1878



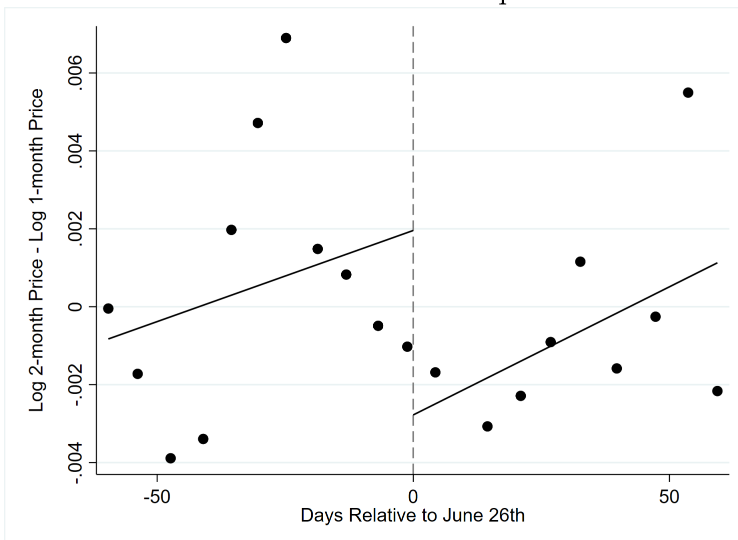
Panel B. Pooled Comparison Years: 1877, 1879, and 1880



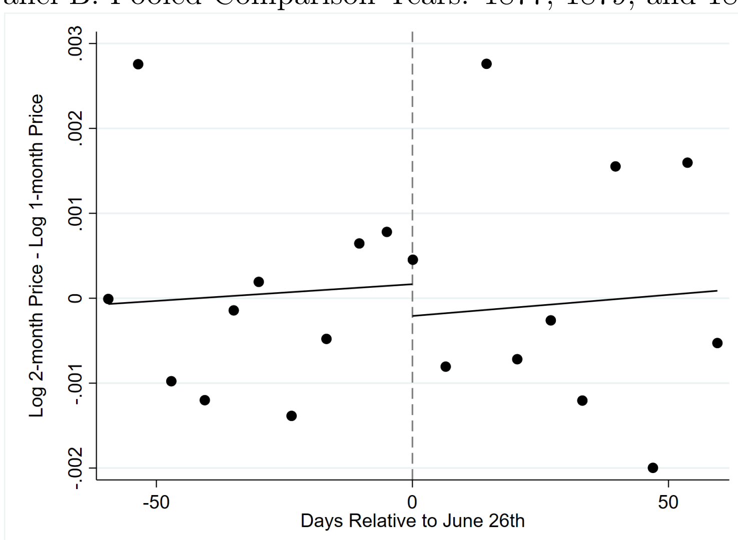
Notes: These binscatter plots show residualized high-to-low price differences after June 26th in each year when controlling for date, date interacted with an indicator for after June 26th, and product fixed effects.

Figure 3.2: Futures Contract Prices and the Telephone

Panel A. The Year of the Telephone: 1878



Panel B. Pooled Comparison Years: 1877, 1879, and 1880



Notes: These binscatter plots show residualized high-to-low price differences after June 26th in each year when controlling for date, date interacted with an indicator for after June 26th, and product fixed effects.

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APPENDIX

AI Data Appendix: Chapter 1

AI.A Productivity of the McKay Stitcher

The US Commissioner of Labor compiled a report in 1899 as the result of an investigation into the effect of machinery use on labor and the cost of production (US Department of Labor, 1899). A portion of the report describes the process of producing shoes first by hand and then with machines. I hand digitized a set of tables regarding the production of medium grade men's shoes. These data describe each task in shoemaking production, the time it requires, and the cost of the typical laborer that would accomplish such work. Atack, Margo and Rhode (2019) evaluate portions of this report and show that the number of tasks expanded with the use of machinery and some tasks even disappeared. I highlight only a few insights from these tables. The time cost of sewing the soles of shoes to the welts and uppers was over 25% of the total production time. The expected time of these same tasks by machine would take a few minutes as opposed to a few hours (this is similar to the 60-fold increase implied by U.S. Bureau of Labor (1886)). These estimates suggest that the McKay stitcher alone saved 23-25% of shoemaker time and nearly the same amount of labor costs. In firms utilizing the division of labor, the savings would have been closer to 50% of shoemaker time.

These dramatic improvements in physical productivity are evident at the county-industry level in terms of employment and quantities as well as in the expanding shipments of shoes.

The Census of Manufacturers in 1860, 1870, and 1880 has been tabulated at the county-by-industry level and then digitized by Hornbeck and Rotemberg (2024). These tabulations report revenue, employment, wagebill, and materials expenditure. I supplement these statistics with reports on shoemaking production in Massachusetts that report the number of cases of shoes produced yearly in the state over the period 1860 through 1880 as well as the number of cases shipped from Boston to many locations across the US in 1875 (Shoe and Leather Reporter, 1871, 1876). From 1870 to 1880 the number of cases of shoes produced grew further from 1.3 million to 2.3 million cases. In 1875, 1.7 million cases were shipped from Massachusetts to outside the New England area. Combining these statistics emphasizes the majority of shoes produced in Massachusetts were shipped outside New England. Table A4 documents the number of cases of shoes shipped from Boston to various US cities and towns in 1875. The "other towns" category contains 309 towns receiving fewer cases than Mobile, AL. The data exclude places within the New England area. Cases during this period contained between 40 and 70 pairs of shoes, depending on the type.

AI.B Occupation Coding and Measurement Error

There can be considerable concern about measurement error in occupation coding. Occupations in 1860 and subsequent occupation choice are essential to this study. There are multiple stages in the process of creating this codes. First, individuals report their occupation to the census taker who may write down the wrong information. Second, the written occupation was digitized. Finally, Ruggles et al. (2021) coded every occupation both in terms of an industry and a 1950 standardization code. I investigate only this third source of error. With access to the original strings via Ruggles et al. (2020), I compare the digitized occupation written by the census taker with the codes reported in the IPUMS datset. Checking all 130,000 reported shoemakers by hand, I find less than 1% of coded shoemakers were false positives. I further compared any raw strings with various references to "shoe", "boot", or various potential misspellings. I find approximately 1,500 occupations that could be classified as shoemakers, but were not recorded as shoemakers. This represents 1.2% of the coded shoemakers.

AI.C Alternative Linking Procedures

Linking individuals across census waves is difficult. Since linking is a discrete process where true match probabilities are not observed, linking is subject to nonclassical measurement error. Additionally, many of the outcome variables I observe could be correlated with the probability of linking. For example, individuals that remain in the same place and have a growing family may be more likely to show up similarly across census waves and therefore be easier to match. This is then correlated with the probability of being linked as well as the probability of exiting an occupation or migrating.

There are various methods of linking census records that leverage different information to inform the linking process. In each census, individuals report their first and last names along with their sex and age. Beyond this, each census varies in the information collected, and therefore varies in the information available for linking. I will discuss the relative merits and potential biases of each linking method used in the paper. Table A13 documents that the main estimates are robust across linking procedures, which provides some confidence that the various biases in linking are not highly correlated with exposure.

The main estimates in the paper use links created by Helgertz et al. (2023). This set of links conditions only on available information in the census and uses a probabilistic model created from training data similar to the machine learning linking introduced by Feigenbaum (2016). This method leverages family information, which does increase the probability of linking individuals living with families and may be biased against those that migrate or have smaller families for other reasons. This method may be more likely to match early and mid career individuals who have more individuals living in their home with them over multiple waves of the census.

To account for concerns about using household information, I also consider census links from Abramitzky et al. (2022). These links are generated by directly matching first names, last names, ages, and places of birth across all individuals in the census and only keeping unique matches. This method does not have the same biases in terms of family or migration, as neither household nor location information are used. This method delivers a much smaller sample of links, but the effect of exposure on incumbent workers remains sufficiently precise to corroborate the main estimates. Estimates using these links are reported in table A13 panel G.

In contrast, Price et al. (2021) and Buckles et al. (2023) use a method combining census information with any other genealogical information available. This method includes potential family information as well as any supplementary documents that genealogists can find to support the links. These links have potential to have much higher match rates, but it may be biased towards individuals who married, had children, or have surviving posterity that research their family history through FamilySearch, a family history database. The data from these efforts is now publicly available under the name "The Census Tree Project." The results in this paper are robust to this alternate linking procedure, as reported in table A13 panel H.

Each set of links produces similar estimates for the incumbent shoemakers, which is encouraging that whatever information used in the linking procedure does not produce substantial bias in the estimates.

AI.D Identifying the Number of Machines in McKay Counties

As discussed in the text, the Census of Manufacturers in 1870 reports 189 identifiable McKay stitchers, with 144 of those in Essex, MA. Due to lost pages of the census, half of Massachusetts counties are missing, including Plymouth, MA, where Lyman Blake ran a factory producing McKay shoes, and Worcester, MA which is known to have used McKay stitchers (Shoe and Leather Reporter, 1874). The imputed number of machines per county are reported in appendix table A1.

Shoe and Leather Reporter (1870) reports 65 McKay machines in use in Philadelphia in 1870 and Shoe and Leather Reporter (1874) reports 88 McKay stitchers in use in Philadelpia as well as 96 in New York, 179 in Essex, and 526 across all of Massachusetts. Since I observe the number of machines in Philadelphia in both years, I assume the same percent growth in machines. To then get the estimated number of machines in 1870 for New York and Massachusetts, this would imply that Massachusetts had 388 machines and New York had 71 Machines.

There are three counties in New York reporting using the McKay stitcher, and I divide the 71 machines in proportion to the number of observed machines in the census data, leading to 41 stitchers in Rockland, 20 stitchers in Kings, and 10 stitchers in Oneida.

For Massachusetts, Shoe and Leather Reporter (1867) and Shoe and Leather Reporter (1874) show 150 stitchers in Essex, MA in 1867 and 180 in 1871. There are 144 accounted for in the Census of Manufacturers. I inflate the number of machines to the midpoint– 165 machines in Essex. I assign the remaining machines to the missing counties equally, equating to 73 machines in Middlesex, Plymouth, and Worcester. The observed levels of shoe production do not indicate otherwise.

George Stribley is recorded to have acquired at least one McKay stitcher (Greve, 1904). In the Census of Manufacturers, his firm is reported to have 50 sewing machines. Establishments using the McKay stitcher typically have a ratio of 3 McKay stitchers to 50 sewing machines, so I assume only 3 in use. In contrast to the leasing system, Stribley purchased his machines during the US Civil War (Ford and Ford, 1881).

Finally, there is one firm in Salt Lake City reporting use of a McKay stitcher in the Census of Manufacturers. Production in Salt Lake City seems low in 1870, but rises to expected levels in 1880 befitting a county using the McKay stitcher. As such, I make the assumption that the one machine in use is the only machine in use in 1870. Given the leasing format and the use of retail and repair shops by Gordon McKay, the McKay stitcher in use in Salt Lake City was likely purchased rather than leased.

This accounts for 524 machines. Given that the number of McKay stitchers in the US in 1870 is at least 700, I then assign another 186 machines to the other counties reporting using the McKay stitcher, proportional to the number reported in the Census of Manufacturers. This is essentially assuming stitchers are just as likely to go unreported in each of these other counties.

These estimates are very back-of-the-envelope but are the result of using all available information. However, table A11 row 7 reports similar results when using the distance to closest stitcher as the measure of exposure. This measure has no relationship with the number of machines, and suggests even controlling for simple distance to any single stitcher captures similar effects.

AI.E State Level Occupation Wages

Constructing the state level wages by occupation depends on three data sources: Meyer (2004), county-by-industry tabulations from Hornbeck and Rotemberg (2024), and LIDO scores from Saavedra and Twinam (2020). The most detailed data on occupations comes from Weeks (1886) which is digitized in Meyer (2004) and is discussed first. Second, I discuss merging this data with the county-by-industry tabulations. Third, I turn to the LIDO scores where no other wage data are available.

In taking the census during this period, census takers were instructed to ask after the profession and were given limited guidance into how these were to be recorded. If an individual stated a specific role in a factory, the census taker may record exactly that specific role. In the data from Ruggles et al. (2021), these original strings have been digitized into text and coded into occupation and industry codes. These codes are the basis for most of the analysis in this paper.

Using the matches between occupation strings and the associated industry and occupation codes, I recreated the same coding procedure for occupations in the Weeks Report. This process was not intended to find the perfect occupation and industry code for each reported occupation. Instead, my purpose was to code each occupation as it was done with the population census. Then, the wages from the Weeks Report match codes in the population census that best reflect the original reported occupation. These wages are reported as daily wages.

I next take the county-by-industry tabulations and divide the total wagebill by the total number of laborers in each state. This is the average annual wage by industry, not by occupation. Low skill occupations in the industry likely have lower wages than the average while high skill occupations have higher wages. I then merge these industries with the occupation-industry wage data from the Weeks Report. The resulting file has average annual wages by industry and average daily wages by occupation-industry. To scale the daily wages into annual wages, I identify a sample of state-industry pairs such that the Weeks Report contains wages for every occupation in that state industry. I average these wages across all individuals in the population census by industry and state to represent the average daily wage in those industries. This results in 2,714 state-occupation-industry groups in 1860 covering 13% of individuals with occupations. For 1870, there are 6,386 groups covering 21% of individuals. For 1880, there are 10,096 groups covering 24% of individuals. I regress the average annual industry wage on the average daily wage where available and use the estimates to scale all daily wages into annual wages.

Where wages from the Weeks Report are unavailable, I use the industry average wages. This increases coverage in 1860 to 26%, in 1870 to 28%, and in 1880 to 30%. For craftsmen, however, coverage is far higher: 70% in 1860, 77% in 1870, and 82% in 1880. The majority of this coverage comes from the Census of Manufacturers data (Hornbeck and Rotemberg, 2024).

Having assigned wages to only 26 to 30 percent of occupations, I fill in the remaining wages using LIDO scores discussed in Saavedra and Twinam (2020). For comparability, I regress LIDO scores on already included wages and use those estimates to scale the LIDO scores to match the yearly wages.

Finally, these wages are aggregated into the 11 occupation categories used in the model.

AII Theory Appendix: Chapter 1

This section contains discussions and derivations related to the conceptual framework in section V. I first discuss nonlinear relationships between exposure and occupation switching. Second I show all the steps in deriving each of the equations in the model.

AII.A A Structural Approach to Import Exposure

As discussed in section III.A, the baseline measure of exposure assumes competition in the product market only occurs locally. This is not true if shoemakers sell their shoes to other counties throughout the US. A full, general equilibrium model would also account for the impact the McKay stitcher has on all target markets of shoemakers.

A general gravity model of trade can be derived through a collection of micro-foundations. In particular, I consider the case of CES demand over shoes with elasticity of substitution σ and Fréchet distributed productivities following Eaton and Kortum (2002). This implies the following gravity equation:

$$X_c^T = \sum_{d \in \mathcal{C}} X_{cd}^T = \sum_{d \in \mathcal{C}} \left[\frac{\left(C_c^T \tau_{cd}\right)^{-\theta^T}}{\sum_{e \in \mathcal{C}} \left(C_e^T \tau_{ed}\right)^{-\theta^T}} Y_d \right]$$

This is the baseline level of shipments to other counties prior to the McKay stitcher. After the McKay stitcher, every target market d gained increased access to the McKay stitcher that decreases the relative market share of traditional shoes everywhere.

$$\text{Exposure}_c^{FMA} \equiv \sum_{d \in \mathcal{C}} X_{cd}^T \times \text{Exposure}_d \tag{3.2}$$

where exposure is defined as in the text:

$$\text{Exposure}_d \equiv \sum_{g \in \Omega} \tau_{gd}^{-\theta} M_g.$$

It is not necessary that $\theta^T = \theta$. In fact, with $\theta^T = \infty$ equation 3.2 becomes simply exposure in county c. Without data on pre-technology intranational trade relationships, I have to make assumptions to arrive at an expression for X_{cd}^T.

First, income Y_d is not observed for the entire county. Following Donaldson and Hornbeck (2016), I substitute for income with population N_d.[6]

I make the simplifying assumption that production capabilities in shoemaking in 1850 were constant across space. This is certainly an oversimplification that ignores the changed industry structure in Massachusetts. However, the relative differences in costs prior to the McKay stitcher were small relative to the size of differences after the introduction of the McKay stitcher. This assumption leads to the costs dividing out of the transportation equation and leading to a very simple relationship with trade costs.

Finally, it seems that trade in shoes was limited outside of Massachusetts, with some transportation of shoes from Massachusetts down the coast during this time period. Estimates with a variety of values for θ^T demonstrate limited sensitivity to the assumption about pre-period tradeability, so long as pre-period tradeability is less than post-McKay stitcher. The historical evidence on trade suggests a rather high θ^T for traditional shoemakers. A high θ^T in this model implies a tighter distribution of productivity draws at the firm level.

Thus, the definition of exposure used in appendix table A11 is:

$$\text{Exposure}_c^{FMA}(\theta^T) \equiv \sum_{d \in \mathcal{C}} \frac{\tau_{cd}^{-\theta^T}}{\sum_{e \in \mathcal{C}} \tau_{ed}^{-\theta^T}} N_d \sum_{g \in \mathcal{C}/\{c\}} \tau_{gd}^{-\theta} M_g$$

where θ^T is the trade elasticity for traditional shoes and θ is the trade elasticity for McKay shoes.

[6] I can also consider the sum total of manufacturing revenue and farm revenue, though this excludes many occupations.

AII.B Derivations

This section includes a variety of derivations to arrive at the main equations in the model.

From Worker Value to Linear Regression

These derivations will follow directly from the appendix described in Artuç, Chaudhuri and McLaren (2010). I merely provide the derivation with my notation and the minor changes to include geography-industry transitions. I suppress the type notation ω, as the derivations for each type proceed equivalently. For notation, let $\mathcal{C}$ be the set of all counties and $\mathcal{J}$ be the set of all occupations. Recall the value of a county-occupation pair c, j as defined in equation 1.3.

(3.3)

$$v_c^j(t) = w_c^j(t) + \beta\mathbb{E}[v_c^j(t+1)] + \max_{d,k}\left\{\epsilon_d^k(t) - \psi^{jk} - \phi_{cd} + \beta\mathbb{E}[v_d^k(t+1)] - \beta\mathbb{E}[v_c^j(t+1)]\right\}$$

To derive equation 1.4, define:

$$\bar{\epsilon}_{cd}^{jk}(t) \equiv \beta\mathbb{E}[v_d^k(t+1) - v_c^j(t+1)] - \psi^{jk} - \phi_{cd} \tag{3.4}$$

Taking expectations of 3.3 with respect to the ϵ vector gives:

$$\mathbb{E}_t[v_c^j(t)] = w_c^j(t) + \beta\mathbb{E}_t[v_c^j(t+1)] + \Theta(\bar{\epsilon}_c^j(t))$$

where $\bar{\epsilon}_c^j(t) = \left(\left\{\bar{\epsilon}_{cd}^{jk}\right\}_{d\in\mathcal{C},k\in\mathcal{J}}\right)$ and

$$\Theta(\bar{\epsilon}_c^j(t)) = \sum_{d\in\mathcal{C}}\sum_{k\in\mathcal{J}}\int_{-\infty}^{\infty}\left[(\epsilon_d^k + \bar{\epsilon}_{cd}^{jk}(t))f(\epsilon_d^k)\prod_{l\neq k}\prod_{e\neq d}F\left(\epsilon_d^k + \bar{\epsilon}_{cd}^{jk}(t) - \bar{\epsilon}_{ce}^{jl}(t)\right)\right]d\epsilon_d^k \tag{3.5}$$

Using equation 3.4,

$$\begin{aligned}\psi^{jk} + \phi_{cd} + \bar{\epsilon}^{jk}_{cd}(t) &= \beta\mathbb{E}[v^k_d(t+1) - v^j_c(t+1)] \\ &= \beta\mathbb{E}_t\left[w^k_d(t+1) - w^j_c(t+1) + \beta\mathbb{E}_{t+1}[v^k_d(t+2) - v^j_c(t+2)]\right. \\ &\quad \left. + \Theta(\bar{\epsilon}^k_d(t+1)) - \Theta(\bar{\epsilon}^j_c(t+1))\right.\end{aligned}$$

$$\begin{aligned}\psi^{jk} + \phi_{cd} + \bar{\epsilon}^{jk}_{cd}(t) = \beta\mathbb{E}_t\Big[& w^k_d(t+1) - w^j_c(t+1) + \psi^{jk} + \phi_{cd} + \bar{\epsilon}^{jk}_{cd}(t+1) \\ & + \Theta(\bar{\epsilon}^k_d(t+1)) - \Theta(\bar{\epsilon}^j_c(t+1))\Big]\end{aligned} \tag{3.6}$$

I assume that $\epsilon^k_d(t)$ is distributed as a type 1 extreme value distribution with parameters $(\gamma\nu, \nu)$. The probability density function $(f(\epsilon))$ and cumulative density function $(F(\epsilon))$ are therefore defined as follows:

$$\begin{aligned} f(\epsilon) &= \frac{e^{-\epsilon/\nu-\gamma}}{\nu} \exp\left\{-e^{-\epsilon/\nu-\gamma}\right\} \\ F(\epsilon) &= \exp\left\{-e^{-\epsilon/\nu-\gamma}\right\}. \end{aligned}$$

The expected value of ϵ is then zero, and the variances is equal to $(\pi^2\nu^2/6)$.

I will first consider the set of switching probabilities: $m^{jk}_{cd}(t)$.

$$m^{jk}_{cd}(t) = \Pr\left[\bar{\epsilon}^{jk}_{cd}(t) + \epsilon^k_d(t) \geq \bar{\epsilon}^{jl}_{ce}(t) + \epsilon^l_e(t) \text{ for all } e \in \mathcal{C}, l \in \mathcal{J}\right]$$

Known properties of the type 1 extreme value distribution implies the following expression for this probability:

$$m^{jk}_{cd}(t) = \frac{\exp(\bar{\epsilon}^{jk}_{cd}(t)/\nu)}{\sum_{e\in\mathcal{C}}\sum_{l\in\mathcal{J}} \exp(\bar{\epsilon}^{jl}_{ce}(t)/\nu)} \tag{3.7}$$

Taking logs,

$$
\begin{aligned}
\ln\left(m_{cd}^{jk}(t)\right) &= \frac{1}{\nu}\bar{\epsilon}_{cd}^{jk}(t) - \ln\left(\sum_{e\in\mathcal{C}}\sum_{l\in\mathcal{J}}\exp(\bar{\epsilon}_{ce}^{jl}(t)/\nu)\right)\\
\ln\left(m_{cd}^{jk}(t)\right) - \ln\left(m_{cc}^{jj}(t)\right) &= \frac{1}{\nu}\bar{\epsilon}_{cd}^{jk}(t) - \frac{1}{\nu}\bar{\epsilon}_{cc}^{jj}(t)\\
&\implies \bar{\epsilon}_{cd}^{jk}(t) = \nu\left(\ln\left(m_{cd}^{jk}(t)\right) - \ln\left(m_{cc}^{jj}(t)\right)\right) \qquad (3.8)
\end{aligned}
$$

where $\bar{\epsilon}_{cc}^{jj}(t) = 0$, because switching costs are assumed to be zero when no change is made.

Still following the derivations of Artuç, Chaudhuri and McLaren (2010), I derive an expression for the option value function by defining the following quantity which is the expectation of the value of the shock minus switching costs of a given choice d, k:

$$
\begin{aligned}
\Psi_{cd}^{jk} &= \int_{-\infty}^{\infty}\left[(\epsilon_d^k - \psi_{cd}^{jk})f(\epsilon_d^k)\prod_{l\neq k}\prod_{e\neq d}F(\epsilon_d^k + \bar{\epsilon}_{cd}^{jk} - \bar{\epsilon}_{ce}^{jl})\right]d\epsilon_d^k\\
&= \frac{1}{\nu}\int(\epsilon_d^k - \psi_{cd}^{jk})e^{-\frac{\epsilon_d^k}{\nu}-\gamma-e^{-\frac{\epsilon_d^k}{\nu}-\gamma}}\prod_{(e,l)\neq(d,k)}e^{-e^{-\frac{\epsilon_e^l+\bar{\epsilon}_{cd}^{jk}-\bar{\epsilon}_{ce}^{jl}}{\nu}-\gamma}}d\epsilon_d^k
\end{aligned}
$$

Using the same properties of type 1 extreme value distributions,

$$
\Psi_{cd}^{jk} = m_{cd}^{jk}\left(-\psi_{cd}^{jk} - \nu\ln(m_{cd}^{jk})\right)
$$

Now adding across destinations d, k, returning to the utility of a worker in equation 3.3 (and noting the relationship between the defined Ψ_{cd}^{jk} and equation 3.5):

$$
\begin{aligned}
\mathbb{E}[v_c^j] &= w_c^j(t) + \sum_{d\in\mathcal{C}}\sum_{k\in\mathcal{J}}\left(\Psi_{cd}^{jk} - \beta m_{cd}^{jk}\mathbb{E}[v_d^k(t+1)]\right)\\
&= w_c^j(t) + \sum_{d\in\mathcal{C}}\sum_{k\in\mathcal{J}}\left(m_{cd}^{jk}\left(-\psi_{cd}^{jk} - \nu\ln(m_{cd}^{jk}) - \beta\mathbb{E}[v_d^k(t+1)]\right)\right)\\
&= w_c^j(t) + \sum_{d\in\mathcal{C}}\sum_{k\in\mathcal{J}}\left(m_{cd}^{jk}\left(\bar{\epsilon}_{cd}^{jk} - \nu\ln(m_{cd}^{jk})\right)\right) + \beta\mathbb{E}[v_c^j(t+1)]
\end{aligned}
$$

Taking logs of equation 3.7 and plugging it in here,

$$\begin{aligned}\mathbb{E}[v_c^j] &= w_c^j(t) + \sum_{d\in\mathcal{C}}\sum_{k\in\mathcal{J}}\left(m_{cd}^{jk}\left(\nu\ln\left(\sum_{e\in\mathcal{C}}\sum_{l\in\mathcal{J}}e^{\frac{\bar{\epsilon}_{ce}^{jl}}{\nu}}\right)\right)\right) + \beta\mathbb{E}[v_c^j(t+1)] \\ &= w_c^j(t) + \beta\mathbb{E}[v_c^j(t+1)] + \nu\ln\left(\sum_{e\in\mathcal{C}}\sum_{l\in\mathcal{J}}e^{\frac{\bar{\epsilon}_{ce}^{jl}}{\nu}}\right)\end{aligned}$$

which finally implies, as in Artuç, Chaudhuri and McLaren (2010), that:

$$\Theta(\bar{\epsilon}_c^j) = \nu\ln\left(\sum_{e\in\mathcal{C}}\sum_{l\in\mathcal{J}}e^{\frac{\bar{\epsilon}_{ce}^{jl}}{\nu}}\right) = -\nu\ln\left(m_{cc}^{jj}\right) \tag{3.9}$$

Now pulling together equations 3.4 and 3.9,

$$\begin{aligned}\psi_{cd}^{jk} + \bar{\epsilon}_{cd}^{jk} &= \beta\mathbb{E}\left[v_d^k(t+1) - v_c^j(t+1)\right] \\ &= \beta\mathbb{E}\left[w_d^k(t+1) - w_c^j(t+1) + \mathbb{E}\left[v_d^k(t+2) - v_c^j(t+2)\right] + \Theta(\bar{\epsilon}_d^k(t+1)) - \Theta(\bar{\epsilon}_c^j(t+1))\right]\end{aligned}$$

$$\begin{aligned}\nu\left(\ln(m_{cd}^{jk}(t)) - \ln(m_{cc}^{jj}(t))\right) &= \mathbb{E}\Big[\beta\left(w_d^k(t+1) - w_c^j(t+1)\right) + \beta\bar{\epsilon}_{cd}^{jk}(t+1) \\ &\qquad - \beta\nu\ln(m_{dd}^{kk}(t+1)) + \beta\nu\ln(m_{cc}^{jj}(t+1)) - (1-\beta)\psi_{cd}^{jk}\Big] \\ \ln(m_{cd}^{jk}(t)) - \ln(m_{cc}^{jj}(t)) &= \frac{\beta}{\nu}\left(w_d^k(t+1) - w_c^j(t+1)\right) \\ &\qquad + \beta\left(\ln(m_{cd}^{jk}(t+1)) - \ln(m_{dd}^{kk}(t+1))\right) - \frac{(1-\beta)}{\nu}\psi_{cd}^{jk} + \mu_{cd}^{jk}(t+1)\end{aligned}$$

which is equation 1.8 in the text (where $\mu_{cd}^{jk}(t+1)$ contains information revealed at time $t+1$.

Maximum of Type 1 Extreme Value Distributions

Commonly called the Gumbel, the maximum of type 1 extreme value distributions (EVD1) with parameters $(-\gamma\nu, \nu)$ is also distributed as an EVD1. In the context of this paper, recall equation 1.3 and that ϵ_d^k is EVD1. Let each bracketed portion be defined by the associated Greek letters.

$$v_c^j(t) = \underbrace{w_c^j(t) + \beta\mathbb{E}[v_c^j(t+1)]}_{\mu_c^j} + \underbrace{\max_{d,k}\left\{\epsilon_d^k(t) - \psi_{cd}^{jk} + \beta\mathbb{E}[v_d^k(t+1)] - \beta\mathbb{E}[v_c^j(t+1)]\right\}}_{\delta_c^j}$$

Then, I am interested in the distribution of δ_c^j.

$$\delta_c^j = \max_{d,k}\left\{\underbrace{\beta\mathbb{E}[v_d^k(t+1)] - \beta\mathbb{E}[v_c^j(t+1)] - \psi_{cd}^{jk}}_{\delta_{cd}^{jk}} + \epsilon_d^k\right\}$$

$$
\begin{aligned}
\ln\left(\Pr[\delta_c^j \leq x]\right) &= \ln\left(\prod_{d,k} \Pr[\delta_{cd}^{jk} + \epsilon_d^k \leq x]\right) \\
&= \sum_{d,k} \ln\left(\Pr[\epsilon_d^k \leq x - \delta_{cd}^{jk}]\right) \\
&= \sum_{d,k} -e^{-\frac{x-\delta_{cd}^{jk}-\gamma\nu}{\nu}} \\
&= -e^{-\frac{x-\gamma\nu}{\nu}} e^{\ln\left(\sum_{d,k} e^{\frac{\delta_{cd}^{jk}}{\nu}}\right)} \\
&= -\exp\left(-\frac{x - \ln\left(\sum_{d,k} e^{\frac{\delta_{cd}^{jk}}{\nu}}\right) - \gamma\nu}{\nu}\right) \\
\Pr[\delta_c^j \leq x] &= \exp\left(-\exp\left(-\frac{x - \ln\left(\sum_{d,k} e^{\frac{\delta_{cd}^{jk}}{\nu}}\right) - \gamma\nu}{\nu}\right)\right)
\end{aligned}
$$

which is the CDF of a type 1 extreme value distribution with parameters: $\ln\left(\sum_{d,k} e^{\frac{\delta_{cd}^{jk}}{\nu}}\right) + \gamma\nu$, and ν. Call the summation term $\bar{\delta}_c^j$ The maximum in equation 1.3 has this distribution. Each occupation value therefore has a distribution $\mu_c^j + \delta_c^j$ were $\delta_c^j \sim EVD1\left(\bar{\delta}_c^j + \gamma\nu, \nu\right)$. I also use the fact that $\delta_c^j - \bar{\delta}_c^j \sim EVD1(-\gamma\nu, \nu)$.

Let Y equal the maximum across all $\{d, k\} \neq \{c, d\}$ of all other occupation values. I can write:

$$
Y_c^j = \max_{\{d,k\} \neq \{c,j\}} \left(v_d^k(t) - \psi_{cd}^{jk}\right)
$$

Just as before,

$$
\begin{aligned}
\ln\left(\Pr[Y_c^j \leq y]\right) &= \ln\left(\prod_{\{d,k\}\neq\{c,j\}} \Pr\left[\mu_d^k + X_d^k - \psi_{cd}^{jk} \leq y\right]\right) \\
&= \ln\left(\prod_{\{d,k\}\neq\{c,j\}} \Pr\left[X_d^k \leq y - \mu_d^k + \psi_{cd}^{jk}\right]\right) \\
&= \sum_{\{d,k\}\neq\{c,j\}} -\exp\left(-\frac{y - \mu_d^k + \psi_{cd}^{jk} - \bar{\delta}_d^k - \gamma\nu}{\nu}\right) \\
&= -\exp\left(-\frac{y - \ln\left(\sum_{\{d,k\}\neq\{c,j\}} \exp\left(\frac{\mu_d^k - \psi_{cd}^{jk} + \bar{\delta}_d^k}{\nu}\right)\right) - \gamma\nu}{\nu}\right)
\end{aligned}
$$

This is the CDF of a new type 1 extreme value distribution with parameters:

$$
(\mathbb{E}[\bar{V}_c^j] + \gamma\nu, \nu) = \left(\ln\left(\sum_{\{d,k\}\neq\{c,j\}} \exp\left(\frac{\mu_d^k - \psi_{cd}^{jk} - \bar{\delta}_d^k}{\nu}\right)\right) + \gamma\nu, \nu\right)
$$

In the main text, I consider only the case of additively separable exit costs and migration costs. With those assumptions, the switching costs can be pulled out of the summation and shift the mean of the distribution. All other properties remain the same.

Difference of EVD1 Distributions is Logistic

I now consider the difference between two different type 1 extreme value distributions. For the sake of generality, I consider the case with jk and cd specific switching costs. Known properties of the type 1 extreme value distribution imply that the difference of two EVD1 distributions with the same variance has a logistic distribution. That is,

$$
\begin{aligned}
Y \sim EVD1(\mu_y, \nu) \qquad \text{and} \qquad & Z \sim EVD1(\mu_z, \nu) \\
\implies & Y - Z \sim \text{Logistic}(\mu_y - \mu_z, \nu)
\end{aligned}
$$

Therefore, as a worker considers the difference between potential occupations and continuing in the current occupation, they compare the optimal outside option with the random compenent of their current county-occupation. As section AII.B demonstrated, both of these distributions are type 1 extreme value. Their difference delivers the the logistic distribution:

$$\max_{\{d,k\}\neq\{c,j\}} \left[v_d^k(t) - \psi^{jk} - \phi_{cd}\right] - \left(\delta_c^j - \bar{\delta}_c^j\right) \sim \text{Logistic}\left(\mathbb{E}[\bar{V}_c^j(t)], \nu\right)$$

where

$$\mathbb{E}[\bar{V}_c^j] = \ln\left(\sum_{\{d,k\}\neq\{c,d\}} \exp\left(\frac{\mu_d^k + \bar{\delta}_d^k - \psi_{cd}^{jk}}{\nu}\right)\right) \tag{3.10}$$

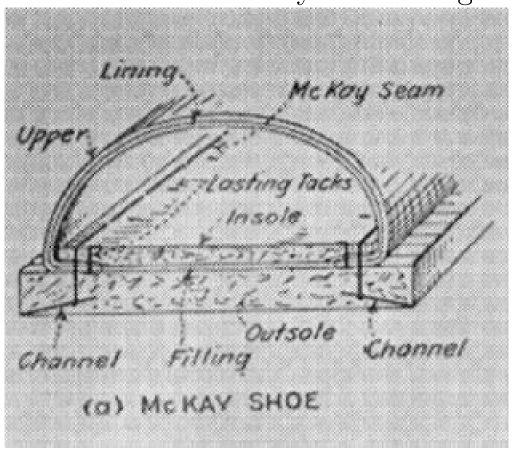
Finally, I can invert the Logistic distribution:

$$\begin{aligned}
F_c^j(x) &= \frac{1}{1+e^{-\frac{x-\mathbb{E}[\bar{V}_c^j]}{\nu}}} \\
1+e^{-\frac{x-\mathbb{E}[\bar{V}_c^j]}{\nu}} &= \frac{1}{F_c^j(x)} \\
-\frac{x-\mathbb{E}[\bar{V}_c^j]}{\nu} &= \ln\left(\frac{1-F_c^j(x)}{F_c^j(x)}\right) \\
x &= \mathbb{E}[\bar{V}_c^j] - \nu\ln\left(\frac{1-F_c^j(x)}{F_c^j(x)}\right) \\
\implies (F_c^j)^{(-1)}(y) &= \mathbb{E}[\bar{V}_c^j] + \nu\ln\left(\frac{y}{1-y}\right).
\end{aligned}$$

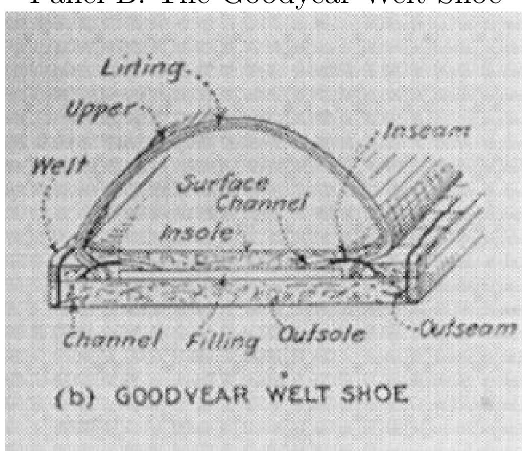
AIII Appendix Figures: Chapter 1

Figure A1: The McKay and Goodyear Welt Shoes

Panel A. The McKay Shoe Design



Panel B. The Goodyear Welt Shoe

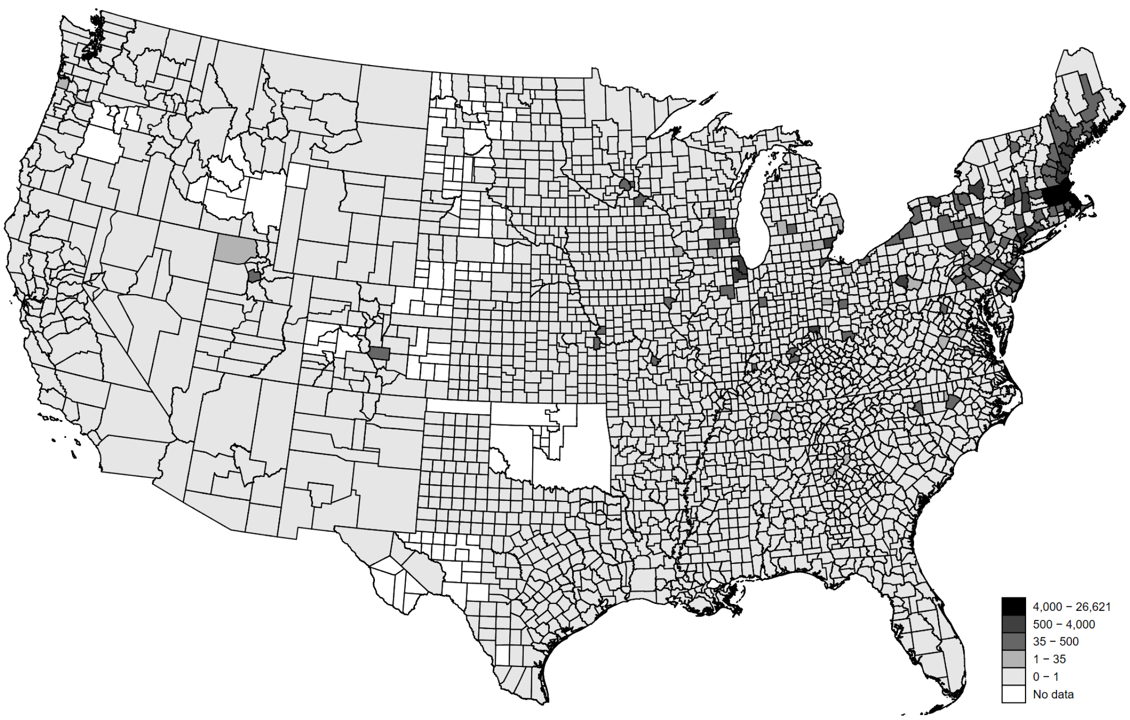


These images are from page 463 of Roe (1922). Panel A shows the design for the McKay shoe, which was originally invented by Lyman Reed Blake. Panel B shows the Goodyear Welt shoe design. This design was for a machine stitched shoe developed twenty years after the McKay shoe. The stitching design is much more similar to the hand stitching employed prior to 1860.

Figure A2: The McKay Stitcher

This machine is kept at the Museum L-A in Lewiston, Maine, United States. This specific design was called the McKay rotating horn machine.

Figure A3: Spatial Distribution of Shoe Manufacturing Employment, 1880



Notes: Shoe manufacturing employment is tabulated at the county level for 1880 and then reapportioned in 1890 county borders as shown above. Bins are divided at time consistent cutoff values forming 5 groups that are comparable with figure 1.2. Darker shades reflect higher employment levels.

AIV Appendix Tables: Chapter 1

Table A1: Estimated Number of McKay Stitchers in 1870, by County

County	Estimated Number of Machines
Essex, MA	165
Rockingham, NH	133
Plymouth, MA	73
Middlesex, MA	73
Worcester, MA	73
Philadelphia, PA	65
Rockland, NY	41
Fairfield, CT	35
Kings, NY	20
Oneida, NY	10
Hillsborough, NH	9
Franklin, ME	9
Barnstable, MA	3
Hamilton, OH	3
Salt Lake, UT	1

Notes: Details on estimating these values are described in section AI.D.

Table A2: Machine Use in Essex, MA

Type of Machinery	(1) Number of Establishments	(2) Median Revenue	(3) Median Employment
No Machine Reported	996	$500	1
Pegging Machine	22	$73,250	52
McKay Stitcher	55	$85,000	51

Notes: Machine use only considers machines known to work on the soles of shoes and therefore does not account for firms using sewing machines only. Employment is reported as employment plus one laborer to account for potential owner labor. This is important for establishments not reporting machine use, as the median employment without accounting for owners is zero workers.

Table A3: Aggregate Production in Massachusetts

	(1)	(2)	(3)	(4)
	Boots & Shoes		Other Manufacturing	
	Value	% Change	Value	% Change
Panel A. Revenue (millions)				
1860	46		437	
1870	56	20.8%	776	77.7%
1880	97	74.4%	1,174	51.4%
Panel B. Employment (thousands)				
1860	62		330	
1870	47	-24.6%	544	64.5%
1880	65	38.7%	677	24.5%
Panel C. Wagebill (millions)				
1860	15		89	
1870	14	-1.6%	135	84.5%
1880	24	66.7%	231	40.1%
Panel D. Wagebill / Employment				
1860	235		270	
1870	307	22.3%	303	-4.1%
1880	369	17.0%	340	18.5%
Panel E. Cases of Shoes (thousands)				
1860	649			
1870	1,250	92.8%		
1880	2,264	81.1%		

Notes: Aggregate values for revenue (Panel A), employment (Panel B), and the wagebill (Panel C) are summed across counties. Panel D is the entries from panel C divided by panel D. Panel E are only available for the state of Massachusetts.

Percents reported in columns 2 and 4 are 1 year change. For example, the percent change in revenue in 1870 is equal to revenue in 1870 minus revenue in 1860 divided by revenue in 1860.

Table A4: Total Shipments of Shoes from Boston Outside of New England, 1875

County	Number of Cases	Percent of Total
New York, NY	138,169	8.25
Cook, IL	116,631	6.97
Philadelphia, PA	106,099	6.34
St. Louis, MO	101,515	6.06
Hamilton, OH	75,212	4.49
Baltimore, MD	68,158	4.07
St. Bernard, LA	49,307	2.94
Jefferson, KY	39,975	2.39
San Francisco, CA	33,810	2.02
Shelby, TN	25,827	1.54
Davidson, TN	25,777	1.54
Wayne, MI	21,671	1.29
Galveston, TX	21,339	1.27
Milwaukee, WI	21,001	1.25
Lucas, OH	18,278	1.09
Allegheny, PA	18,264	1.09
Charleston, SC	17,152	1.02
Henrico, VA	17,089	1.02
Cuyahoga, OH	15,768	.94
Vanderburgh, IN	13,532	.81
Marion, IN	13,517	.81
Ramsey, MN	12,504	.75
Norfolk, VA	12,373	.74
Erie, NY	11,519	.69
Monroe, NY	11,182	.67
Fayette, KY	11,063	.66
Adams, IL	9,565	.57
Buchanan, MO	9,452	.56
De Kalb, GA	9,385	.56
Franklin, OH	9,025	.54
Chatham, GA	8,897	.53
Bibb, GA	8,372	.50
Knox, TN	7,996	.48
Mobile, AL	7,657	.46
Other towns	587,236	35.07

Notes: Cases contained between 50 and 60 pairs of shoes depending on the type and quality of shoe.

Table A5: Summary Statistics of Sample Individuals in 1860

	(1) Shoemakers	(2) All Craftsmen	(3) Carpenters	(4) Tailors
Exposure	1.09	0.90	0.86	1.03
	(0.83)	(0.95)	(0.94)	(0.88)
Personal Property	444	724	562	780
	(14,200)	(15,800)	(13,900)	(14,700)
Real Estate Property	842	1,246	1,084	1,081
	(18,500)	(18,100)	(15,700)	(15,700)
Total Property	1,286	1,970	1,646	1,861
	(23,400)	(25,300)	(22,100)	(21,900)
Age	35	35	36	36
	(10)	(9)	(9)	(8)
Observations	30,126	177,536	52,919	9,470

Notes: Each column shows summary statistics for the baseline characteristics of shoemakers and each counterfactual comparison group. The sample is conditional on being linked from the 1860 census to the 1870 and 1880 censuses. Column 1 reports summary statistics for shoemakers in 1860, column 2 for all other craftsmen, column 3 for carpenters, and column 4 for tailors. Variables and categories are the 1860 baseline values.

The exposure variable is defined in equation (1.1) and normalized across counties. Property values and age are self reported in 1860.

Standard deviations are reported in parentheses.

Table A6: Incumbent Workers: Evaluating Pre-trends

	Exit Occupation (1)	Migrate >100 Miles (2)	Log Property Value (3)
Panel A. Baseline			
Exposure × Shoemaker	0.022	-0.003	0.010
	(0.007)	(0.002)	(0.015)
Shoemaker	-0.084	-0.000	-0.445
	(0.009)	(0.004)	(0.021)
Observations	219,851	219,851	180,791
Number of FE Groups	7,881	7,881	7,746
Panel B. Drop Massachusetts			
Exposure × Shoemaker	0.006	-0.003	0.019
	(0.005)	(0.003)	(0.017)
Shoemaker	-0.086	-0.000	-0.435
	(0.007)	(0.004)	(0.019)
Observations	190,060	190,060	157,592
Number of FE Groups	7,568	7,568	7,437
Panel C. Drop McKay Counties			
Exposure × Shoemaker	0.017	-0.004	0.008
	(0.007)	(0.002)	(0.016)
Shoemaker	-0.098	0.001	-0.424
	(0.007)	(0.004)	(0.019)
Observations	182,709	182,709	152,387
Number of FE Groups	7,528	7,528	7,394
Panel D. Clustering by State-Occupation Pair			
Exposure × Shoemaker	0.022	-0.003	0.010
	(0.011)	(0.003)	(0.023)
Shoemaker	-0.084	-0.000	-0.445
	(0.012)	(0.005)	(0.035)
Observations	219,851	219,851	180,791
Number of FE Groups	7,881	7,881	7,746

Notes: All columns are regressions on the exposure measure, shoemaker fixed effects, and individual observables in 1850: indicator of literacy, quadratic of age. All estimates are comparing shoemakers with all other craftsmen in 1850. Panel A is the baseline estimate, panel B drops Massachusetts counties, panel C drops McKay counties, and panel D clusters by state-occupation.

The outcome variables are: an indicator that occupation in 1860 is different than 1850 (column 1), an indicator of whether the reported location in 1860 is more than 100 miles from the location in 1850 (column 2), and the log of property value in 1860 (column 3).

Robust standard errors clustered by 1850 county-occupation are reported in parentheses.

Table A7: Incumbent Workers: Robustness to Migration Definition

	Short Run 1860-1870 (1)	Long Run 1860-1880 (2)	Continuing Effects 1870-1880 (3)
1. Baseline: Migrate >100 miles			
Exposure × Shoemaker	0.003	0.004	0.003
	(0.002)	(0.003)	(0.002)
2. Migrate >50 miles			
Exposure × Shoemaker	0.002	0.004	0.003
	(0.002)	(0.003)	(0.002)
3. Migrate >200 miles			
Exposure × Shoemaker	0.002	0.004	0.003
	(0.002)	(0.003)	(0.002)
Observations	200,330	200,330	200,330

Notes: All columns are regressions on the exposure measure, shoemaker fixed effects, county-town fixed effects, and individual observables in 1860: indicator of literacy, quadratic of age, inverse hyperbolic sine (IHS) of log personal property, and IHS of real estate property. All results are comparisons between shoemakers and all other craftsmen.

The outcome variables are: indicators for whether the later year county is over 100 miles away from the individuals earlier year county (panel A), over 50 miles (panel B), or over 200 miles (panel C).

Robust standard errors clustered by county-occupation are reported in parentheses.

Table A8: Target Occupations of Shoemakers

Occupation	(1) Frequency	(2) Percent
Panel A. Detailed Target Occupations in 1870		
Shoemakers and Repairers, Except Factory	12,678	43.60
Operative and Kindred Workers	5,214	17.93
Farmers (Owners and Tenants)	4,182	14.38
Managers, Officials, and Proprietors	2,169	7.46
Laborers	941	3.24
Farm Laborers, Wage Workers	844	2.90
Carpenters	436	1.50
Salesmen and Sales Clerks	275	0.95
Truck and Tractor Drivers	158	0.54
Other Occupations	2,184	7.51
Panel B. Detailed Target Occupations in 1880		
Shoemakers and Repairers, Except Factory	10,780	37.59
Farmers (Owners and Tenants)	5,534	19.30
Operative and Kindred Workers	4,333	15.11
Managers, Officials, and Proprietors	2,529	8.82
Laborers	1,407	4.91
Farm Laborers, Wage Workers	463	1.61
Carpenters	429	1.50
Salesmen and Sales Clerks	271	.95
Truck and Tractor Drivers	174	0.61
Other Occupations	2,756	9.61

Notes: For shoemakers in 1860, panel A tabulates 1870 occupations and panel B tabulates 1880 occupations for the same individuals. Column 1 reports the number of individuals and column (2) reports the percentage of the total in that occupation. Percentages are reported out of all shoemakers reporting occupations in that decade. This excludes individuals that left the work force.

Table A9: Incumbent Shoemakers: Wage Scores

	Wages in 1870		Wages in 1880	
	OCC Score	LIDO Score	OCC Score	LIDO Score
	(1)	(2)	(3)	(4)
Exposure × Shoemaker	-0.013	-0.009	-0.018	-0.015
	(0.003)	(0.003)	(0.003)	(0.003)
Shoemaker	-0.005	0.014	0.009	0.044
	(0.005)	(0.004)	(0.005)	(0.004)
Control Mean	3.16	3.04	3.17	3.07
R-squared	0.222	0.266	0.212	0.312
Observations	180,060	170,587	186,068	160,349
Number of FE Groups	9,557	9,438	9,648	9,174

Notes: All columns are regressions on the exposure measure, shoemaker fixed effects, and individual observables in 1860: indicator of literacy, quadratic of age, inverse hyperbolic sine of personal property and real estate property, and the log outcome variable in 1860 (pre-technology). All regressions are comparing shoemakers with all other craftsmen.

The outcome variables are: the log of occupation score in 1870 and 1880 (Columns 1 and 3) and the individual LIDO score in 1870 and 1880 (Columns 2 and 4).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Table A10: Incumbent Workers: IHS Property Values in 1870

	IHS Total Property (1)	IHS Personal Property (2)	IHS Real Estate Property (3)
Exposure × Shoemaker	-0.103	-0.111	-0.096
	(0.028)	(0.030)	(0.032)
McKay County × Shoemaker	-0.406	-0.405	-0.292
	(0.085)	(0.115)	(0.087)
Shoemaker	-0.151	-0.143	-0.102
	(0.031)	(0.030)	(0.039)
Control Mean	6.60	5.21	5.15
R-squared	0.207	0.184	0.257
Observations	200,330	200,330	200,330
Number of FE Groups	9,831	9,831	9,831

Notes: All columns are regressions on the exposure measure, an indicator for McKay counties interacted with being a shoemaker, shoemaker fixed effects, county-town fixed effects, and individual observables in 1860: indicator of literacy, quadratic of age, and the inverse hyperbolic sine (IHS) of personal property and real estate property. All estimates compare shoemakers with all other craftsmen.

The outcome variables are: the IHS of the sum of personal property and real estate property (column 1), the IHS of self-reported personal property values (column 2), and the IHS of self-reported real estate property values (column 3).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Table A11: Incumbent Workers: Robustness to Exposure Definition

	Exit Occupation (1)	Migrate >100 Miles (2)	Log Property Value (3)
1. Baseline	0.076	0.003	-0.058
	(0.011)	(0.002)	(0.012)
2. Include Own County	0.097	0.002	-0.067
	(0.011)	(0.002)	(0.011)
3. Average Price of Transported Goods = 100	0.028	0.003	-0.030
	(0.013)	(0.002)	(0.013)
4. Trade Elasticity = 8	0.088	0.004	-0.061
	(0.012)	(0.002)	(0.011)
5. Using 1870 Railroad Network	0.067	0.004	-0.053
	(0.011)	(0.002)	(0.012)
6. Using Mean of 1860 and 1870 Transportation Costs	0.072	0.003	-0.056
	(0.011)	(0.002)	(0.012)
7. Distance to Closest Stitcher	0.077	-0.001	-0.063
	(0.013)	(0.002)	(0.010)
8. Firm Market Access, $\theta^T = 15$	0.052	0.001	-0.056
	(0.013)	(0.002)	(0.012)
Observations	200,330	200,330	77,467

Notes: All columns are regressions on the exposure measure, shoemaker fixed effects, and individual observables. Each panel reports a different specification used in computing the estimates.

The outcome variables are: an indicator that occupation in 1870 is different than 1860 (column 1), an indicator of whether the reported location in 1870 is more than 100 miles from the location in 1860 (column 2), and the log of property value in 1870 (column 3).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Table A12: Incumbent Workers: Robustness to Specification

	Exit Occupation (1)	Migrate >100 Miles (2)	Log Property Value (3)
1. Baseline			
Exposure × Shoemaker	0.076	0.003	-0.058
	(0.011)	(0.002)	(0.012)
2. Control for expanding railroad network			
Exposure × Shoemaker	0.076	0.004	-0.067
	(0.012)	(0.002)	(0.013)
3. No Individual Controls			
Exposure × Shoemaker	0.077	0.003	-0.088
	(0.011)	(0.002)	(0.013)
4. County Fixed Effects			
Exposure × Shoemaker	0.086	0.003	-0.062
	(0.012)	(0.002)	(0.011)
5. No Fixed Effects			
Exposure × Shoemaker	0.103	0.000	-0.090
	(0.019)	(0.003)	(0.020)
6. State-Occupation Clustering			
Exposure × Shoemaker	0.076	0.003	-0.058
	(0.018)	(0.002)	(0.011)
7. Twoway Clustering, County and Occupation			
Exposure × Shoemaker	0.076	0.003	-0.058
	(0.019)	(0.002)	(0.008)
Observations	200,330	200,330	77,467

Notes: All columns are regressions on the exposure measure and shoemaker fixed effects. Each panel reports a different specification used in computing the estimates.

The outcome variables are: an indicator that occupation in 1870 is different than 1860 (column 1), an indicator of whether the reported location in 1870 is more than 100 miles from the location in 1860 (column 2), and the log of property value in 1870 (column 3).

Robust standard errors clustered by county-occupation are reported in parentheses for rows 1 to 5.

Table A13: Incumbent Workers: Robustness to Sample Definition

	Exit Occupation (1)	Migrate >100 Miles (2)	Log Property Value (3)
Panel A. Baseline			
Exposure × Shoemaker	0.076	0.003	-0.058
	(0.011)	(0.002)	(0.012)
Observations	200,330	200,330	77,467
Panel B. Compare with Carpenters			
Exposure × Shoemaker	0.091	0.006	-0.067
	(0.012)	(0.002)	(0.015)
Observations	78,716	78,716	31,043
Panel C. Compare with Tailors			
Exposure × Shoemaker	0.032	-0.013	-0.051
	(0.008)	(0.003)	(0.026)
Observations	36,289	36,289	10,948
Panel D. Compare with Laborers			
Exposure × Shoemaker	0.078	-0.003	-0.025
	(0.008)	(0.003)	(0.015)
Observations	123,153	123,153	23,957
Panel E. Drop McKay Counties			
Exposure × Shoemaker	0.062	0.003	-0.059
	(0.010)	(0.002)	(0.012)
Observations	169,463	169,463	69,025
Panel F. Drop Massachusetts Counties			
Exposure × Shoemaker	0.050	0.003	-0.053
	(0.008)	(0.002)	(0.013)
Observations	177,961	177,961	70,834
Panel G. Drop the South			
Exposure × Shoemaker	0.072	0.003	-0.052
	(0.011)	(0.002)	(0.012)
Observations	186,233	186,233	73,037
Panel H. The Census Tree Project Links			
Exposure × Shoemaker	0.066	0.002	-0.056
	(0.013)	(0.003)	(0.010)
Observations	407,047	407,047	127,661
Panel I. ABE Census Links			
Exposure × Shoemaker	0.080	0.002	-0.069
	(0.014)	(0.006)	(0.016)
Observations	63,174	63,174	53,292

Notes: All columns are regressions on the exposure measure and shoemaker fixed effects. Each panel reports a different sample used in computing the estimates.

The outcome variables are: an indicator that occupation in 1870 is different than 1860 (column 1), an indicator of whether the reported location in 1870 is more than 100 miles from the location in 1860 (column 2), and the log of property value in 1870 (column 3).

Robust standard errors clustered by county-occupation pair are reported in parentheses.

Table A14: Children of Shoemakers: Full-Time Student Status

	Student in Next Decade	
	(1)	(2)
Panel A. Children Born before 1860		
Exposure × Shoemaker	-0.020	-0.019
	(0.007)	(0.007)
McKay County × Shoemaker		-0.017
		(0.014)
Shoemaker, Parent	0.002	0.005
	(0.008)	(0.008)
Control Mean	.18	.18
Observations	48,413	48,413
Number of FE Groups	1,155	1,155
Panel B. Children Born between 1860 and 1870		
Exposure × Shoemaker	-0.024	-0.023
	(0.007)	(0.007)
McKay County × Shoemaker		-0.018
		(0.021)
Shoemaker, Parent	-0.010	-0.007
	(0.009)	(0.009)
Control Mean	.18	.18
Observations	45,077	45,077
Number of FE Groups	1,150	1,150

Notes: All results are comparisons between the children of shoemakers and the children of other craftsmen. Column 1 reports regressions on the exposure measure and parent-shoemaker fixed effects, and county fixed effects. Panel A is a sample of children born before 1860, and panel B is the sample of children born to 1860 shoemakers or craftsmen between 1860 and 1870.

The outcome variable is an indicator for whether the child reports student as their occupation in the next decade (1870 for panel A and 1880 for panel B).

Robust standard errors clustered by parent's county-occupation are reported in parentheses.

Table A15: Children of Shoemakers: Wages in 1880 and 1900

	Wages in 1880		Wages in 1900	
	OCC	LIDO	OCC	LIDO
	(1)	(2)	(3)	(4)
Exposure × Shoemaker	-0.027	-0.020	-0.030	-0.020
	(0.006)	(0.005)	(0.005)	(0.005)
Shoemaker, Parent	-0.025	-0.027	-0.018	-0.015
	(0.008)	(0.008)	(0.007)	(0.006)
Control Mean	2.99	2.97	3.16	3.09
R-squared	0.156	0.205	0.092	0.141
Observations	71,902	47,185	89,865	81,721
Number of FE Groups	1,199	1,124	1,216	1,198

Notes: All columns are regressions on the parents' exposure and parent shoemaker fixed effects. All regressions are comparing the children of shoemakers with the children of all other craftsmen.

The outcome variables are: the log of occupation score in 1880 and 1900 (columns 1 and 3) and the individual LIDO score in 1880 and 1900 (columns 2 and 4).

Robust standard errors clustered at the parent's county-occupation pair are reported in parentheses.

Table A16: Children of Shoemakers: Property after 40 Years

	Own a Home	Paid off Mortgage
	(1)	(2)
Exposure × Shoemaker	-0.006	-0.004
	(0.005)	(0.006)
McKay County × Shoemaker	-0.024	-0.024
	(0.010)	(0.018)
Shoemaker, Parent	-0.007	0.004
	(0.006)	(0.008)
Control Mean	.58	.32
R-squared	0.050	0.067
Observations	115,589	64,223
Number of FE Groups	1,655	1,559

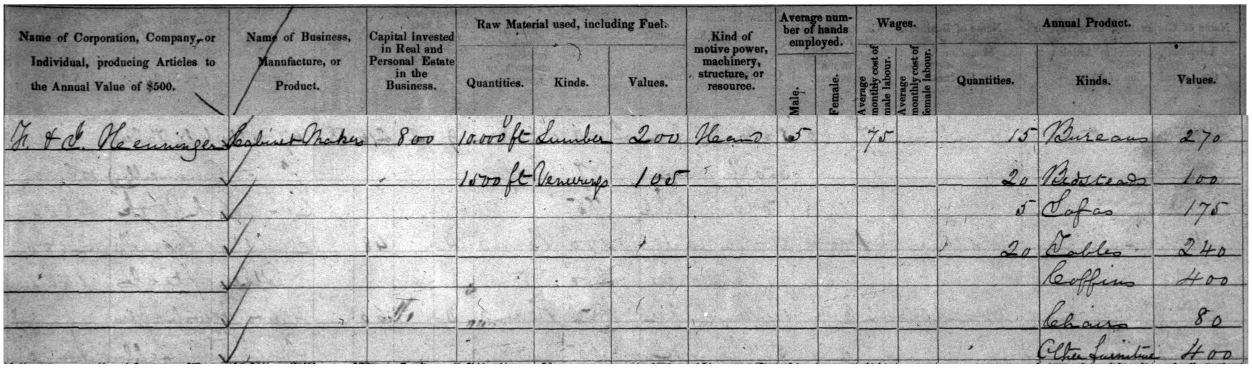
Notes: All columns are regressions on the parents' exposure in 1860, an indicator for a parent being a shoemaker in a McKay county in 1860, and an indicator for whether a child's parent was a shoemaker in 1860. The sample contains sons born before 1870.

The outcome variables are: indicators for whether a child owns a home in 1900 (column 1) and whether a child has paid off their mortgage, conditional on owning a home in 1900 (column 2).

Robust standard errors clustered at the parent's county-occupation pair are reported in parentheses.

AV Appendix Figures: Chapter 2

Figure A4: Image from 1850 US Census of Manufacturers



Name of Corporation, Company, or Individual, producing Articles to the Annual Value of $500.	Name of Business, Manufacture, or Product.	Capital invested in Real and Personal Estate in the Business.	Raw Material used, including Fuel.			Kind of motive power, machinery, structure, or resource.	Average number of hands employed.		Wages.		Annual Product.		
			Quantities.	Kinds.	Values.		Male.	Female.	Average monthly cost of male labour.	Average monthly cost of female labour.	Quantities.	Kinds.	Values.
F. & J. Henninger	Cabinet Maker	800	10000 ft	Lumber	200	Hand	5		75		15	Bureaus	270
			1800 ft	Veneering	105						20	Bedsteads	100
											5	Sofas	175
											20	Tables	240
												Coffins	400
												Chairs	80
												Other furniture	400

AVI Appendix Tables: Chapter 2

Table A17: Market Access and County Aggregates

Value Added	Output	Wagebill	Capital	Mat Val
	(1)	(2)	(3)	(4)
Log Market Access	0.094	0.080	0.062	0.101
	(0.077)	(0.114)	(0.087)	(0.067)
Observations	1,857	1,857	1,857	1,857

Notes: Each column is a regression of the output variable on market access along with county fixed effects, state-year fixed effects, a polynomial of latitude and longitude coordinates interacted with year.

Outcome variables are: log county revenue (column 1), log county wagebill (column 2), log county capital expenditure (column 3), and log county materials expenditure (column 4).

Robust standard errors, clustered at the state-level, are reported in parentheses.

AVII Appendix Figures: Chapter 3

Figure A5: The Business Directory from October 1, 1878

THE TELEPHONE JOURNAL. 7

BUSINESS DIRECTORY.

BAKERIES.

WIRE. CALL.
152 4 CHICAGO BAKERY CO., 196–202 S Clark st.
125 3 DAKE BAKERY, 24–26 N. Clinton st.

BAKING POWDERS AND YEAST.

46 2 KIRKHAM, C. H., 9 Wabash ave.
1 3 STEELE & PRICE, 110–112 Randolph st

BARRELS.

116 2 BRADSHAW, F M., 280 Centre ave

BANKS.

78 4 CORN EXCHANGE NATIONAL BANK, Chamber of Commerce
78 2 CHICAGO CLEARING HOUSE, 80–82 5th ave.

BASE BALL SUPPLIES.

1 2 SPAULDING, A. G & BRO., 118 Randolph st.

BROOM CORN.

104 3 GROSS, J P. & CO., 233–235 E. Kinzie st.

BILLIARD TABLES.

2 BRUNSWICK, J M. & BALKE CO., 47–49 State st.
3 BRUNSWICK, J. M. & BALKE CO., Rush, corner Kinzie st.

BRASS AND METAL.

93 4 SCOVILLE MFG. CO., 183 Lake st.
76 5 UNION BRASS CO., 99–103 Ohio st.

BOXES—WOOD AND PAPER.

502 2 HAIR & ELPHICKE, 545 W 22d st.
154 5 RANDALL, A. S. & T. P., 184 Monroe st.
176 2 RITCHIE & DUCK, 135 Michigan ave.
504 2 STEPHENS, HENRY, Throop and 22d sts.
53 5 SCHULTZ, H., 51 State st.

CANNED GOODS.

18 5 ARMSBY, J. K. & CO., 22–24 River st.
42 5 CLARK & LOVEDAY, 34–36 S. Water st
38 4 WAIDNER, F A & BRO., 45 River st.
110 3 RAILTON, W H., 9 La Salle st.

CHILDREN'S CARRIAGES.

194 4 WILL, HENRY & CO., 378 5th ave

COMMERCIAL COLLEGE.

5 3 BRYANT & STRATTON, 77–81 State st

CONFECTIONERS.

41 4 BROOKS & NEEMES, 36–38 Michigan ave
13 3 KRANZ, JOHN, 78–80 State st.
93 3 PAGE, M. E. & CO., 211–213 Lake st.
20 3 SPOEHR, C. A., 416 State st.

COFFIN MANUFACTURERS.

194 2 HILL, F H. & CO., 292 Franklin st

CORDS AND TASSELS.

3 4 PETERS, M., 61 Washington st

CHROMOS.

113 4 BOWEN, H. S., 86 Market st.
82 3 KELLY, WM. & CO., 199 Randolph st.
82 2 KELLY, WM. & CO., 202 Randolph st.

CITY MESSENGER OFFICE.

75 3 McCLORY, T A., 133 Madison st.

CAR AND BRIDGE COS.

168 2 PULLMAN PALACE CAR CO., Adams st., corner Michigan ave.
160 2 WELLS & FRENCH CO., 146 Dearborn st.
500 3 WELLS & FRENCH CO., Blue Island ave

COMMISSION MERCHANTS.

88 2 GERSTENBURG, C. & CO., 199 Kinzie st.

COMMERCIAL AGENCIES.

WIRE. CALL.
2 CHICAGO COMMERCIAL AGENCY, 162 Washington st.

COAL.

29 2 BOWEN & LESTER, 57 Lake st.
9 3 DRAKE & MOODY, 88 Washington st.
196 4 DRAKE & MOODY, 470 S. Clark st.
5 4 KELLEY & MORLEY, 97 Washington st.
123 4 LAW, ROBT., 180 Madison st.
100 2 LAW, ROBT., North Pier
5 3 WATSON COAL & MINING CO., 101 Washington st.
*WILMINGTON COAL ASSOCIATION, 41 W. Van Buren, cor. Canal.

CORONER.

88 4 CORONER'S OFFICE, Room 10, County Building

DISTILLERS AND RECTIFIERS.

130 2 GARDEN CITY DISTILLING & RECTIFYING CO., 57 S. Canal st.
506 3 GARDEN CITY DISTILLING & RECTIFYING CO., Canalport ave. and Morgan st.
58 5 HAMBURGER BROS., 1–3 Randolph st.
96 5 RIVERDALE DISTILLING CO., 263 Kinzie st.

DETECTIVE AGENCY.

128 2 PINKERTON, ALLAN, 191–193 5th ave.

DRUGGISTS.

61 3 BUCK & RAYNER, 117 Clark st.
61 4 BUCK & RAYNER, 135 State st.

DRUGS, PAINTS AND OILS.

114 5 ARMSTRONG & CO., 246 Lake st.
50 3 CHICAGO WHOLESALE DRUG, PAINT AND OIL EXCHANGE, 42 Wabash ave
125 4 CHICAGO WHITELEAD AND OIL CO., Clinton and Fulton.
92 4 FRAZER LUBRICATING OIL CO., 184 Kinzie st.
1 4 HURLBUT, H. A. & CO., 75 Randolph st
45 4 HANFORD, P. C & CO., 3 Wabash ave.
196 5 LAKE SHORE & MICHIGAN SOUTHERN OIL HOUSE, Clark and 12th sts.
54 3 LORD, STOUTENBURGH & CO., 86 Wabash ave.
49 3 MORRISON, PLUMMER & CO., 54 Lake st.
164 4 MURRAY & NICKELL, 77 Jackson st.
96 3 PARKER, COIT & CO., 206 Kinzie st.
84 3 PIONEER OIL CO., 217 No. Water st.
101 2 SENOUR, P. P. & CO., 205 Randolph st.
22 2 SPRAGUE, SMITH & CO., 49 Dearborn st.
37 3 STANDARD OIL CO., 17 Wabash ave
21 3 VAN SCHAAK, STEVENSON & CO., 92–94 Lake st
121 5 UNION OIL CO., 50 Erie st.

DRUG COMMISSION.

22 3 BARRETT, M. L., 38 Dearborn st.

ENGRAVERS.

152 3 BAKER & CO., 184 No. Clark st.
3 2 DRANT & HAWTINS, 114 Dearborn st.

EXCHANGES.

10 2 FURNITURE MANUFACTURERS' EXCHANGE, 69 Dearborn st.
80 2 LUMBERMAN'S EXCHANGE, 238 No. Water st.
153 2 PROVISION, GRAIN & STOCK BOARD, Exchange Place.

ELECTROTYPE AND STEREOTYPE.

200 2 BLOMGREN BROS. & CO., 162–164 No. Clark st.

EXPRESS COS.

204 2 ADAMS EXPRESS CO., 53 Madison st.
58 3 BRINK'S EXPRESS, 39 Randolph st.
55 2 UNITED STATES EXPRESS CO., 89 Washington st.

FISH AND OYSTERS.

25 2 BOOTH, A., 63 Lake st.
13 5 LAFLIN & CO., 40 State st.

FRUIT BUTTER.

92 3 KLIEN, H P. & CO., 155 Kinzie st.

A Page from the Classified Section
Chicago Telephone Directory, October 1, 1878

AVIII Appendix Tables: Chapter 3

Table A18: Log Difference between High and Low Weekly Futures Prices

	Log Difference in Price					
	All Products			Animal Products		
	± 6 weeks	± 9 Weeks	± 12 Weeks	± 6 weeks	± 9 Weeks	± 12 Weeks
	(1)	(2)	(3)	(4)	(5)	(6)
After the Telephone	-0.019	-0.024	-0.017	-0.030	-0.051	-0.051
	(0.007)	(0.007)	(0.008)	(0.012)	(0.012)	(0.010)
Number of Products	13	13	13	6	6	6
Observations	515	764	998	237	347	446

Notes: All columns are regressions on the date, the date interacted with after the June 26th of each year, fixed effects for all product-expiration groups, an indicator for any date after the June 26th, and finally an indicator for after June 26th only in 1878 (the introduction of the telephone). The reported value is the coefficient on this last term. The sample for each column varies according to the indicated time window: 6 weeks for column 1, 9 weeks for column 2, and 12 weeks for column 3.

The outcome variables are the log of the difference between the high and low prices for each product in a given week.

Robust standard errors are reported in parentheses.

Table A19: Spot Prices: Robustness of Comparison Years

	Log Difference Between High and Low Prices					
	All Products			Animal Products		
	6 Weeks	9 Weeks	12 Weeks	6 Weeks	9 Weeks	12 Weeks
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Compare with 1877						
After the Telephone	-0.030	-0.032	-0.030	-0.041	-0.044	-0.047
	(0.010)	(0.008)	(0.007)	(0.012)	(0.010)	(0.010)
Number of Products	45	45	45	21	21	21
Observations	873	1,330	1,791	469	703	935
Panel B. Compare with 1879						
After the Telephone	-0.032	-0.043	-0.039	-0.036	-0.054	-0.056
	(0.008)	(0.007)	(0.007)	(0.011)	(0.010)	(0.009)
Number of Products	44	44	44	21	21	21
Observations	903	1,355	1,821	495	740	986
Panel C. Compare with 1880						
After the Telephone	-0.019	-0.015	-0.021	-0.030	-0.030	-0.048
	(0.008)	(0.006)	(0.006)	(0.011)	(0.009)	(0.009)
Number of Products	44	44	44	21	21	21
Observations	849	1,299	1,751	468	706	949

Notes: All columns are regressions on the date, the date interacted with after the June 26th of each year, fixed effects for all product groups, an indicator for any date after the June 26th, and finally an indicator for after June 26th only in 1878 (the introduction of the telephone). The reported value is the coefficient on this last term. Panels A, B, and C report comparisons with only 1877, 1879, and 1880, respectively. The sample for each column varies according to the indicated time window: 6 weeks for Columns 1 and 4, 9 weeks for columns 2 and 5, and 12 weeks for columns 3 and 6. Columns 1-3 use all products, while columns 4-6 consider only animal products.

The outcome variables are the log of the difference between the high and low prices for each product in a given week for spot prices.

Robust standard errors are reported in parentheses.

Table A20: Futures Contract Prices: Robustness of Comparison Years

	Log Difference Between High and Low Prices					
	All Products			Animal Products		
	6 Weeks	9 Weeks	12 Weeks	6 Weeks	9 Weeks	12 Weeks
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Compare with 1877						
After the Telephone	-0.001	-0.002	0.002	-0.003	-0.006	-0.005
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Number of Products	14	14	14	6	6	6
Observations	1,319	1,984	2,585	614	917	1,173
Panel B. Compare with 1879						
After the Telephone	-0.006	-0.010	-0.009	-0.011	-0.018	-0.017
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Number of Products	15	15	15	6	6	6
Observations	1,438	2,150	2,820	655	963	1,245
Panel C. Compare with 1880						
After the Telephone	-0.001	-0.001	-0.003	-0.002	-0.008	-0.013
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Number of Products	15	16	16	7	7	7
Observations	1,445	2,197	2,914	667	992	1,293

Notes: All columns are regressions on the date, the date interacted with after the June 26th of each year, fixed effects for all product-expiration groups, an indicator for any date after the June 26th, and finally an indicator for after June 26th only in 1878 (the introduction of the telephone). The reported value is the coefficient on this last term. Panels A, B, and C report comparisons with only 1877, 1879, and 1880, respectively. The sample for each column varies according to the indicated time window: 6 weeks for Columns 1 and 4, 9 weeks for columns 2 and 5, and 12 weeks for columns 3 and 6. Columns 1-3 use all products, while columns 4-6 consider only animal products.

The outcome variables are the log of the difference between the high and low prices for each product in a given day for futures prices.

Robust standard errors are reported in parentheses.

Table A21: Relative Futures Contract Prices: Robustness of Comparison Years

	Log Difference between Two-month and One-month Futures Contract Prices		
	± 6 Weeks	± 9 Weeks	± 12 Weeks
	(1)	(2)	(3)
Panel A. Compare with 1877			
After the Telephone	0.012	0.009	0.007
	(0.004)	(0.004)	(0.004)
Number of Products	5	5	5
Observations	546	826	1,052
Panel B. Compare with 1879			
After the Telephone	0.005	0.006	0.009
	(0.003)	(0.003)	(0.003)
Number of Products	5	5	5
Observations	619	940	1,217
Panel C. Compare with 1880			
After the Telephone	0.025	0.030	0.047
	(0.005)	(0.004)	(0.005)
Number of Products	5	5	5
Observations	613	936	1,230

Notes: All columns are regressions on the date, the date interacted with after June 26th of the same year, fixed effects for 5 distinct products, and an indicator for any date after the counterfactual introduction of the telephone. Panels A, B, and C report the effect when comparing only with 1877, 1879, and 1880, respectively. Column 1 uses a sample of dates within 6 weeks of June 26th, column 2 within 9 weeks, and column 3 within 12 weeks.

The outcome variables are the log of the difference between the average daily price for two-month and one-month futures contracts.

Robust standard errors are reported in parentheses.