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Abstract

This paper presents a new picture of the labor market effects of technological change in pre-WWII United States. I show that, similar to the recent computerization episode, the electrification of the manufacturing sector led to a "hollowing out" of the skill distribution whereby workers in the middle of the distribution lost out to those at the extremes. To conduct this analysis, a new dataset detailing the task composition of occupations in the United States for the period 1880-1940 was constructed using information about the task content of over 4,000 occupations from the *Dictionary of Occupational Titles* (1949). This unique data was used to measure the skill content of electrification in U.S. manufacturing. OLS estimates show that electrification increased the demand for clerical, numerical, planning and people skills relative to manual skills while simultaneously reducing relative demand for the dexterity-intensive jobs which comprised the middle of the skill distribution. Thus, early twentieth century technological change was unskill-biased for blue collar tasks but skill-biased on aggregate. These results are in line with the downward trend in wage differentials within U.S. manufacturing up to 1950. To overcome any threat to the exogeneity of the electricity measure, due for example to endogenous technological change, 2 instrumental variable strategies were developed. The first uses cross-state differences in the timing of adoption of state-level utility regulation while the second exploits differences in state-level geography that encouraged the development of hydro-power generation and thus made electricity cheaper. The results from these regressions support the main conclusions of the paper.

JEL Codes: J23, O33, N32, N33

Keywords: Technological change, skill bias

1 Introduction

Electricity has been described by Jovanovic and Rousseau as one of the "two most important general purpose technologies to date"[1], along with computerization in the latter part of the twentieth century. Electrification of factories transformed the ways in which goods were manufactured in the United States after 1900. Economic historians have long been interested in this episode but typically the research focus has been on identifying the energy input savings and productivity gains[2]. However, other interesting questions remain– how did the relative position of labor change during this time of upheaval, and were workers of various skill levels affected differently? Here, I focus on these labor market effects during the years 1880 to 1940—specifically, I use new data on workplace tasks to show that electrification caused a "hollowing out" of the skill distribution, similar in nature to the phenomenon described in studies of computerization and inequality in the United States since 1960. In doing so, the paper helps explain why Goldin and Katz (2008) find evidence of skill-bias while Lindert and Williamson (1980) document a fall in the skill premium earned by high-skill blue collar workers. In the race between education and technology, this paper resurrects technology as a contributor to inequality trends during this period.

This paper takes the most direct approach yet to identifying the skill content of technological change in the period 1880-1940 in the United States. Previous research has used indirect measures of skill such as average establishment wages or occupational pay rates as the variable of interest[3]. Furthermore, pre-1940 there is no consistent and nationally-representative measures of education and incomes, which motivates the focus on quantity variables in this paper. Here, I will measure skill directly, according to the task composition of each job, and I will analyze the impact of technological change on the relative demand for tasks including managerial, clerical, dexterity and manual tasks. I define a task as a particular activity that is required of an occupation, or the intensity with which a particular skill is used—for example, the "manual" measure describes the extent to which strength is needed in an occupation, while the "clerical" measure details the degree of numerical accuracy and office skills required in a job[4]. In this way, I identify the types of changes that electrification exacted on the labor market over this period, controlling for shocks to labor supply such as increased educational attainment and immigration which might also have altered the skill distribution of American-born workers. Furthermore, I adopt two different instrumental variables approaches to provide the most rigorously tested results yet of the labor market effects of electrification. One instrument exploits differences across states in the timing of adoption of state-level regulation of the electric utility industry and the other uses cross-state

[1] Jovanovic and Rousseau (2005), p. 1.

[2] For instance, the dissertation of Woolf (1980) is focused on electrification and its effect on energy demand.

[3] Previous treatments include Atack, Bateman and Margo (2004) and Goldin and Katz (1998). Acemoglu (2002) criticized the dearth of direct evidence on this issue for the historical period.

[4] I go into more detail about the nature of the task measures in Section 4.1 and in the Data Appendix. See Table I for a full description of each of the variables mentioned in the text.

variation in geography to predict the extent of electricity adoption in a state's manufacturing sector. I find evidence that, looking at the manufacturing sector as a whole, numerical, clerical, planning and interpersonal skills increased in demand relative to manual and dexterity skills while, looking only at the skills used intensively on the factory floor, manual skills increased in importance relative to tasks requiring more skill and dexterity. The identification of this pattern of "polarization" in the labor force is a new result for the electrification era[5].

This result is important for several reasons. First, it provides a more nuanced and complete understanding of the nature of technological change in the early twentieth century. This may in turn have implications for another line of research, namely the literature that seeks to explain trends in inequality over this period. Previous research, typified by the work of Goldin and Katz, portrayed technological change in this era as being simply skill-biased or education-biased at all levels of production. In particular, Goldin and Katz (2008) looked across industries that were adopting electric power at different rates over the period 1909-1940 and showed that in 1940 industries that had adopted electricity more quickly over the period 1909-1929 employed more educated blue collar workers. Thus, they asserted that technology was skill-biased and that the downward trend in the education premium to 1950 must be explained by the increased supply of educated workers as a result of the "high-school revolution". However, I show here that, for the bulk of workers (those on the factory floor), electrification led to unskill-biased technological change, which may provide an alternative explanation for falling wage differentials between artisanal and manual workers[6].

One notable conclusion of this paper is that technological change has had remarkably consistent labor market effects over at least a century and a half. Various authors[7], most recently Atack, Bateman and Margo (2004), have shown that the move from artisanal to factory work in the mid-nineteenth century may have been de-skilling, or at least not biased in favor of skilled workers. They used detailed plant-level data for 1850-1880 and found that the advent of the factory likely led to an increased division of labor so that teams of unskilled workers could perform tasks previously done by a handful of skilled workers. Late in the period, as steam power predominated, there may have been an increase in the use of skilled labor which may have partially offset the bias in favor of unskilled workers. For the period since 1960 in the United States, Autor, Levy and Murnane (2003) used a modern dataset on the tasks required of occupations that is similar to the historical dataset used here to investigate the skill content of computerization. Using variation across industries and over time they found that demand for non-

[5] Chin *et al* (2006) also find a "hollowing out" type of result but they use data from only one industry, the merchant marine. They identify evidence of overall unskill-biased technical change in this industry at the same time as new professional jobs such as merchant engineer came into being.

[6] Lindert and Williamson (1980), pp. 78-9 showed clearly this trend using a variety of wage series.

[7] See also Field (1980)– he analyzed the skill composition of the Massachusetts workforce from 1820 to 1880 and found no great increase in skill intensity prior to 1870.

routine tasks increased while demand for routine-cognitive and routine-manual skills fell, suggesting that computers are complementary to the former but substitute for the latter. This skill bias explains a substantial part of the increase in inequality[8] for that period, and dwarfs the contribution of other more controversial causes, including the growth of trade and outsourcing and the weakening of union power. The results of this paper show that technological change up to 1940 exhibited characteristics of both of these episodes– the unskill-biased component and the hollowing out effect. The fact that, for the 80% of the manufacturing workforce who comprised the production sector, technology was unskill-biased before 1940 suggests that technological change may have played a larger role in the decline of wage differentials than has been identified heretofore.

The paper is organized as follows. Section 2 describes the nature of electrification and its predicted effects on relative labor demands. In Section 3 I present a theoretical model upon which the empirical analysis is based and in Section 4 I introduce the data. Section 5 explains the empirical strategy and presents the primary results of the paper. Section 6 concludes.

2 Electrification

Jovanovic and Rousseau (2005) have identified 1894 as the start date of the electrification era because the median industrial sector had achieved a 1% diffusion rate by then. As shown in Figure I, in 1900 steam was still the dominant source of power but by 1910 electricity was catching up rapidly, overtaking steam some time in the 1910s. This change was due to the technological advances in electricity production at central generating stations, as evidenced by the halving of electricity prices from 1909 to 1929[9]. What effect did this dramatic shift in power have on American industries and, in particular, what was the direction of this technological change?

Through historical documentation on engineering advances one can trace the key changes in the character of the American factory following the switch to electricity. The most fundamental shift involved the removal of the steam engine and the overhead shafts and belts which delivered power from engines to machines. In terms of labor demand, the direct effects of this change include a decrease in demand for maintenance workers and a decrease in demand for unskilled laborers who had previously carried unfinished products and tools around the factory but who were now replaced by overhead cranes operated by semi-skilled or skilled workers. The indirect effects are less obvious. Electricity allowed for factory re-organization and the introduction of complementary technologies. In the words of Devine

[8] For summaries of how the wage distribution became polarized during this time see: Autor, Katz and Kearney (2006), Autor, Katz and Krueger (1998), Acemoglu (1999) and Machin and Van Reenen (1998) among others.

[9] Woolf (1980), Table 3.2, p. 63. Originally in *Electric Power and Government Policy* (Twentieth Century Fund: New York, 1949), p. 782.

(1985), "electrification and plant reorganization often went hand-in-hand"[10]. With steam power, the main objective in the design of a factory was to minimize the inefficiencies of the steam engine—this usually meant that machines requiring the most energy were placed closest to the steam engine and machines of the same type were grouped together. The advent of electricity facilitated the move to “straight-line production” in which products passed through a line of machines. This proved a much faster method of production, contributing to the huge productivity gains that have been associated with technological change in this period[11]. These indirect savings were hailed as much bigger than the direct energy savings, as outlined by an engineer with the Crocker-Wheeler Electric Company:

"There were many factories which introduced electric power because we engaged to save from 20 to 60 percent of their coal bills; but such savings as these are not what has caused the tremendous activity in electric power equipment that is today spreading all over this country...those who first introduced electric power on this basis found that they were making other savings than those that had been promised, which might be called indirect savings"[12].

Some portion of the indirect savings was likely due to more efficient use of labor—a possibility that is supported by the historical literature. Most of the evidence regarding the labor market effects of technological change to 1940 relates to the factory floor. An early reference, from the 1900 population census, stated that “A factor that has had a real tendency to lower the actual earnings of the wage earner in many industries is the displacement of the skilled operator by machinery which permits the substitution of a comparatively unskilled machine hand”[13]. It added that the use of power and standardization of products had allowed the unskilled worker to become a skilled operator through the introduction of physical capital[14]. This characterization may well be appropriate post-1900 as well–Hounshell’s survey of the innovations made by the Ford Motor Company in the 1900s and 1910s states that the company’s new factories and machines were designed with simplicity in mind, with the aim that all machinery could be tended by unskilled workers[15]. But, speed and accuracy were also key goals in production, so skilled workers would still be required to some extent. The assembly line was among the innovations that resulted in more routinized jobs and it is argued that electricity was essential to its introduction[16]. An early study of the effects of mechanization by Jerome (1934) focused on the displacement of labor, mainly post-World War I. His work includes examples of new technologies

[10] Devine (1985), p. 46.

[11] David and Wright estimated that TFP increased at 5% per annum for 1919-1929. David and Wright (2003), p. 135.

[12] Crocker, F.B. (1901) "The Electric Distibution of Power in Workshops" *Journal of the Franklin Institute*, Vol. 151, No. 1, p. 9.

[13] Quoted in: *Recent Economic Changes in the United States: Report of the Committee on Recent Economic Changes of the President’s Conference on Unemployment* (McGraw-Hill, New York: 1929), p. 92.

[14] *Recent Economic Changes in the United States: Report of the Committee on Recent Economic Changes of the President’s Conference on Unemployment* (McGraw-Hill, New York: 1929), pp. xi, 80.

[15] Hounshell (1984), p. 230.

[16] Schurr *et al* (1990), p. 291.

that displaced skilled labor—e.g., talking pictures eradicated the need for theatre musicians and the electric integraph decreased the need for clerks making calculations manually[17]. In all, 842 labor saving technologies were analyzed and it was found that 536 involved the replacement of hand methods with mechanical processes, 259 involved improvements in power equipment, and 47 the displacement of horse-powered equipment with generating power. Most of the displacement of hand methods was in the handling sector which tended to be unskilled-intensive[18], while the increased need for precision and production of more complex goods suggests an increase in more skilled supervisory staff[19]. Handling made up a different proportion of the total labor force in each industry, implying that the skill bias of mechanization would differ by sector. Re-organization and further division of labor also helped to reduce skilled labor—for example within the cotton yarn and cloth industry, in the weaving sector some small tasks were taken from weavers and given to unskilled hands, leaving the weavers to focus on weaving alone[20]. Jerome's case studies suggest that there was no general rule as to the direction of skill bias of technological change in this period—within the glass industry, for example, skilled labor was displaced in the manufacture of bottles and window glass, while the reverse was true in plate glass[21]. Bright provides another example in his study of the Ford Motor Company. Ford's introduction of the assembly line in 1913 for production of its fly-wheel magnetos (used to start engines) turned what had been a one-man job into a 29-man operation and reduced overall work-time per magneto by 34% including a reduction in materials handling. Each of the 29 men on the assembly line also performed simpler tasks and required less training than the original workman[22]. Tasks such as inspection, assembly and machine repair were more difficult to automate or replace. So, the newly electrified factory was characterized by assembly line production but, before the 1940s, there was not a great deal of progress towards automatic control of these assembly lines so it remained quite a labor-intensive process[23]. In summation, the literature indicates that there was some replacement of craft skills as a result of electrification, along with the replacement of some manual functions (but not those involving assembly). To bolster the idea that these changes were complementary to electricity, I used data from Jerome's case studies and identified the correlation between the share of output produced using new technology with horsepower per worker, for four industries and found large positive correlations (iron and steel– .95; printing– .73; cigar manufacture– .95; machine tools– .41).

[17] Jerome (1934), p. 32.

[18] This point is reinforced by the description of the changes made in the 1910s at the Ford Highland Park plant. Arnold and Faurote (1972). Originally in *The Engineering Magazine* (New York, 1915), p. 25.

[19] Jerome (1934), pp. 46, 65.

[20] Jerome (1934), p. 83.

[21] Jerome (1934), p. 97.

[22] Bright (1958).

[23] Schurr *et al* (1990), ch. 2 explains that the military started developing automatic control during World War I but that there were few successful industrial applications by 1930. Bright (1958) pp. 222-3 also claims that automation was not as widespread or as advanced by 1940 as is commonly assumed.

Moving beyond the factory floor to the manufacturing sector as a whole, Nye argues that "industrial managers used electricity to maximize economies of scale by constructing large, continuous-process manufacturing plants"[24]. Electrification and the consequent factory restructuring may have promoted the introduction of scientific management because it encouraged the consolidation of industrial plants[25] and made production a lot faster so that a variety of tasks had to be completed simultaneously in order for each process to run smoothly. Thus, more clerical staff were hired to supervise and record the factory timekeeping, to monitor orders as they progressed in production and so forth. More managers may also have been needed to control quality over the newly differentiated production process—the integrity of the final product now depended on the performance of a larger number of workers and the smooth operation of a larger body of machinery which was run faster than ever before. Outside of manufacturing, jobs were likely created in sales and distribution due to electricity and the complementary growth in the home and office appliance industry, patterns that will be investigated in a future paper.

The range of descriptions found in the historical literature demonstrates that the overall effect of electrification on relative labor demand is ultimately an empirical question. Answering this question will be the goal of the remainder of this paper.

3 A Model of Task Demand

This section presents a simple model of labor demand which will provide the structure for the empirical specification used below. All variables vary by state, s, and year, t, but I have omitted the subscripts in equations (1) and (2) for clarity. In this model, there is one final good, Y, whose price is normalized to 1. Production workers (P) and non-production workers (C) must work together to produce Y as specified in equation (1):

$$Y = \left[A_P P^{\frac{\theta-1}{\theta}} + A_C C^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{1}$$

where A_P and A_C are technology parameters and θ is the elasticity of substitution between production and non-production workers. All workers perform a range of tasks but non-production workers perform more clerical and managerial types of tasks and to a higher level than production workers. Placing this in the context of early twentieth-century manufacturing, non-production workers may be thought of as the white collar factory employees who were engaged in record-keeping and supervisory duties while production workers may be thought of as the blue-collar factory employees who were directly

[24] Nye (1990), p. 209.

[25] Nye (1990) claimed that electrification facilitated consolidation of plants by firms, who created larger plants at fewer sites than before. Nye (1990), p. 385. Also, Chandler (1977), especially pp. 240-241, 274-299.

involved in goods production. Production workers are further divided into 2 types– those who perform more manual tasks (M) and those who are more specialized in dexterity tasks (D). Manual tasks are highly intensive in physical strength. Dexterity tasks require a high level of hand-eye or hand-eye-foot coordination. The dexterity and manual tasks are combined in the following way:

$$P = \left[A_M M^{\frac{\sigma-1}{\sigma}} + A_D D^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where σ is the elasticity of substitution between M and D workers.

Firms choose combinations of tasks in order to maximize profits which yields the following equations for relative labor demand:

$$\ln\left(\frac{D}{M}\right)_{st} = \sigma \ln\left(\frac{w_M}{w_D}\right)_{st} + \sigma \ln\left(\frac{A_D}{A_M}\right)_{st} \tag{3}$$

$$\ln\left(\frac{C}{P}\right)_{st} = \theta \ln\left(\frac{w_P}{w_C}\right)_{st} + \theta \ln\left(\frac{A_C}{A_P}\right)_{st} \tag{4}$$

where w_M is the wage of the manual (M) workers, w_D is the wage of the dexterity (D) workers, w_P is some average of the production workers' wages and w_C is the wage of the clerical workers. These labor demand equations suggest that equilibrium relative task employment is determined by relative wages and the relative productivities of tasks. Equations (3) and (4) can be adapted further to motivate the empirical analysis. It is assumed that electrification will have some effect on the relative productivities of the tasks, $\left(\frac{A_D}{A_M}\right)$ and $\left(\frac{A_C}{A_P}\right)$, and no structure is imposed on this relationship. Thus, a measure of electrification will proxy for the relative productivity terms in the regressions. The model assumes that labor is supplied perfectly elastically across states so that relative wages are equalized across states[26]. In other words, the relative wage terms, $\left(\frac{w^*_M}{w*_D}\right)_t$ and $\left(\frac{w^*_P}{w*_C}\right)_t$, will vary over time only and this effect will be captured by the time fixed effects in the regressions below. This assumption might appear strong, but is likely reasonable in the context of this paper which uses data from decennial censuses which reflect the long run equilibrium across states and over time. Using these assumptions, I get the following estimating equations (5) and (6) :

$$\ln\left(\frac{D}{M}\right)_{st} = \sigma \ln\left(\frac{w^*_M}{w*_D}\right)_t + \sigma \ln\left(\frac{A_D}{A_M}(electricity)\right)_{st} \tag{5}$$

[26] In fact all that is needed here is that labor markets be integrated enough across states such that relative wages move together across them.

$$\ln\left(\frac{C}{P}\right)_{st} = \theta \ln\left(\frac{w_P^*}{w_{*C}}\right)_t + \theta \ln\left(\frac{A_C}{A_P}(electricity)\right)_{st} \tag{6}$$

More generally, the relative productivity terms might also be a function of capital per worker and there may be shocks to labor supply that influence the dependent variables. The period 1880-1940 saw some notable labor supply shocks such as the influx of "new" immigrants from Southeast Europe and the high school revolution which led to a significant increase in the supply of educated workers. Equation (8) below controls for these effects on relative task employment.

4 Data

To examine the labor market effects of electrification, I combine data from several sources on electrification, individual characteristics and the tasks required of each industrial occupation. In this section, I describe each data source. The data cover the entire U.S. but are limited to the manufacturing sector and, for the empirical analysis, are aggregated to the state-year level.

4.1 Task Data

The task data come from a 1956 publication of the United States Employment Service that was originally constructed to facilitate the matching of unemployed workers to available jobs during the Great Depression. The publication consists of task or trait descriptions for 4000 jobs based on experts' ratings on a variety of measures and its contents were digitized for the first time for this project. Full descriptions of the occupations are listed in the second edition of the *Dictionary of Occupational Titles* (henceforth DOT), published in 1949[27]. As stated above, a task is a feature of a job and, more specifically, details the extent to which a particular skill or activity is used within an occupation. For example, the "manual" variable describes, on a scale of 1 to 5 where 5 includes the heaviest occupations, the level of physical strength needed in an occupation. The "clerical" variable measures, on a scale of 1 to 5, the amount of clerical competency required to perform an occupation, where 1 is the value given to occupations where clerical accuracy is most important. A stenographer would rate low on the manual variable, as it is mostly a sedentary job, and it receives the second highest score in the clerical variable, lower than an occupation such as proofreader where clerical accuracy is even more paramount. In contrast, an example of a job in which clerical accuracy is very unimportant is a machinist. Some variables are dichotomous, such as the "dealingwithpeople" measure, which states whether or not an

[27] Estimates of Worker Trait Requirements for 4,000 Jobs (1956). The second edition contains many job descriptions from the first edition, published in 1939.

important feature of a job is dealing with customers or colleagues[28].

Several studies have confirmed the integrity of this task dataset. Trattner *et al* (1955) conducted one such study to investigate whether the task ratings would change if the analysts constructing them used factory visits instead of DOT descriptions as their basis. He constructed two groups of eight analysts and had them rate ten jobs from various parts of the occupational structure in ten aptitude categories. One group used dictionary definitions to construct their rating (like the task data used in this paper), while the other went directly into the workplace, in different parts of the country. He found that the two sets of ratings were very similar. The U.S. Employment Service conducted its own survey to assess whether or not there were substantial analyst effects in the data (because the rating for a particular task and occupation might be constructed by a single analyst, with their own set of biases and assumptions), and they found that the ratings were consistent across analysts[29]. Ann Miller (1980) headed an evaluation of the DOT project in 1980, after the fourth edition of DOT had appeared. The criticisms outlined in her report should not hinder my use of the early data because they are mainly concerned with the fact that the same 1950s methodology was still being used in the 1970s. Overall, the data are likely to accurately reflect the task content of jobs in 1949. One caveat is that the data come from the end of the sample period used in this paper and so may not be perfectly representative of the task content of jobs in 1880—however, I have checked the definitions listed in the DOT against those given in an earlier description of jobs from the U.S. Army in 1918 and found that there was little change over these years in the task content within occupations[30]. There is also a precedent in the historical literature for using twentieth century DOT data to describe the nature of jobs in the past– van Leeuwen and Maas (2011) present HISCLASS which is a database of occupational descriptions augmented by DOT task data from 1965.

In line with the structure suggested by the model presented in Section 3, I constructed proxies for 3 types of tasks– manual, dexterity and clerical. Manual tasks are proxied simply using the strength task intensity measure. Dexterity tasks are represented using a simple average of 4 DOT task measures: finger dexterity, manual dexterity, eye-hand-foot coordination and motor coordination. Clerical tasks are usually represented by an average of clerical and numerical accuracy, but in some specifications I have created a "managerial" variable which also includes measures of the extent to which a job involves supervising a project or supervising and dealing with people. Finally, the DOT data were coded into an electronic format so that they could be matched with information from the decennial censuses on

[28] See Table I below for a full description of all the task variables used in this paper.

[29] Estimates of Worker Trait Requirements for 4,000 Jobs (1956), v.

[30] Swan (1918). The comparison showed that the conclusions of this paper might, if anything, be biased downwards because the changes within occupations that I identified from 1918 to 1949 mostly involved moving from hand methods to mechanization. Thus the drop in dexterity use is under-estimated by leaving out this within occupation change. I also tried limiting the sample to 1900-1940, as jobs more plausibly did not change during these years and found no change to the results.

the occupations in which individuals were working[31].

4.2 Individual Characteristics

The U.S. decennial censuses, 1880-1940, provide information about individuals[32] including their sex, age, race, place of birth, the occupation and industry in which they worked, and their literacy status. In line with other researchers, the following adjustments were made to the data. Individuals aged less than 12 or over 70 were dropped, as were those who were in school during the past year, those in group quarters, those reported as disabled, those living on military establishments, those who gave a non-occupational response or who stated that they were not in the labor-force, and those for which there was no person weight or a person weight equal to zero was given. Finally, 11 occupations for which a satisfactory match could not be found in the task data were dropped[33].

4.3 Power Data

The U.S. censuses of manufactures, 1880-1940, provide information about the quantity and sources of power used in manufacturing industries across states. For 1880, no information on electricity usage was recorded so an extrapolation was used on the 1890-1940 data. The main electrification variable used in this paper is the share of total industrial horsepower used in a state-year that comes from electricity[34]. The censuses of manufactures also provide information on the amount of capital used in each state-year, which will be included as a control in some specifications below. The capital stock data were deflated using the Bureau of Labor Statistics' wholesale price index for 1890-1951[35]. There is a small issue with the comparability of these data over time– from 1920 only establishments producing a minimum of $5000 worth of goods were included, whereas the minimum inclusion point was $500 prior to that date. However, the Bureau of the Census and others claim that the changing scope of the census had little effect on the overall statistics, as the plants which were omitted constituted a small proportion of the workforce and the power employed—thus, I assume that the data are fully comparable across censuses[36].

[31] This data will soon be available at the author's website.

[32] This comes from the IPUMS 1% sample for each census year 1880-1940. See References for full citation.

[33] See Data Appendix for further details.

[34] The regressions were also run using total horsepower, which does not have a significant effect on task composition. This is a useful robustness check and supports the notion that it is really electricity that is changing the types of jobs that are being done in U.S. manufacturing.

[35] Downloaded from Historical Statistics of the United States, Table Cc 84-95. Originally from: Bureau of Labor Statistics, *Handbook of Labor Statistics*, Bulletin No. 1016 (1950), p. 118.

[36] Thorp, William L. (1929) p. 378, "Horsepower Statistics for Manufactures" *Journal of the American Statistical Association*, Vol. 24, No. 168: pp. 376-385.

4.4 Final Dataset

The power data was merged to the census data by state and year, while the task data was incorporated by matching occupations and industries from the DOT dataset with those defined in the population census. I have described the latter matching process in more detail in the Data Appendix. The task variables were then "cleaned" of variation due to changes in the demographic composition of the population over the period. To do this, regressions were run for each census year in which the dependent variable was one of the task measures and the independent variables included age, age squared (to control for experience), race, gender and literacy[37]. The residuals from these regressions were then used as the final task variables, i.e., as the dependent variables in the regressions described in the next sections. Since the tasks are measured on a somewhat arbitrary, and ordinal, scale I normalize the values along a (0,1) spectrum by ordering them according to the distribution of tasks in the 1880 census—in other words, any changes in the task variables are changes relative to a 1880 baseline[38].

The final dataset contains observations on 606,756 individuals who worked in manufacturing 1880-1940, yielding 298 observations when aggregated to the state-year level.

5 Empirical Analysis

This section presents summary statistics for some of the variables of interest, then outlines the empirical strategy used to identify the labor market effects of electrification and presents the results of weighted OLS and 2SLS estimations. Finally, some robustness checks are discussed.

5.1 Summary Statistics

Figure II below shows the variation in the use of electricity across states, 1900-1940. These maps illustrate that there is substantial cross-state variation in electrification[39]. The cross-state variation in the diffusion was the result of a number of factors including– the potential to use hydro-electric power, which had a lower marginal cost than thermal power creation; the availability of municipal power which aimed to charge lower prices; and the population level and density, which affected the ability of power companies to spread the high fixed costs of power generation over a larger number of consumers and justified 24-hour running of their fixed capital.

[37] The 1940 census does not contain a literacy variable, so I assumed that those who reported no schooling were illiterate and all others literate.

[38] The normalization was conducted such that, in 1880, a value of 0.34 indicates that 34% of the population in 1880 worked in an occupation which was equally or less intensive in the use of that task.

[39] The maps show that in the smaller southwestern states the electricity measures are more noisy. This could be due to the small size of the manufacturing sectors in these states (New Mexico and Nevada had the smallest manufacturing outputs even in 1940) in this period. The results are not driven by these states.

Since immigration is included as a control variable in the extended specifications, as laid out below, it is appropriate to briefly discuss immigration during this period. Immigration was very high before 1914 and was virtually shut off after that time. The last immigrants entering the United States were probably the lowest skilled immigrants ever to enter in the era of mass migration before World War I. The evidence for this can be found both in the historical commentary and in an analysis of the occupational concentration of immigrants in the early decades of the century. In particular, among recent (those who immigrated within the previous 10 years) Southeastern European immigrants recorded in the 1910 census, only 69% could speak English, and over the longer period, 1860-1930, immigrants from Southeastern Europe were 10-20 percentage points less likely to be literate than native-born Americans[40]. Immigrants were less likely to be clerical or professional workers than natives, and they were concentrated in jobs that used more manual and less intellectual or craft skills than natives, as is shown in Table II below. They worked in jobs that required less on-the-job training, more repetitive tasks, and were less likely to involve dealing with people[41]. As a result, the regressions will control for variation in the task supply due to immigration by including the foreign-born share present in each state-year. The interpretation of the coefficient on $FBShare$ is discussed in detail in the Results section.

Table III presents the task scores for a variety of occupations, and also shows one of the main task ratios of interest—that of clerical skills to manual skills. This table demonstrates that the task variables are reasonable and, broadly speaking, the ordering of occupations is as would be expected. Occupations such as cashiers, who regularly deal with money and numbers, and draftsmen, who make mechanical drawings using mathematical knowledge rate more highly on the numerical and clerical tasks than do jobs like firemen and brakemen, which are extremely heavy, physical occupations. Table IV presents similar information for dexterity tasks and displays a similarly plausible ranking of occupations according to their relative dexterity/manual intensity.

5.2 Empirical Strategy

The following specification follows from equations (5) and (6) and was run for a variety of left hand side variables, weighted in each case using the *person weight* census variable[42]:

$$\ln R_{st} = c + \tau_1 Elecrate_{st} + \alpha_t + \beta_s + \epsilon_{st} \tag{7}$$

[40] These figures are from the author's analysis of the IPUMS decennial census data.

[41] Table II was constructed using IPUMS and the task dataset, which includes measures of job training, repetitiveness and extent to which jobs involve dealing with colleagues/customers. Jerome's study supports these findings. Jerome (1934), p. 7.

[42] A Breusch-Pagan test was performed and the results suggested that heteroskedasticity was not a problem in this data, thus weighted OLS is preferred to feasible GLS.

where α and β are year (t) and state (s) fixed effects which capture common variation in relative wages and state-specific technologies, respectively. *Elecrate*, the proportion of total horsepower in each state-year that comes from electricity, is the main variable of interest. On the left hand side, R_{st} reflects a variety of task variable ratios, to be used to identify the effect of electrification on changes in the relative demand for each type of labor. The following task ratios were analyzed: *dexterity/manual*; *clerical/dexterity*; *clerical/(manual+dexterity)*; and (*managerial+clerical)/(manual+dexterity)*, where *clerical* is an average of numerical and clerical tasks, *manual* is a measure of the degree of strength needed in a job, *dexterity* is a measure of how much physical manipulation is needed in an occupation and *managerial* is a combination of the planning, supervising and dealing with people task measures. Each R_{st} variable is the log of the ratio of the mean values of the task variables for the sample of workers in each state and year. Note that since the same task data are used for each period there is no within-occupation variation over time, and thus the results are driven by occupational shifts that occurred within states over time.

Extended specifications were developed which include controls for other factors that may have influenced relative task employment, namely capital per worker, the share of workers who are immigrants and the education level of the labor force. Specification (7) can therefore be rewritten as:

$$\ln R_{st} = c + \tau_1 Elecrate_{st} + \tau_2 Caplab_{st} + \tau_3 FBShare_{st} + \tau_4 EducProxy_{st} + \alpha_t + \beta_s + \epsilon_{st} \qquad (8)$$

where $Caplab$ is logged, adjusted for price changes over time, and measures capital per worker; $FBShare$ is the proportion of total population in each state-year that is foreign-born; and $EducProxy$ is a constructed measure of average years of education by state and year. These variables are included to control firstly for the fact that capital may be more complementary to a particular type of labor, thus affecting relative labor demand, and secondly for the shock to task supply caused by immigration (and its cessation after 1914) and finally for the changes in educational attainment which also may have affected task supply[43]. The construction of $EducProxy$ is discussed in the next section. In regressions where $FBShare$ is included the dependent variable includes the relative task employment of native-born Americans only.

5.2.1 Variable Construction

A proxy was needed for educational attainment because, prior to 1940, the U.S. census provided no information on this topic. However, information is available on school enrollments by state and demographic

[43] I note however that if the model presented above is absolutely correct then these changes in task supply could work entirely through changes in relative wages at the state level and would therefore not affect the relative employment of tasks. The approach taken here is to present the results for the extended specifications as robustness checks, to account for the fact that the model is unlikely to fully represent reality.

characteristics for each census year, and were obtained for every state-year through interpolation. Following Margo (1986), this information was used to construct a probabilistic measure of education for each individual based on their year and state of birth, sex, and race[44]. The formula used to construct this measure is given below and was implemented separately for each sex, race, state and year of birth cell, where $p(j)$ is the enrollment rate for that cell at each age j.:

$$\sum_{j=5}^{20} p(j)$$

The assumption here is that individuals can enter school at age five and must finish their schooling before age 21. The proxy is found to be quite reasonable, with known educational leaders such as Iowa consistently ranking first and known educational laggards such as Georgia and Alabama occupying the lowest positions in each year. In order to maintain the integrity of this measure, the sample was limited to 1900-1940 and to people aged between 20 and 40 who were in the manufacturing labor force in those years.

An instrumental variable was constructed for the foreign-born share in the population, based on the Card (2001) shift-share instrument, to control for the possibility that immigrants might be attracted to areas with a particular occupation profile, or with a particular electrification profile– perhaps states that electrified later, given the set of skills that the immigrant population possessed. Three states did not exist in the 1880 IPUMS (Hawaii, Alaska and Oklahoma), so the sample size was reduced to 287 for this test. The instrument uses the fact that immigrants tend to group together in existing enclaves corresponding to their countries' of origin. I calculated the population levels of each nationality n in the 1880 census, across states s, and multiplied this by the national growth rates g of those nationalities in subsequent censuses. These were then aggregated to the state-year level to give an imputed measure of the immigrant population. Formally:

$$ImputedFBShare_{s,t} = \frac{\sum_n (Pop_{n,s,1880}) * (1 + g_{n,1880-t})}{Nativepop_{s,t} + \sum_n (Pop_{n,s,1880}) * (1 + g_{n,1880-t})}$$

Regressions were then run using $ImputedFBShare$ as an instrument for the $FBShare$ variable in the extended specification. The results are discussed below.

5.3 OLS Results

Table V displays the baseline OLS results. The first two columns illustrate that electrification during this time led to a "hollowing out" of the labor force, as clerical tasks and manual tasks increased relative to dexterity tasks. This mirrors the more recent polarization of the U.S. labor force which was

[44] As described in Margo (1986).

primarily driven by computerization. Recalling from Table IV that occupations that are intensive in dexterity largely consist of skilled blue-collar jobs, the results indicate that demand for these tasks, and thus for skilled blue-collar work, decreased relative to demand for pure manual, or low-skill, tasks and for white-collar, clerical tasks. Furthermore, these results are broadly in line with the descriptions of technological change from the historical literature which indicated that, among blue collar workers, the most skilled were often displaced by machinery, but that more clerical and supervisory work was necessitated by the increased speed and volume of production that came with electrification. It is somewhat difficult to interpret the coefficients in these regressions due to the fact that the task ratios do not reflect economic variables in any obvious way, but if we take a state such as Illinois, in which the average manufacturing employee (i.e. an individual working in a representative occupation with the state average dexterity/manual task score) in 1880 was a craftsman and apply the predicted task effects from the regressions, then by 1940 that craftsman has become an operative, i.e. a significantly less-skilled worker[45]. Using the coefficients from Table V, I find that technological change caused quite a large swing in the relative importance of tasks during this time. In fact, the swings are much stronger than I observe in the raw data, suggesting that other factors such as demographic shifts, increased educational attainment and immigration had an offsetting effect on relative task use in U.S. manufacturing– if these factors had not been in play the hollowing out of the labor force and presumably of wages would have been much stronger.

These findings are robust to the inclusion of capital per worker, the share of workers who are foreign-born and the educational attainment of the labor force as control variables, as shown in Table VI. The lack of data on the capital stock for 1930 and 1940 accounts for the large decrease in the sample size in this specification. The coefficient on the foreign-born variable suggests that native-born workers moved into jobs that were relatively more intensive in clerical tasks in the presence of more immigrants. This is the expected response given the different task profile of immigrants and natives (Table II) and shows that natives responded to an influx of lower skilled manual-task performing immigrants, which likely lowered the returns to such tasks, by shifting their skill supply away from manual tasks. These results are in line with Peri and Sparber (2009) who found that in the U.S., over 1960-2000, immigration encouraged natives to move into jobs that used communication tasks more intensively, in which they possessed a comparative advantage over immigrants. This result is similarly obtained by Gray (2011) using data on the U.S. labor market, 1860-1930. Regressions using the $ImputedFBShare$ as an instrument for the $FBShare$ variable yielded even stronger coefficients on the electrification variable. The F-statistic in

[45] A craftsman is somebody who has been trained in a particular trade and probably manufactures a product from start to finish by himself. An operative is a worker with less skill and training who likely completes part of a good and uses some capital to achieve that goal.

the first stage regression is about 92 so the instrument is strong. This approach further ensures that the results are not contaminated with the effects of a third variable associated with both immigration and electrification[46]. The results shown in Table VI imply that shocks to task supply as measured by changes in educational attainment and immigration levels and shocks to task demand that occur through changing levels of physical capital are not responsible for the movements in relative task employment and lend more weight to the idea that electrification is the main driver of the trends identified above.

Table VII displays OLS results in which the dependent variables are the individual task measures, rather than the ratios used in Tables V and VI. The results show that the changes in relative demand are driven mainly by increased demand for numerical and clerical tasks combined with diminishing demand for high-skilled blue collar dexterity tasks. Demand for raw manual tasks changed little due to electrification. One advantage of the task data is that the evolution of task demand within the production and non-production worker categories can be analyzed. Table VIII presents results using a restricted sample containing only production (or blue collar) workers. Even by 1940 non-production workers made up only 19% of employment in manufacturing in the sample, so the focus on the production sector is warranted. Interestingly, the production sector does show signs of increased relative demand for managerial tasks, indicating that supervision and coordination became more important features of this sector post-electrification. This is also in line with the historical literature. So again, there appears to be a "hollowing out" of the labor force even within the factory floor personnel.

These results represent an update to the literature on historical technological change in the American economy. Specifically, Goldin and Katz (1998) claimed that technological change during this period increased the demand for high skill workers, even at the level of the factory floor. This paper, in contrast, suggests that the increase in education levels among blue-collar workers may have been only a supply-side phenomenon and that, on the demand side, education was important only as a signal of worker ability or effort and that in fact there was some de-skilling occurring at the factory floor level.

5.4 Instrumenting for Electrification

Despite the careful construction of several control variables, it may still be the case that neither equation (7) nor equation (8) identifies the causal effect of electrification on relative task employment. One potential reason for this is that *Elecrate* may vary across states partly in response to the existing composition of manufacturing activity or to the relative task supply that prevails. Such endogenous technological change has been examined in similar contexts by authors such as Acemoglu (1998). In this case, the identification strategy employed above will fail and OLS estimates will be biased and

[46] These results are not reported formally here but are available upon request.

inconsistent. Understanding the motivations of factory owners in adopting electricity is useful in assessing the magnitude of this bias: as was discussed in Section 2 a recurring theme in the literature is that managers were primarily motivated by the desire to save on energy used in production and were pleasantly surprised when electricity ultimately allowed them to also economize on labor. Clearly this favors the exogeneity of electrification to labor demand, however a variety of instrumental variables strategies will also be employed to ensure identification of the true labor market effects of electrification.

The first instrument considered exploits cross-state heterogeneity in the adoption of state-level regulation of the electric utility industry. One of the main drivers of the decrease in the cost of electricity was the development of central electric power stations. This development was facilitated in part by the advent of state-level regulation of the industry, first adopted in 1907 by Wisconsin. Before that time, the electric industry was regulated at the local level, so that each company that wanted to produce and sell electricity in a particular city or locale had to obtain a separate license from each. This system stunted the growth of utilities and the economies of scale that such a growth might bring. After 1907, states gradually adopted state-level regulation by a single utility commission and expanded their powers. Much research has been conducted investigating the true effects of this regulation. Hausman and Neufeld (2002) found that state-level regulation of electric utilities lowered their costs of borrowing (by allowing them to diversify and reduce their level of risk[47]) and thus increased electricity output. One example comes from the Illinois branch of the Edison company, under the management of Samuel Insull. In the 1910s he was able to link small rural areas to the much larger transmission network, thus facilitating a doubling of profit margins for the utility and a reduction in prices for consumers, and in the longer run leading to the development of a regional electric grid[48]. Adoption of state-level regulation was at this time a contentious political issue–in most states the Progressive movement was a strong supporter of this policy, as they hoped to bring cheap electricity to households. This was part of the broader Progressive agenda of increasing the size of government and making it a protector of the rights of ordinary working people, especially in cases where companies were building up monopoly power[49]. One historian declares the Progressives to have been the main cause of a variety of early twentieth century legislative changes pertinent to the interaction between businesses and government, including the Hepburn Act of 1906 which implemented controls on railroad rates, the Clayton Anti-Trust Act of 1914, and, most relevant to this discussion, the establishment of various state regulatory commissions to regulate corporate behavior[50]. Prominent Progressives who supported state-level regulation included

[47]Hausman and Neufeld (2002), pp. 1051, 1053. Knittel (2006), p. 207 also points out that state regulation reduced utilities' transactions costs and spurred production.
[48]Kahn (1988), pp. 3-4.
[49]Stromquist (2006), pp. 53-54, 63, 71.
[50]Walker and Vatter (1997), p. 20.

Woodrow Wilson in New Jersey and Hiram Johnson in California[51]. This evidence supports the idea that state-level regulation was positively correlated with cheaper electricity but was not independently related to the task composition of employment, as it was driven by political considerations, suggesting that it is a valid instrumental variable.

In order to capture the extent of regulation within states, an index of state regulation was constructed and a value assigned to each state-year. First, the values displayed in Table 2 of Hausman and Neufeld (2002) were used for the early period, 1880-1920, though I extended this ranking using information on regulation found in a number of other sources[52]. For the later period, states with no state-level regulation were assigned a score of 0, while those with weak state regulation were assigned a score of 1 and those with strong regulation were assigned 2. For these years, states were assigned a score of 2 if (i) they had state regulation in that year and (ii) if the state regulatory commission had more than 50% of the regulatory powers listed in the sources– these powers included oversight of mergers and consolidations, oversight of accounting practices and setting of rates and standards for the industry. States received a score of 1 if they had state regulation but gave the regulatory commission only limited powers (less than 50% of the powers listed). The resulting index was then used as an instrument for electrification in 2SLS regressions.

The first set of 2SLS results are presented in Table IX and are broadly in line with the OLS results, while not always maintaining significance. The instrument produced a first-stage F-statistic of 90. The coefficients on *dexterity/manual* are even larger than under OLS and are just significant at the 10% level. The coefficients on *clerical/manual* are encouragingly close to those of the OLS baseline, but much precision has been lost here. These results suggest that endogeneity is not a significant problem and that the results are robust to using solely the exogenous variation in the electricity variable.

A potential criticism of the instrument based on utility regulation is that manufacturers in particular areas may have lobbied for a change in the regulatory environment, anticipating the drop in electricity prices. I thus introduce a second, and more plausibly exogenous, instrument to deal with endogeneity of the electricity variable– it uses cross-state variation in geography. The argument here is that differences across states in their elevation, river length and river gradient should predict the ease with which states can engage in hydro-electric power generation but not affect state occupational composition through any other channel. This reasoning is supported by details given in the *Handbook for Dam Engineering*

[51] Wilcox (1914), p. 71, and Jones (1914), p. 96. See also Hausman and Neufeld (2002), p. 1055– the Progressives had originally been in favor of municipal ownership of electric utilities but most gradually came around to the idea of state regulation.

[52] The source used for 1930 was: *Bonbright Utility Regulation Chart* (Second edition, 1930. Bonbright and Company: New York). The source used for 1940 was: *Electric Power and Government Policy: A Survey of the Relations Between the Government and the Electric Power Industry* (The Twentieth Century Fund: New York, 1948), Table II-1.

(1977) which explains that the cost of constructing a hydro-electric facility is reduced if the natural geography of the area makes it ideal for dam construction– this will be the case where rivers have natural falls with narrow streams ahead of the falls[53]. Other research has used this type of variable for similar purposes. Duflo and Pande (2007) used geographic variables to instrument for the construction of irrigation dams in India to explore the effect of such dams on agricultural output and a range of poverty outcomes. Similarly, Lipscomb *et al* (2008) used river gradient and a variety of other geographic variables as instruments for hydro-electric power generation location in Brazil. In the historical U.S. case, hydro-electric generation was a significant component of total electricity generation by utilities[54]. As already stated, hydro-electric power had a lower marginal cost than thermal power and thus easier access to hydro-electric power should correlate highly with cheaper electricity for industrial consumers. In practice, I use mean elevation by state and interact this with decade-level total rainfall. Including rainfall provides time variation in the instrument and also makes intuitive sense– decades with lower than usual rainfall should have seen higher electricity prices as producers would have had to rely to a greater extent on coal-burning generation and it may have taken some time to increase capacity at such plants. Data on rainfall is only available for 1900-1940, so this strategy limits the sample size to 1910-1940 only but has the advantage of generating variation across the time dimension[55]. One potential problem with this instrument is that geography may affect the size of the agricultural sector in a state, which may in turn have repercussions for the task composition of industry. I find that there is a fairly strong (.52) correlation between the size of the agricultural sector and mean elevation, but that the correlation between the extent of agriculture and the actual instrument of elevation interacted with rainfall is much smaller (.22) and similarly the extent of agriculture is negatively but not substantially correlated with observed electrification (-.26). Since much of the decline in the agricultural sector had already occurred by 1910, this should not be a significant problem.

Running 2SLS regressions, the results suggest that, similar to the results obtained using state-level regulation laws as an instrument, the *dexterity/manual* results hold strongly and the pattern of increasing relative demand for clerical tasks over all others cannot be rejected but is now statistically insignificant. Table X presents the formal results. For this specification, I use only $FBShare$ as a control variable, as the sample size has already been reduced in the early period and would be diminished too much by including capital as a control. To summarize, the instrumental variable results suggest that endogeneity was not a great problem and that the OLS results reflected the true effect of electrification on the task composition of U.S. manufacturing. However, the 2SLS results are weaker for the clerical-

[53]Golze (1977), pp. 549, 557, 48-116.

[54]Hydroelectricity made up 40% of power generated by U.S. utility companies around 1910, according to the Census of Manufactures.

[55]Rainfall data were taken from the *Global Historical Climatology Network*, Version 2, (2009). Precipitation was aggregated to the decade level.

task bias than the OLS results. The next section will look into this matter further and show that this may reflect the fact that clerical tasks increased most rapidly before 1920, and thus may have been affected by factors other than electrification. Electrification may have only magnified a previous trend towards an increasing white-collar intensity of the labor force.

5.5 Further Investigation

Here, I present some additional results with the aim of constructing a richer picture of changes in the U.S. labor market 1880-1940. The previous results showed the basic trends in the skill content of jobs and highlighted the decline in the relative importance of dexterity-intensive jobs. This section addresses whether these changes affected all dexterity workers equally.

Firstly, regressions were run for females and males separately. The results were very strong for males while for females there were few significant results. Women represented only 24% of the manufacturing labor force by 1940, so the lack of significant results is not so surprising given the smaller sample size. To investigate this further, regressions were also run using the share of females in the labor force as the dependent variable. This share increased by 12 percentage points 1880-1940 and electrification can explain a 5 percentage point increase. Thus electrification did have an effect on the number of women moving into paid employment, but does not appear to have significantly changed the types of jobs women were doing, which tended to be clerical-intensive[56]. This finding is in line with Adshade and Keay's (2010) more thorough analysis of female employment and compensation in Ohio manufacturing which suggested that technological change during this period was biased in favor of females. This makes sense, given that craft skills became less important during this period, an occupational category from which women had traditionally been excluded.

Secondly, regressions were run separately for non-whites. The results suggest that there was little effect on non-white relative performance of clerical tasks, but that there was a much bigger relative decline in dexterity task performance compared to white workers. However, it is well-documented that there was substantial migration of blacks out of the rural South into Northern manufacturing during the later part of the period examined here. This migration could be driving the results here. More explicitly, the concern is that blacks were moving into Northern manufacturing jobs and naturally entered the labor force at the bottom of the occupational ladder, in manual jobs, rather than being displaced out of dexterity jobs into manual jobs. There is also evidence that blacks were deliberately kept in lower status occupations with limited contact with white workers[57]. In general, migration across states or from rural

[56] Black and Spitz-Oener (2010) do find significantly different effects of technological change on men and women, using German data on workplace tasks and computerization. They conclude that "polarization" was much stronger for women than men.

[57] For example, Sundstrom (1998), pp. 8-9. He highlights in particular that black women with high school

to urban areas could be a threat to the identification strategy used above. To examine this issue, I split the sample into white migrants, white non-migrants, non-white migrants and non-white non-migrants and re-ran the typical regressions. I defined migrants as those whose state of current residence was different to their state of birth. The results are shown in Tables XI and XII, for non-whites and whites respectively. They show that the results for white migrants and non-migrants all match those identified above for the full sample, although the coefficients are smaller for migrants, indicating that they may indeed have moved to avoid fluctuations in the labor market and that geographic mobility mitigated the hollowing out effect. However, there are no significant results for non-whites. Because of the small sample size for this group, it is difficult to definitively say that migration drove the results in this case, but that is certainly a possibility.

It would also be interesting to know what happened to workers who were displaced from their original tasks as a result of technological change. In particular, were these workers moving into other sectors such as transportation and distribution, or the retail and wholesale sectors which grew so strongly during this time? Or, did the workers simply move down the skill ladder within manufacturing and accept jobs as manual laborers? A number of surveys were conducted in the 1920s and 1930s which asked workers how their situations had changed following a prior lay-off[58]. The surveys analyzed the fortunes of garment cutters in Chicago and workers from a rubber company who were laid off in New Haven and Hartford. The general trends show that workers did not find employment in the same occupations or with wages as high as they had enjoyed previously. Many workers moved into jobs such as drivers and truckers which involved less skilled work than they had previously done. Additionally, work on the printing industry by Elizabeth Baker found that displaced workers preferred to try to remain in the same occupation or industry but that, once displaced by technology, it was more difficult to find similar permanent employment. Workers who had planned to become pressmen instead became chauffeurs, salesmen, transport conductors and some became mechanics or carpenters[59].

Using the IPUMS data, Figure III depicts the sectoral composition of the U.S. labor force for the period of interest. The decline in the agricultural sector stands out clearly in this diagram, but it is also clear that manufacturing grew somewhat and the retail sector grew steadily, as a share of total employment. After 1920, the professional sector, which includes those employed in financial and advertising services, grew noticeably. To get some idea of whether workers were displaced out of manufacturing employment or simply moved down the occupational ladder within manufacturing, I ran regressions using the share of the labor force engaged in the manufacturing sector as the dependent

diplomas were much less likely to enter clerical occupations than white women. See also Sundstrom (1994) for a more comprehensive discussion of the "Color Line" in various aspects of American economic life, 1910-1950.

[58] Clague & Couper (1931) and Myers (1929).

[59] Baker (1933), p. 78.

variable and electrification as the main explanatory variable. The results show that electrification increased the manufacturing share of total employment, but that this relationship is only significant over the period 1880-1920. After 1920, electrification appears to have had an almost zero influence on this share. This may suggest that it became harder over time for displaced workers to stay within the manufacturing sector. Breaking up the sample into 1880-1910 and 1910-1940 and running the original regression using task ratios as the dependent variable sheds some light on the manufacturing share findings. Table XIII presents the results and shows that it was in the early part of the sample period that the main increase in relative intensity of clerical tasks occurred and that the relative decline in dexterity tasks did not occur until after 1910. This is consistent with the initial increase in the manufacturing share of employment just discussed. These latest results combine with the weakened effect of electricity on clerical tasks identified in the instrumental variables regressions to suggest that while electricity probably was biased towards clerical skills, other factors that predominated pre-1920 may have been just as important in growing the non-production sector over the entire sample period. These factors include the merger movement of the 1890s which led to an increase in the average size of firms and thus an increased demand for clerical work, as well as the new ideas of the managerial movement which led to firm restructuring.

5.6 Additional Robustness Checks

A variety of additional robustness checks were performed. I experimented with dropping outliers from the sample, including states that were very small and young in the early years of the sample (Nevada, Arizona, New Mexico), states that were large and early adopters of electricity (California) and unusual regions (the South). Similarly, a variety of specifications were re-run using only electricity that was purchased from an electric utility to construct the electrification rate (earlier specifications used total electricity which includes electric power generated at the factory itself). None of these changes altered the results[60]. Results from regressions using total task employment as the dependent variable instead of mean task intensity also yielded consistent results.

State-specific time trends were added to the basic specifications and the results displayed some loss of precision, as expected, but no great change in coefficient sign and size. This is an important robustness check, as it shows that general changes in states over time are not the main determinants of the results. This specification uses only variation from sudden changes in electrification rates within states over time and adds weight to the results displayed above.

Thus far in the analysis the regressions have been weighted by total employment in each state-

[60] The results of these robustness checks are not presented formally here but are available upon request.

year, as proxied by the total number of workers employed (using the census weight value). However, the number of *hours worked per individual* becomes available in the 1940 census, allowing for a more detailed measure of employment. I therefore combined these data with information on total hours worked per year at the state level collected from the 1910 and 1930 censuses of manufactures along with city-level data for 1920 collected by Robert Whaples[61] and similar data for 1880 from Atack and Bateman (1990). No data could be found for 1900 so interpolated data was used. The data suggests that hours worked per year decreased by 43% at the national level over the period 1880-1940[62] such that accounting for this margin of employment change is important. When incorporating hours worked into the regression weights, the coefficient on electrification remains the same in most cases and in some becomes larger, suggesting that the pattern of change in relative hours worked reinforces the effect found using relative numbers of workers.

6 Conclusion

Technological change in the United States has displayed a remarkably stable effect on workplace tasks from the advent of the factory to the proliferation of the computer. For the early twentieth century, electrification resulted in a hollowing out of the labor force such that high-skill blue-collar tasks declined in relative importance to low-skill manual tasks, while demand increased for clerical and managerial tasks. Instrumenting for electrification using differences in timing of adoption of state regulation of utilities or cross-state variation in geography reinforces the results found in OLS regressions. The results also hold with the addition of other controls for shocks to labor supply, as well as under a variety of robustness checks. By examining the evolution in the use of particular tasks over time, it is shown that these changes in relative employment were driven by a significant increase in the employment of clerical tasks along with a significant decline in the employment of dexterity tasks, while demand for manual tasks remained relatively stable over the period. The results suggest that general purpose technologies benefit workers with general skills and hurt those who possessed valuable skills that were complementary to the previously dominant technology. The fact that technological change seems to have been so similar in character across these periods lends weight to the theory put forward by Goldin and Katz (2008) that increased inequality in the United States in the latter part of the twentieth century was driven more by the slowdown in educational attainment and less by a change in the nature of

[61] The data were compiled by Whaples (1990a), Table A, Appendix 4. Whaples (1990b) identified a relationship between electrification and the decline in the length of the workday before 1920. I thank Robert Whaples and Michael Haines, who directly supplied the data, for their help in constructing this measure.

[62] Based on the author's measure of hours worked per year. About 17% of this reduction occurred before 1930, with a substantial further decline during the 1930s. My data appears to be broadly in line with the existing literature on hours worked– according to eh.net, working hours per week declined by 38% 1880-1940: http://eh.net/encyclopedia/article/whaples.work.hours.us

technological change, although there may be some room for revision in their assertion that the declines in wage inequality before 1950 were driven mainly by increases in educational attainment– this paper has shown that factory floor production was the dominant sector in manufacturing, with over 80% of the sector's workforce, and it exhibited a notable unskill-biased technological change during this time.

A companion paper will analyze the effects of these changes in the nature of American manufacturing on individual workers of different skill types, making use of linked census data from the 1880 100% database through the 1910 census and synthetic cohort analysis to uncover whether or not the shifts were mainly within or across cohorts and how individuals shifted occupations. This will allow for a better understanding of who the true winners and losers were from electrification.

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A Data Appendix

Here, I outline how the task dataset was matched to the population census, and give some examples to illustrate the process. For most of the individual observations, I used the census occupation and industrial classifications and found a match for them in the DOT task data, using the occupational definitions listed in the 1949 *Dictionary of Occupational Titles*. The IPUMS variables used were *occ1950* (which classifies the occupation of individuals across census years 1850-1950) and *ind1950* (which does the same for industry classification). In some cases, more than one DOT could be matched to each census occupation-industry cell. In such cases, I used a third IPUMS variable, *occstrng*, which reports the exact response given by the census respondent when asked about their occupation. For that occupation-industry cell, I assigned the weighted average of the relevant DOTs, where the weights were constructed according to the responses listed in *occstrng*. The examples given below should make clear the procedure. I concorded the data this way in order to achieve as rich a dataset as possible, avoiding aggregating together people who are not doing exactly the same occupation and thus whose task content was somewhat different. For a small subset of occupations, it was deemed appropriate to also match by sex, because they involved distinctive male and female jobs. The occupational categories concerned include janitors, maids, and policemen. For a limited range of individuals, I was able to match by occupation only—these tended to be professional occupations which were invariant by industry, as shown by the examples listed below.

A.1 Examples

Easy concordances: Matching task data to census data only by occupation.

Census occupation "Chemical Engineer" matched to DOT "Chemical Engineer, R&D".

Census occupation "Librarian Assistant" matched to DOT "Librarian Assistant".

Census occupation "Architects" matched to DOT "Architect, Marine".

Difficult Concordance: Matching task data to census data by occupation and industry.

Census occupation "Machinist" was matched to different DOTs depending on the census industry: for example, for the motor vehicle industry, the task data for "Machinist, automobile" was used; for the photographic equipment industry, the task data for "Machinist, camera" was used. Most of the other industries were matched to the task data for "Machinist", which is a generic title. For some industries the match was more complex, and involved a weighted average of several DOT occupations. For example, here is the breakdown for the ship building and repairing industry: 50% "Machinist, marine-gas engine" and 50% "Machinist, outside". So, for this occupation and industry cell, 50% of individuals listed an occupation (in the *occstrng* variable) that more closely matched the DOT description for

"Machinist, marine-gas engine" and 50% more closely matched the "Machinist, outside" description. In consequence, the cell received the simple average of task scores for the two occupations.

Certain census occupation categories were difficult to match to the task data. Compromise solutions were found for the following: religious workers (an average of social and group workers, nurses and teachers was used); clergymen (an average of recreation, group and social workers was used); policemen and detectives (only a DOT for an official government-employed policeman was lacking so I used industrial policeman/guard instead); marshals and constables (see policemen and detectives); sheriffs and bailiffs (see policemen and detectives); statisticians and actuaries (an average of census taker and mathematician was used); midwives (an average of an untrained nurse and gynecologist was used); apprentice auto mechanics (an average of auto mechanic helper and apprentice automobile upholsterer was used); barbers (barber apprentice was used). In the cases of statistician, policeman and barber, these compromises were supported by a U.S. Army publication of 1918, which outlined the duties involved in various jobs and listed some alternative jobs with similar tasks[63]. These occupations made up no more than 0.05% of the total sample. No such compromise solution could be found for the following occupations, which were consequently omitted: apprentice mechanics, except auto; conductors, bus and street railway; garage laborers and car washers and greasers; boarding and lodging housekeepers; paperhangers; real estate agents and brokers; postmasters; auctioneers; members of the armed services; managers and superintendents, building; mail carriers; attendants, auto service and parking. This gives a total of twelve occupations omitted from the analysis, out of over two hundred and fifty. Military personnel were dropped in any case, so there were in fact 11 omitted occupations, which constituted only 0.06% of the original sample[64]. For some individuals in categories such as "professions, technical and kindred workers not elsewhere classified", a suitable DOT match could not be found because nothing was recorded in *occstrng* and the category is by definition vague and a catchment for difficult to classify individuals. These also had to be dropped, but amounted to no more than 0.32% of the sample size.

[63] Swan, John J. (1918) *Trade Specifications and Index of Professions and Trades in the Army* (Government Printing Office).

[64] In fact several of the occupations contained no observations after the IPUMS data was reduced to only manufacturing industries and the other changes described in the text were made. The occupations concerned were: conductors, bus and street railway; boarding and lodging house keepers; and postmasters.

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Graphs and Tables

Table I

Description of Task Variables Used

Variable Name	**Variable Description**
Numerical	Ability to perform arithmetic operations quickly and accurately.
Clerical	Ability to perceive pertinent detail in verbal or tabular material, to observe differences in copy, to proofread words and numbers and to avoid perceptual errors in arithmetic computation.
Dexterity	Average of: hand & finger dexterity, manual dexterity of the hands and hand-eye coordination.
Manual	Degree to which strength is used in the occupation.
DealingwithPeople	Dummy variable describing whether or not an important feature of the job is dealing with people.
Direction, Control & Planning (DCP)	Dummy variable describing whether or not an important feature of the job is to direct, control and plan an entire activity or those of others.
Specificinstructions	Dummy variable describing whether or not an important feature of the job is working under instructions from a supervisor.
Repetitive	Dummy variable describing whether or not an important feature of the job is that it is repetitive.
Training Time	The amount of specific vocational preparation necessary for a worker to acquire the knowledge and abilities necessary for average performance in a particular job.

Notes: These definitions are based on those given in the Estimates of Worker Traits for 4,000 Jobs manual for job rating experts.

Table II

Task Intensity of Top 10 Immigrant Jobs: 1900

Task	**Immigrants**	**Natives**
Manual	.53	.43
DealingwithPeople	.53	.58
Dexterity	.43	.55
Training Time	.58	.65
Repetitive	.6	.46
Specificinstructions	.44	.38

Notes: The task variables are normalized to a (0, 1) distribution. The figures above are means for each group created from IPUMS data for 1900. Standard t-tests showed that the distributions are significantly different for natives and immigrants at the 1% level in all cases.

Table III

Task Content of Representative Occupations: Clerical/Manual

Occupation	**Clerical Skills**	**Manual Skills**	**Clerical/Manual**	**Clerical/Manual Percentile**
Janitors & sextons	0.00	0.78	0.00	0.00
Porters	0.28	0.93	0.30	0.10
Meat cutters, except slaughter & packing house	0.53	0.94	0.57	0.20
Forgemen & hammermen	0.72	0.94	0.77	0.30
Stone cutters & carvers	0.78	0.91	0.85	0.40
Carpenters	0.78	0.80	0.99	0.50
Stationary engineers	0.98	0.78	1.28	0.60
Guards, watchmen & doorkeepers	0.54	0.38	1.65	0.70
Compositors & typesetters	0.80	0.37	2.28	0.80
Bookkeepers	0.56	0.07	8.05	0.90
Managers, officials & proprietors	0.75	0.08	9.38	1.00

Notes: Figures are based on the author's calculations from the 1900 population census distribution of occupations. The occupations presented were chosen because they represent each decile of the whitecollar/manual distribution. *Clerical* is an average of numerical and clerical skills. *Manual* is simply the degree of strength required of a job. All variables in columns 1 and 2 are shown on the (0,1) scale, as explained in the text.

Table IV

Task Content of Representative Occupations: Dexterity/Manual

Occupation	**Dexterity Skills**	**Manual Skills**	**Dexterity/Manual**	**Dexterity/Manual percentile**
Plumbers & pipe fitters	0.01	0.94	0.01	0.00
Cranemen, derrickmen etc	0.04	0.66	0.06	0.10
Locomotive Engineers	0.07	0.4	0.18	0.20
Filers, grinders & polishers	0.17	0.52	0.36	0.30
Molders, metal	0.49	0.87	0.57	0.40
Sawyers	0.76	0.78	0.97	0.50
Heaters, metal	0.84	0.78	1.08	0.60
Dyers	0.94	0.48	1.97	0.70
Engravers	0.61	0.34	2.96	0.80
Designers	0.49	0.12	6.03	0.90
Jewelers, watchmakers etc	0.88	0.14	6.29	1.00

Notes: Figures are based on the author's calculations from the 1900 population census distribution of occupations. The occupations presented were chosen because they represent each decile of the dexterity/manual distribution. *Dexterity* is an average of 4 dexterity measures—hand-eye-foot coordination, hand dexterity, finger dexterity and motor coordination. *Manual* is simply the degree of strength required of a job. All variables in columns 1 and 2 are shown on the (0,1) scale, as explained in the text.

Table V

Baseline OLS Results

	dexterity/manual	**clerical/dexterity**	**clerical/ manual+dexterity**	**manager+ clerical/ manual+dexterity**
Elecrate	-.17***	.31***	.22***	.26***
	(.05)	(.08)	(.08)	(.11)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	.83	.86	.87	.90
Observations	297	297	297	297

Notes: The dependent variable is specified in the first row and includes native-born Americans **and** immigrants. *manual+dexterity* is a simple average of the manual and dexterity variables. Similarly with *manager+clerical*.

Table VI

Extended OLS Specification

	dexterity/manual	clerical/dexterity	clerical/ manual+dexterity	manager+ clerical/ manual+dexterity
Elecrate	-.15**	.32***	.25***	.30***
	(.07)	(.10)	(.09)	(.09)
FBShare	-.01	.46***	.45***	.10
	(.14)	(.16)	(.16)	(.18)
lnCaplab	.03	-.09*	-.07*	-.05
	(.05)	(.05)	(.04)	(.05)
EducProxy	-.001	-.003	-.003	-.01
	(.01)	(.01)	(.007)	(.01)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	.69	.90	.92	.95
Obs.	198	198	198	198

Notes: The dependent variable includes **only** native-born Americans. The explanatory variables are specified in the first column. The method of estimation is Ordinary Least Squares, weighted by the *person weight* variable from IPUMS. Standard errors are shown in parentheses and were clustered at the state level.

Table VII

OLS Regressions Decomposed

	clerical		dexterity		manual		managerial	
Elecrate	.19***	.22***	-.16***	-.19***	-.003	-.04	.23	.20
	(.06)	(.07)	(.04)	(.06)	(.04)	(.05)	(.20)	(.14)
FBShare	-.04	.49***	.02	-.08	-.01	-.02	-1.23***	-.68*
	(.17)	(.14)	(.10)	(.10)	(.07)	(.09)	(.38)	(.37)
lnCaplab		-.07*		.07**		.04		-.07
		(.04)		(.03)		(.03)		(.12)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.86	.89	.86	.89	.89	.92	.89	.95
Obs.	297	199	297	199	297	199	296	199

Notes: The dependent variable in each regression is specified in the first row. The explanatory variables are specified in the first column. The method of estimation is Ordinary Least Squares. Standard errors are shown in parentheses and were clustered at the state level. All regressions were weighted using the *person weight* variable from IPUMS.

Table VIII

OLS Regressions for Production Workers Only

Dependent Variable	dexterity/ manual		clerical/ dexterity		clerical/ manual+dexterity		manager+ clerical/ manual+dexterity	
Explanatory variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Elecrate	-.21***	-.25***	.38***	.47***	.26***	.32**	.34***	.39***
	(.06)	(.08)	(.10)	(.12)	(.08)	(.10)	(.10)	(.09)
FBShare	.18	-.18*	.01	.62***	.13	.52***	-.23	.15
	(.13)	(.09)	(.24)	(.16)	(.18)	(.14)	(.21)	(.13)
lnCaplab		.06		-.15**		-.11**		-.10
		(.06)		(.06)		(.05)		(.06)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.87	.81	.86	.91	.89	.94	.94	.98
Obs.	298	200	298	200	298	200	298	200

Notes: The dependent variable in each regression is specified in the first row. The explanatory variables are specified in the first column. The method of estimation is Ordinary Least Squares. Standard errors are shown in parentheses and were clustered at the state level. All regressions were weighted using the *person weight* variable from IPUMS. Even numbered columns include capital per worker as a control.

Table IX

Instrumenting for Electrification with Utility Regulation

Dependent Variable	**dexterity/manual**	**clerical/dexterity**	**clerical/ manual+dexterity**	**manager+ clerical/ manual+dexterity**
Elecrate	-.43*	.43	.22	-.05
	(.26)	(.33)	(.29)	(.32)
FBShare	-.02	.57***	.55***	.22*
	(.10)	(.11)	(.11)	(.13)
lnCaplab	.01	-.14***	-.13**	-.15***
	(.04)	(.04)	(.04)	(.05)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
First Stage F-stat	90	90	90	90
R^2	.68	.92	.93	.95
Obs.	194	194	194	194

Notes: The dependent variable in each regression is specified in the first row. The explanatory variables are specified in the first column. The method of estimation is Two Stage Least Squares. Robust standard errors are shown in parentheses. All regressions were weighted using the *person weight* variable from IPUMS.

Table X

Instrumenting for Electrification with Geography

Dependent Variable	dexterity/manual	clerical/dexterity	clerical/ manual+dexterity	manager+ clerical/ manual+dexterity
Elecrate	-1.18*	1.34	.72	-.09
	(.70)	(1.57)	(1.39)	(1.33)
FBShare	.43	-.43	-.19	-.28
	(.38)	(.56)	(.44)	(.46)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
First Stage F-stat	79	79	79	79
R^2	.58	.80	.88	.90
Obs.	195	195	195	195

Notes: The dependent variable in each regression is specified in the first row. The explanatory variables are specified in the first column. The method of estimation is Two Stage Least Squares. Standard errors are shown in parentheses and were clustered at the state level. All regressions were weighted using the *person weight* variable from IPUMS. The instrument used here is the interaction of mean state elevation with total state rainfall between census years. Other candidates as instruments which are highly correlated with the one presented would interact decadal rainfall with river gradient, mean state gradient or total stream length by state. The capital variable was not included in this specification because of the even greater implied loss in sample size.

Table XI

OLS Results for Non-whites

Dependent variables	dexterity/manual		clerical/dexterity		clerical/ manual+dexterity		manager+ clerical/ manual+dexterity	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Elecrate	-.10	.14	.10	.10	.05	.04	.05	.10
	(.21)	(.21)	(.29)	(.35)	(.20)	(.26)	(.16)	(.28)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.60	.67	.69	.65	.71	.65	.78	.74
Observations	233	215	233	215	233	215	233	215

Notes: The method of estimation is Ordinary Least Squares. Standard errors are shown in parentheses and were clustered at the state level. All regressions were weighted using the *person weight* variable from IPUMS. The odd numbered columns present results for non-migrants, and the even numbered columns present results for migrants.

Table XII

OLS Results for Whites

Dependent variables	dexterity/manual		clerical/dexterity		clerical/ manual+dexterity		manager+ clerical/ manual+dexterity	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Elecrate	-.16***	-.14**	.38***	.28***	.29***	.20**	.28**	.16*
	(.06)	(.07)	(.09)	(.09)	(.09)	(.09)	(.12)	(.09)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.79	.73	.86	.79	.87	.81	.91	.84
Observations	233	215	233	215	233	215	233	215

Notes: The method of estimation is Ordinary Least Squares. Standard errors are shown in parentheses and were clustered at the state level. All regressions were weighted using the *person weight* variable from IPUMS. The odd numbered columns present results for non-migrants, and the even numbered columns present results for migrants.

Table XIII

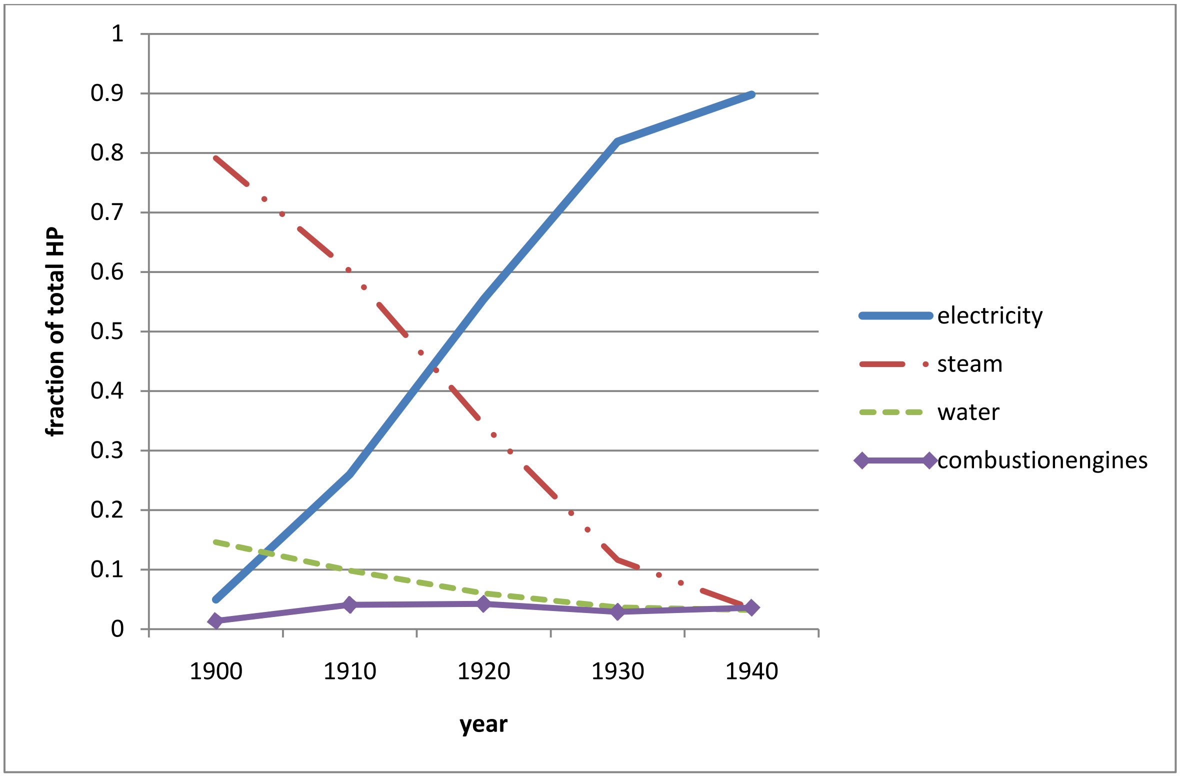
Baseline OLS using 2 sample periods: 1880-1910 & 1910-1940

Dependent Variable	**dexterity/manual**		**clerical/dexterity**		**clerical/ manual+dexterity**		**manager+ clerical/ manual+dexterity**	
Explanatory variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Elecrate	-.01	-.13*	.52***	.21***	.51***	.14*	.55***	.13
	(.17)	(07)	(.15)	(.07)	(.14)	(.07)	(.13)	(.10)
FBShare	-.22*	.16	.46***	-.13	.35**	-.04	-.05	-.33
	(.12)	(.12)	(.15)	(.29)	(.16)	(.25)	(.16)	(.29)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.66	.87	.92	.91	.94	.91	.98	.91
Obs.	148	200	148	200	148	200	148	200

Notes: The dependent variable in each regression is specified in the first row. The explanatory variables are specified in the first column. The method of estimation is Ordinary Least Squares. Standard errors are shown in parentheses and were clustered at the state level. All regressions were weighted using the *person weight* variable from IPUMS. Odd columns show results for the 1880-1910 sample, even columns show results for the 1910-1940 sample.

Figure I

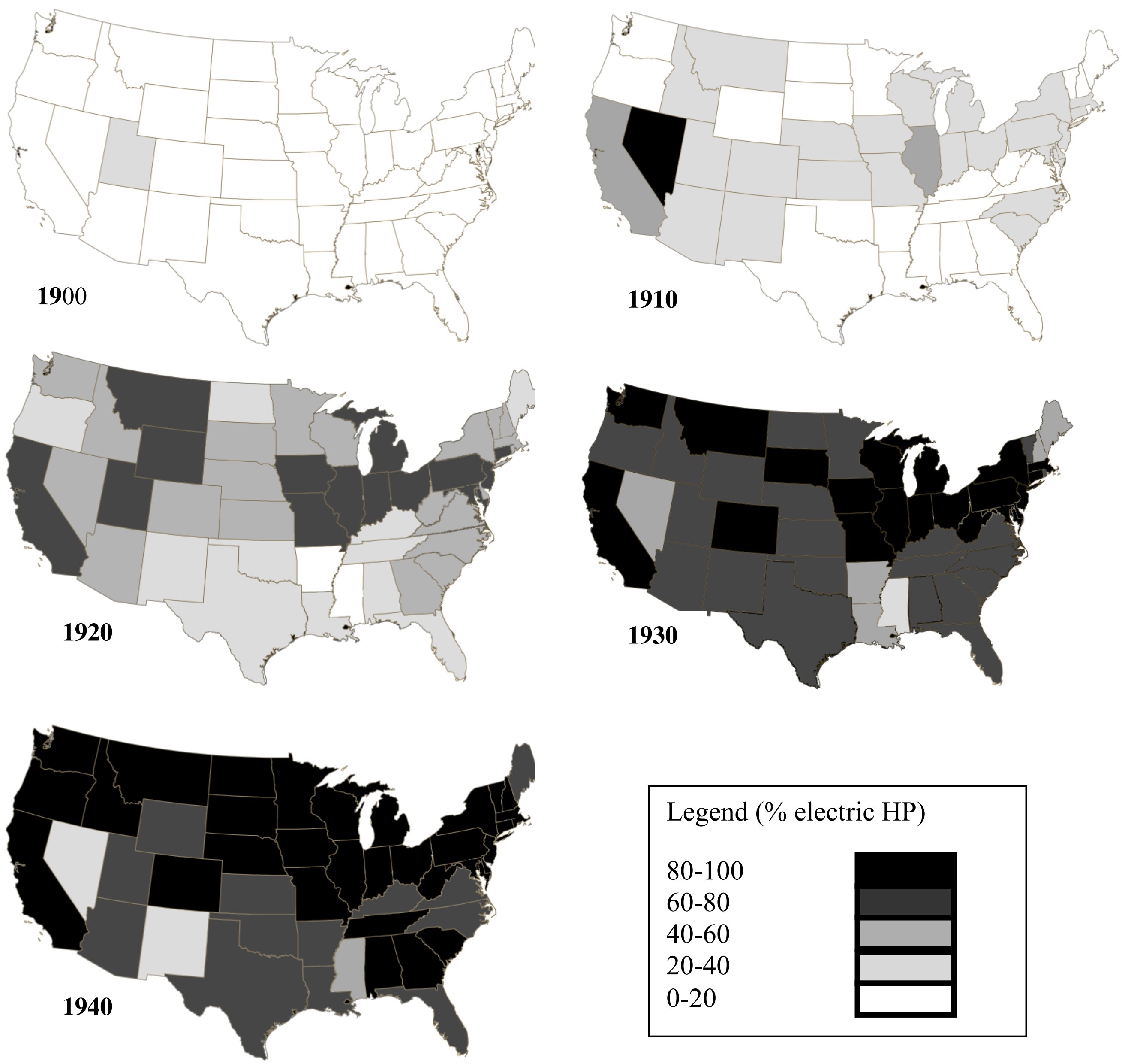
Electrification at the National Level: 1900-1940



Notes: The data are from the Censuses of Manufactures, 1900-1939. Water refers to power created at the firm level with their own water wheels, steam refers to power created at the firm level in steam engines, and electricity refers to power created either at the firm level and that was converted to electricity, or purchased electricity.

Figure II

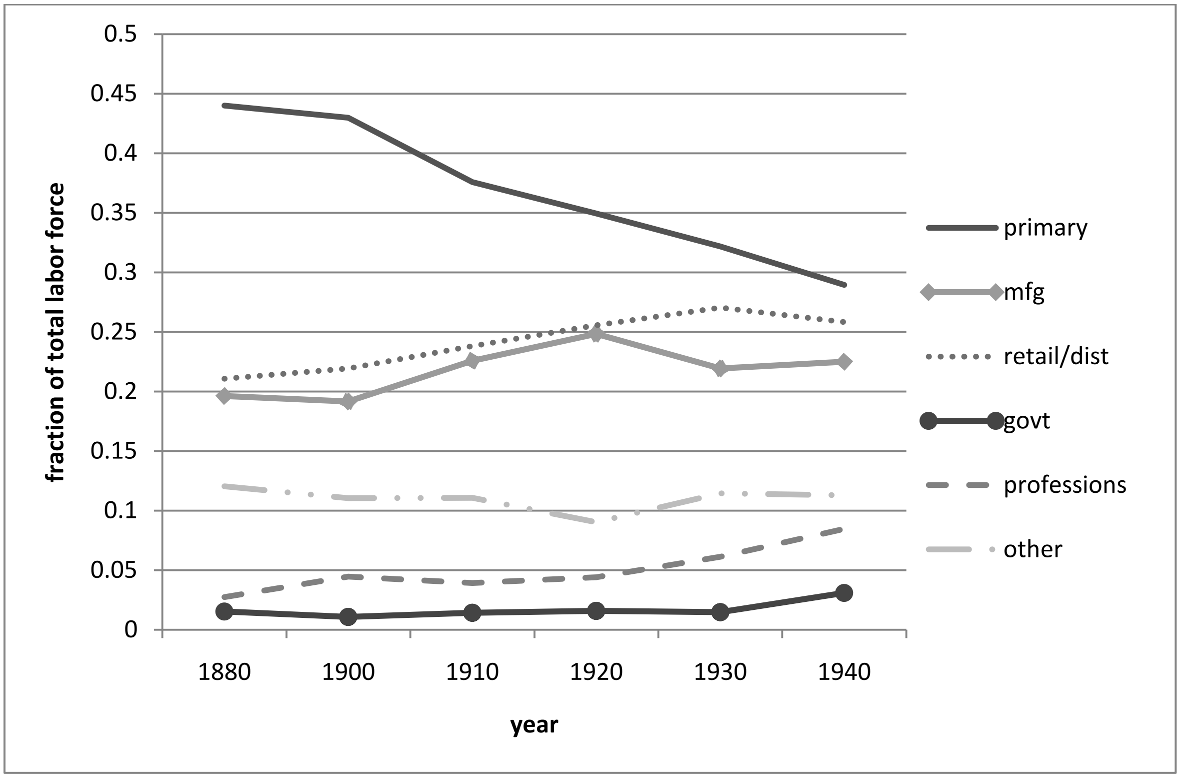
Electrification Rates by State & Year



Notes: Data are from the Censuses of Manufactures for each census year.

Figure III

Sectoral Composition of US Labor Force: 1880-1940



Notes: The data are from IPUMS census data, 1880-1940, using information on industries.

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