The labor market consequences of electricity adoption in the concrete industry during the Great Depression

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The 1920s and 1930s witnessed changes in the US labor market, with a shift away from dexterity-intensive occupations, a productivity speedup, and low job creation. This paper asks whether the adoption of electricity can explain these changes. The identification strategy uses a state’s initial loading on the technology to generate electricity—hydroelectric power or coal power—as an instrument for changes in the price of electricity. It also uses a newly digitized dataset for the concrete industry from 1929 to 1935 to provide plant-level measures of labor market outcomes. Technical progress in electric utilities caused, in the downstream industry of concrete, a decrease in employment and in the labor share of income, as well as an increase in labor quantity productivity and electrical intensity.

Keywords: electricity, Great Depression, labor market, unemployment, labor productivity, labor share of income.

JEL codes: N12, N32, N62.

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1 Introduction

A previous paper (chapter 1 of Morin, 2014) explained US labor market changes since the 1980s with the adoption of computers: structural changes such as a shift away from routine and automated occupations, a productivity speed-up, and a decline in the labor share of income. Similar changes happened in the 1920s and 1930s: a shift away from dexterity-intensive, repetitive occupations (Gray, 2013) an increase in the growth rate of labor productivity (Field, 2003), and low job creation (see the literature review at the end of the introduction).

This paper uses that model, designed to explain labor market changes with the adoption of computers since the 1980s, and asks whether it can also explain labor market changes during the 1930s. The model is general enough to apply to other technologies: this paper simply replaces “computers” with “electricity” and the 1980s with the 1930s. Testing the model in the context of electricity has several advantages compared to computers: electricity prices vary across regions depending on the source of power (hydroelectric or coal) but computers prices are the same everywhere; electricity is a homogenous good requiring no hedonic price adjustments; and electricity is measured with consumption instead of initial investment. This test also disentangles technology from competing explanations for labor market changes in the 1980s, such as offshoring (Elsby, Hobijn and Sahin, 2013) and unionization (Berger, 2012): in the 1930s, offshoring was infeasible and unionization rates were increasing (Farber and Western, 2000).

The model has two main assumptions, which find support in the economic history of electrification. First the model assumes a decrease in the price of electricity, estimated at 7% per year between 1899 and 1947 by Gordon (1992, Table 1) and at 5.8% between 1902 and 1950 by the Historical Statistics of the United States (see Appendix C.3). Second, the model assumes substitutability between electrical machinery and some types of jobs: Goldin and Katz (2010, page 112) cite the example of laborers on the factory floor who were replaced by the conveyor belt, while Jerome (1934) documents the introduction of labor-saving machinery in many industries. To emphasize the parallels with the recent period, this paper also labels these jobs as routine (even though a routine occupation relative to electricity is different from a routine occupation relative to computers).
As an overview of the medium-term implications, the model matches the structural changes in the 1930s with these two assumptions. As electrical machinery becomes more competitive compared to workers, firms replace one with the other. The trend of automation causes employment to shift away from routine occupations, which substitute technology, and into nonroutine occupations, which complement technology. The same decrease in the price of electricity has a larger effect on the growth rate of labor productivity when electricity is cheap—because firms replace workers in routine occupations with electrical machinery—than when electricity is expensive—because firms forego investment in electrical machinery and hire workers in routine occupations instead. The price of electricity has a level effect: the same decrease in the price from a lower level causes a higher increase in the growth rate of labor productivity, which explains the productivity speedup of the 1920s and 1930s.

As an overview of the short-term implications, the model matches the cyclical changes with the additional assumption of labor market frictions. Firms know that they will have to hire more nonroutine jobs in the medium-term. If they destroy nonroutine jobs during the recession, they know that they will have to hire them back in the recovery and pay a hiring cost. To avoid the hiring costs, firms hoard nonroutine jobs during the recession and the burden of adjustment falls on routine jobs. Routine jobs do not entail this hiring cost in the recovery because of their declining trend. Firms did not lay off workers in nonroutine occupations during the recession, so they do not hire them back in the recovery. They may hire back workers in routine occupations but, since the medium-term trend of employment in routine occupations is decreasing, routine jobs do not recover back to peak. Total employment is constant, even as output recovers, which is the definition of a jobless recovery.

The crucial assumption underlying this behavior of the model is the substitutability between routine jobs and electrical machinery. If electrical machinery is equally substitutable to routine and nonroutine jobs, as with a Cobb-Douglas production function, then the model predicts a constant trend for the routine share of employment, the labor share of income, and productivity growth. When a business cycle shock vanishes, the economy returns to the constant trend, so recessions and recoveries have the same dynamics independently of the price of electricity.

This paper tests several predictions of the model. First, it uses the labor share of income to
test the crucial assumption of substitutability between routine jobs and electrical machinery. If the elasticity of substitution between electrical machinery and routine jobs is greater than 1, the labor share of income should decrease as electricity becomes cheaper; if the elasticity of substitution between electrical machinery and all jobs equals 1—as in a Cobb-Douglas production function—the labor share of income should be unrelated to the price of electricity. Second, the paper tests the other predictions of the model for employment, productivity, and electrical intensity.

The ideal test of the model would be a random assignment of input prices across regions and a subsequent analysis of the labor market outcomes. Compared to this ideal test, the first part of the identification strategy uses geography as an instrument for the change in the price of electricity in the 1930s. Electricity at this time came either from hydroelectric power or coal power. Hydroelectric power had high efficiency in 1930, extracting 90% of the potential energy of falling water, and had few opportunities for cost savings. Coal power had low efficiency, extracting 25% of the thermal energy of coal, and had many opportunities for cost savings.¹ The price of electricity decreased in regions with coal power, such as New Jersey, but not in regions with hydroelectric power, such as California. A state’s initial loading on coal power is an instrument for the supply-side change in the price of electricity.

The second part of the identification strategy consists of choosing the concrete industry, whose location decisions are orthogonal to the geography of electricity prices. Concrete plants produce a non-traded good and locate near their customers rather than near cheap electricity. The industry has high transport costs (ready-mix concrete, for example, has to be conveyed to the final location in a few hours) and is among the most dispersed and non-traded industries with a Gini concentration coefficient of 30% in 1935.² Concrete plants locate in New Jersey or California

¹National Electric Light Association (1931, page 43).
²The most dispersed of all industries is ice cream with a Gini concentration coefficient of 17%. This coefficient (Holmes and Stevens, 2004, page 2810) measures the difference between the distribution of economic activity compared to population. Denote the number of states with \( N \), the share of population in state \( k \) as \( \text{pop}_k \), and the share of activity (number of plants or total employment) state \( k \) for industry \( i \) as \( \text{act}_k \). Define the location quotient \( LQ \) as the ratio of activity to population: \( LQ_{ki} = \text{act}_k / \text{pop}_k \). Order the share of activity by non-decreasing order of location quotients: \( LQ_{1i} \leq LQ_{2i} \leq \cdots \leq LQ_{Ni} \). The Gini inequality coefficient for industry \( i \) is:

\[
\text{Gini}_i = 1 - \sum_{k=1}^{N} \text{pop}_k \times \left( \frac{\text{act}_{k_i} + 2 \sum_{l=k+1}^{N} \text{act}_{l_i}}{N} \right).
\]
to be close to their customers, after which they react to the change in the price of electricity in each state. Measurements of labor market outcomes for the concrete industry provide a quasi-experiment to assess the causal effect of technical progress in electric utilities on downstream industries.

This paper uses the universe of concrete plants from the Census of Manufactures, from 1929 to 1935, digitized for the first time for this project. It has information on employment, wage-bill, revenue, cost of electricity, consumption of electricity, and the number and horsepower of electric motors. Linking plants across years produces a panel of 629 continuing plants.\(^3\)

The instrumental variable regressions suggest that technical progress in the electric utility industry caused a decline in the labor share of income of the concrete industry and an increase in the use of electric motors, consistent with the mechanism of capital-labor substitution in the model. As a reminder, a Cobb-Douglas production function has constant factor shares: a decrease in the price of an input leaves the other input shares unaffected. The empirical result in this paper is consistent only with a production function where the elasticity of substitution between electricity and labor is greater than 1—the crucial assumption of the theoretical model. The instrumental variable regressions also suggest that cheaper electricity caused a decrease in employment, an increase in labor quantity productivity, and an increase in electrical intensity. These results are robust to several alternative specifications, such as dropping plants located near the construction of dams. Furthermore, the coal instrument is not correlated with banking failures or housing construction over the 1920s, lending support to the validity of the instrument.

**Related literature.** This paper relates to several strands of the literature: electrification during the 1930s, the parallels between electricity and computers, and the jobless recovery from the Great Depression. On electrification in the 1930s, several studies have used aggregate-level data or Ordinary Least Squares to assess the effects of electrification on the labor market. Gray (2013) studied worker-level evidence from the first half of the 20th century and found that electrification was correlated with a shift away from occupations intensive in dexterity skills, similar to the

\(^3\)A previous version of this paper used less precise linking of plants across years and a sample size of 742 plants. This version uses automated linking software with a bigram comparator, more precise linking across years, and a smaller sample size of 629 plants. The quantitative results are similar but the standard errors are smaller because plants less likely to be the same in the first version added noise to the regression.
findings of Autor, Levy and Murnane (2003) for computerization in the late 20th century. Field (2003) used aggregate-level growth accounting and argued that the 1930s had an unprecedented increase in TFP and were the “most technologically progressive decade of the century” because of electricity. Woolf (1984) used industry-level data from the Census of Manufactures between 1909 and 1929 and found that “firms sought labor-saving and capital-using techniques in response to cheaper energy ... [and reduced] labor’s share of income.” The evidence from previous studies is consistent with the thesis of this paper, whose contribution is to use plant-level data, to propose a new instrument for the adoption of electricity, and to test broader implications of technology adoption (labor share of income, employment, and productivity).

This paper also relates to the literature on the parallels between electricity and computers. David (1990) argued that both electricity and computers generated productivity growth in the wider economy after a long lag, causing the productivity speedups of the 1920s and 1990s. Syverson (2013) found that the speedup in labor productivity of the 1990s was of a similar magnitude as that of the 1920s, documented by Kendrick (1961, page 71).

This paper also relates to the literature on the jobless recovery and technological unemployment during the Great Depression. Irving Fisher in 1928 proposed technology as an explanation for the jobless recovery from the 1927 recession: “increased productivity per worker, aided by improved machinery and organization and more willing labor, is partly responsible for the anomaly of growing unemployment during an extended period of increased business activity” (quoted by Woirol, 1996, page 28). Keynes coined the term of “technological unemployment”: “unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour.” Frances Perkins, secretary of the Department of Labor, stated in a Congressional testimony in 1935 that “you would be surprised at the number of labor-saving devices which have been introduced in industry in the last 2 or 3 years” (Committee on Finance, 1935, page 206). The New York Times invented the expression “jobless recovery” in the 1930s:

“During November [of 1938, the Works Progress Administration] rolls showed some decline, but

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4Field (2011, page 25) questioned the exact dating of the productivity speedup of Kendrick because of his choice of dates: “The problem is that Kendrick compared a fully employed economy in 1929 with a 1937 economy in which 14.3 percent of the labor force was still out of work ... If we seek a peacetime peak-to-peak comparison, we are better served by choosing as an endpoint 1941, when unemployment, although still averaging 9.9 percent, was closer to what it was in 1929 but before war spending or production could seriously have influenced the economy.”
it was slight enough to make observers wonder whether the country were experiencing a 'jobless recovery.'

Relative to this literature, the contribution of this paper is to suggest the decline in the price of electricity as a possible reason for technological unemployment.

2 Data and definitions

This paper assesses the effect of technical progress in electric utilities on labor market variables. It uses two data sources at the state-level from publications by the Census Bureau and at the plant-level from micro-data at the National Archives. The Census Bureau published a state-level summary of the electric light and power industry in 1927 and 1937. It also published state-level information on other variables, such as wages in manufacturing in 1929 and 1935 in the state- and industry-level publications of the Census of Manufactures.

The plant-level dataset is from the Census of Manufactures in 1929 and 1935, which covers the universe of manufacturing plants with sales above five thousand dollars. This dataset is at the National Archives and Records Administration in Washington D.C. Two barriers prevent the wider use of this dataset: the schedules are in paper or microfilm format and the National Archives protect them with in-house access only. This paper focuses on the concrete industry, digitized for the first time for this project. I scanned all the microfilm schedules (around 2,500 for 1929 and 1,100 for 1935). The archivists marked as lost one microfilm roll with 300 plants in 1935 for states Alabama to Iowa but I was able to locate a backup copy in a different location. No schedules from the Census of Manufactures are missing from my sample. A professional data entry firm tabulated these schedules into electronic format. I verified the tabulations and corrected outliers, such as missing commas in the separation of cents and dollars. I also cleaned the names of states, counties and cities. The Census Bureau had no unique plant identifier and I matched the plants across years based on their name, location and ownership (see Appendix 2). From the 3,500 plants present in both 1929 and 1935, I obtained a panel of 629 continuing plants.

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5 Article “Jobless recovery?” of 27 November 1938.
6 This threshold in 1929 corresponds to around $66 thousand today and is high above the average sales for the concrete industry of $38 thousand in 1929 prices.
The concrete industry has three advantages for identification. First, it sells non-traded products (Syverson, 2004), which guarantees that concrete plants locate near their customers and their geographic distribution is exogenous to the regional variation in the price of electricity. Second, the concrete industry is intensive in electricity: continuing plants spent on average 1% of revenue in electricity in 1929, which puts concrete in the upper sixth of manufacturing industries that use the most electricity. Third, concrete plants are small and bought all of their electricity from the grid: the Census Bureau asked about generation of electricity, which is zero for all firms in the balanced panel.

The Census asked about production by quantity and value, employment, wages, number of electric motors, horsepower of electric motors, kilowatt-hours purchased and their cost, and kilowatt-hours generated. The top panel of Table 1 shows summary statistics for continuing concrete plants. The concrete industry has many small plants, with an average of 21 employees. The bottom panel shows summary statistics for the change between 1929 and 1935. On average, concrete plants had a decrease in output, the labor share, employment, the price of electricity, and an increase in the horsepower of electric motors.

Concrete plants use labor-saving electrical machinery at several stages of production of concrete: machinery for crushing and grinding stones into a finer aggregate, machinery for pumping and unloading units to convey cement, electric power shovels and conveyor belts or elevators to move materials, mixing machines that produce a more homogenous product with less cement compared to manual mixing, and waste-heat boilers (Jerome, 1934, page 80; Orchard, 1962, page 404).

The concrete industry had a decline in the labor share of revenue of 14 percentage points, from 28.7% in 1909 to 14.4% in 1939, illustrated in Figure 1. Half of this decrease, or 7 percentage points, occurred during the Great Depression. The other half occurred during the other recessions of 1927 and 1937.  

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7The labor share of value added shows similar numbers: a decline of 17 percentage points from 46% in 1909 to 29% in 1939, of which 7 percentage points occurred during the Great Depression. Nevertheless, this measure is less comparable across years because it sometimes omits fuel and energy.
Summary statistics for 1929

<table>
<thead>
<tr>
<th>Number of plants</th>
<th>Employment of all plants</th>
<th>Average employment per plant</th>
<th>Electricity share of income</th>
<th>Electricity and fuel share of income</th>
<th>Kilowatt hours purchased</th>
</tr>
</thead>
<tbody>
<tr>
<td>629</td>
<td>7964</td>
<td>21</td>
<td>1.3%</td>
<td>2.4%</td>
<td>18,076</td>
</tr>
</tbody>
</table>

Summary statistics for the change between 1929 and 1935

<table>
<thead>
<tr>
<th>Change from 1929 to 1935 (log-points, annualized)</th>
<th>Mean</th>
<th>S.d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output value</td>
<td>-0.09</td>
<td>0.15</td>
</tr>
<tr>
<td>Labor share</td>
<td>-0.02</td>
<td>0.10</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.04</td>
<td>0.13</td>
</tr>
<tr>
<td>State-level cost of electricity</td>
<td>-0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Horsepower of electric motors</td>
<td>0.01</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Table 1: Summary statistics for the concrete industry.

Figure 1: The decline in the labor share of revenue of the concrete industry accelerated during the Great Depression.
Details: wages divided by revenue every two years from 1909 to 1939, from the publication Census of Manufactures for the year 1939. Shaded areas are NBER recessions.
3 Methodology

3.1 Overview of the model

This subsection summarizes the production side of the theoretical model. The General Equilibrium properties of the model (household side and equilibrium of the labor, product, and capital markets) are omitted here and the interested reader is referred to Morin (2014). Plant \( i \) rents two types of capital, electric capital \( K_{E,i,t} \) and non-electric capital \( K_{NE,i,t} \). The first assumption is a long-term decrease in the rental rate of electric capital.

**Assumption 1.** The rental rate \( r_{E,i,t} \) of electric capital decreases exogenously with time:

\[
r_{E,i,t} \downarrow \text{ in } t.
\]

Plant \( i \) hires workers in two types of occupations, routine occupations \( L_{R,i,t} \) and nonroutine occupations \( L_{NR,i,t} \). The production function of plant \( i \) is:

\[
Y_{i,t} = A_{i,t} K_{NE,i,t}^{\alpha} L_{NR,i,t}^{\beta} M_{i,t}^{\gamma},
\]

\[
M_t = \left( K_{E,i,t}^{\frac{\varepsilon-1}{\varepsilon}} + L_{R,i,t}^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{1}{\varepsilon}},
\]

where \( A_{i,t} \) is Total Factor productivity. The production function has constant returns to scale, with \( \alpha + \beta + \gamma = 1 \). This production function has Cobb-Douglas aggregation of three factors: non-electric capital \( K_{NE,i,t} \), employment in nonroutine occupations \( L_{NR,i,t} \), and a third factor, which is a Constant-Elasticity-of-Substitution aggregate between electric capital \( K_{E,i,t} \) and employment in routine occupations \( L_{R,i,t} \). The second crucial assumption is gross substitutability of electric capital and employment in routine occupations tasks in the production function:

**Assumption 2.** The elasticity of substitution between electric capital and employment in routine occupations is greater or equal to 1:

\[
\sigma \geq 1.
\]
Plant $i$ operates under perfect competition and has profits

$$\text{profits}_{i,t} = p_{i,t} Y_{i,t} - w_{i,t} (L_{NR,i,t} + L_{R,i,t}) - r_{NE,i,t} K_{NE,i,t} - r_{E,i,t} K_{E,i,t},$$

where $w_{i,t}$ is the wage, $p_{i,t}$ is the price of output. The firm maximizes the present value of profits, discounted with the market interest rate $r_t$.

As in Morin (2014, ch 1), the wage $w_{i,t}$ is the same for routine and nonroutine occupations because the household supplies both tasks with no friction. Unlike Morin (2014, ch 1), hiring costs are zero in this setting, which guarantees a closed-form solution. The interested reader is referred to Morin (2014, ch 1) for more details on the supply side of the labor market and the short-term implications of the model when including adjustment costs.

### 3.2 Testable predictions

Morin (2014, ch 1) shows that the General Equilibrium model with hiring costs has five predictions for the labor market: (1) labor productivity speeds up, (2) employment shifts away from routine occupations and into nonroutine occupations, (3) the labor share of income declines, (4) recessions accelerate the structural decline in routine occupations, (5) recoveries from recessions are jobless, i.e., employment recovers slower than output.

Testing the theory requires choosing the predictions to test with the available data. One prediction of the model—routinization of production—is the subject of Gray (2013). She merged the worker-level Census of Population from 1900 to 1950 to the Dictionary of Occupational Titles. She defined an occupation as routine if it required high dexterity and low manual or clerical skills. She found that states with faster electrification also shifted away from these routine occupations, similar to the findings of Autor, Levy and Murnane (2003) for computerization in the late 20th century and consistent with the thesis in this paper.

The prediction of acceleration of routinization cannot be tested with this dataset. This prediction requires high-frequency information on employment by detailed occupations, which is unavailable in the Census of Manufactures (see Appendix A.3). If electricity complements nonroutine
occupations, the positive impact on nonroutine jobs could offset the negative impact on routine jobs, which biases against finding a positive net effect.

Therefore, the rest of this paper focuses on the three testable predictions: employment, productivity, and the labor share of income. The prediction of jobless recoveries finds some support in the data, with electricity adoption causing a slower recovery of employment between 1933 and 1935. A more general formulation of this prediction, for example if labor supply has a reallocation cost across occupations, is that electricity causes a decrease in employment over the whole period of 1929-1935, which is also tested.

The period covered is 1929 and 1935 for three reasons. First, the plant schedules of the Census of Manufactures survived only for this period and the years before or after were destroyed. Access to plant-level data is important in order to link plants across years and avoid compositional bias due to the turnover of plants. It also contains more information, such as output in tons of concrete and the horsepower of electric motors, which is not otherwise available. Second, the major turmoil in labor markets during the Great Depression provides variation in the dependent variables and allows a more precise estimation of the regression coefficients.

3.3 Linear regressions

The model implies the following non-linear equations for the labor share of income and the electric capital-labor ratio (see Appendix B for proofs):

$$\frac{w_{j,t}L_{j,t}}{p_{j,t}Y_{j,t}} = \beta + \gamma \left(1 + \left(\frac{r_{E,j,t}}{w_{j,t}}\right)^{1-\sigma}\right)^{-1},$$  \hspace{1cm} (2)

$$\frac{K_{E,j,t}}{L_{j,t}} = \left(\frac{r_{E,j,t}}{w_{j,t}}\right)^{-1} \left(\frac{\beta}{\gamma} + \left(1 + \frac{\beta}{\gamma}\right)\left(\frac{r_{E,j,t}}{w_{j,t}}\right)^{\sigma-1}\right)^{-1},$$  \hspace{1cm} (3)

where $j$ indexes a unit of observation such as firms $i$ or regions $k$. The equation for labor quantity productivity $Y_{j,t}/L_{j,t}$ is similar and omitted.

These equations include a “level effect:” when electrical machinery is too expensive and $\sigma > 1$, the non-linear term vanishes from the equation and the labor share of income is constant. When
technology is too expensive, a decrease in the price of electricity has little impact on the economy, as firms prefer to hire workers instead. The “level effect” was discussed in Morin (2014, ch 1).

To translate these predictions into regression equations, I consider the log-linear version of the equations. The problems in using a log-linear version of non-linear equations with a level effect are minimal because the level effect is more important over decades of decrease in the price of the technology, rather than the six years between 1929 and 1935. The next simulations illustrate that the log-linear regressions are an accurate approximation to the non-linear relationships, I use the General Equilibrium model from the Morin (2014, ch 1) to simulate 300 artificial economies. All simulations use the same parameters, equal to those from the calibration in Morin (2014, ch 1), except for the rate of decrease $\phi$ in the price of electricity, which follows a uniform distribution between 1% and 18%. I solve the model for each artificial economy $j$ and estimate the following log-linear equations:

\[
\Delta \log \frac{w_{j,t}L_{j,t}}{p_{j,t}Y_{j,t}} = 0.0011 + 0.047 \Delta \log \left( \frac{r_{E,j,t}}{w_{j,t}} \right) + error \quad (4)
\]

\[
\Delta \log \frac{K_{E,j,t}}{L_{j,t}} = -0.0023 - 1.556 \Delta \log \left( \frac{r_{E,j,t}}{w_{j,t}} \right) + error \quad (5)
\]

Under the assumption $\sigma > 1$, the slope coefficient should be positive for the labor share of income and smaller than -1 for the computer capital-labor ratio. The scatter plot in Figure 2 shows that the log-linear regression from the model is an accurate approximation to the non-linear expression.

Two further difficulties arise in the context of electricity. First, the relative rental rate $r_{E,j,t}/w_{j,t}$ of electrical machinery is unobserved and I use the price of electricity in cents per kilowatt-hour as a proxy, which implies measurement error and an attenuation bias toward zero. Second, the average price of electricity at the plant-level is far from the marginal price: several forms of fixed costs (see Appendix C) introduce measurement error in the price of electricity paid by small

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8The usage cost of electricity has two components: the price of electricity in kilowatt-hours and the rental rate of an electric motor. Regional variation in the usage costs stems mostly from the price of electricity because the rental rate of electric motors is likely to be the same for all regions. The rental rate of an electric motor has three components: the interest rate, the price of investment, and the depreciation rate. Each of these components should have similar values across regions: the interest rate was set by the Federal Reserve for all regions and the electrical machinery industry was concentrated in five states which served a national market with similar investment prices and depreciation rates.
concrete plants. Fixed costs should lose importance when considering a larger entity such as the state, whose average price of electricity should be closer to the marginal price. The preferred measure of the price of electricity is the state-level average price from the Census of Electric Light and Power Stations for 1927 and 1937.9 This measure minimizes the importance of fixed costs, making the average price closer to marginal price, and is close to the price of electricity paid by industrial users, since power stations sold on average 69% of their current to industrial consumers.10

The regression equations are:

\[
\Delta \log \frac{w_{i,t}L_{i,t}}{p_{i,t}Y_{i,t}} = \text{constant} + a \Delta \log (p_{E,k,t}) + \text{error.} \tag{6}
\]

\[
\Delta \log \frac{Y_{i,t}}{L_{i,t}} = \text{constant} + b \Delta \log (p_{E,k,t}) + \text{error} \tag{7}
\]

\[
\Delta \log L_{i,t} = \text{constant} + c \Delta \log (p_{E,k,t}) + \text{error} \tag{8}
\]

\[
\Delta \log \frac{K_{E,i,t}}{L_{i,t}} = \text{constant} + d \Delta \log (p_{E,k,t}) + \text{error} \tag{9}
\]

where \(i\) indexes plants, \(k\) indexes states, \(w_{i,t}L_{i,t}\) is the aggregate wage-bill at the plant-level, \(p_{i,t}Y_{i,t}\) is the output value at the plant-level, \(p_{E,k,t}\) is the change in the price of electricity at the state-level, \(Y_{i,t}/L_{i,t}\) is labor quantity productivity in tons of concrete, \(L_{i,t}\) is employment, and \(K_{E,i,t}/L_{i,t}\) is a measure of electrical intensity at the plant-level (the horsepower of electric motors per worker). Alternative regressions use on the right-hand side \(\Delta \log (p_{E,k,t}/w_{k,t})\), the change in the price of electricity relative to the state-level wage: if so, the left-hand side of (6) uses the wage at the plant-level for the concrete industry and the right-hand side uses the wage at the state-level for all manufacturing industries. The theory predicts \(a > 0, b < 0, c > 0,\) and \(d < -1\): a decrease in the price of electricity should cause a decrease in the labor share of income, an increase in productivity, a decrease in employment, and an increase in electrical intensity.11

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9Stigler and Friedland (1962) used this measure to assess the effect of regulation on electricity prices. To the best of my knowledge, the Census of Electric Light and Power Stations is the only source of data for the price of electricity at the state-level during this period.

10Census of Electric Light and Power Stations, 1927, page 51.

11The model normalizes the price of output \(p_{i,t}\) to 1, so other prices are in real terms. The regressions use a nominal price with no deflator—deflating prices by a nation-wide price or wage index would affect the intercept of the regression and not the slope.
3.4 Endogeneity and an instrument

The identifying assumptions for regression equations (6) to (9) are that the average price of electricity, of labor, and of output are close to the marginal prices and that the error term is uncorrelated with the regressors. Then $a$ and $a'$ are consistent and unbiased estimators.

Estimating a regression of quantities on prices raises concerns about endogeneity and is a challenge to identification: it is unclear whether the regression estimates the demand or supply equation. This paper is interested in the demand for electricity and requires an instrument that shifts the electricity supply curve and not the demand curve. This endogeneity should bias the estimation of the downward-sloping electricity demand curve toward the upward-sloping electricity supply curve. The coefficients should be further away from zero in Instrumental Variables (IV) compared to Ordinary Least Squares (OLS). A similar argument suggests that endogeneity also biases the coefficient on the labor share of income toward zero because the labor share of income is decreasing in the electric capital-labor ratio in the model.

The identification strategy to deal with the endogeneity bias consists of two parts: using geography as an instrument for the change in the price of electricity and choosing the non-traded industry of concrete. As an instrument for the supply-side change in the price of electricity, this paper uses the share of coal in the generation of electricity in 1927. In 1930, power plants extracted 90% of the potential energy of falling water and had few opportunities for cost-saving innovations. Power plants extracted 25% of the potential energy of burning coal to power steam turbines, had many opportunities for cost-saving innovations.\(^{12}\) The generation of electricity from coal improved thanks to a “rise in steam pressures and steam temperatures used, and ... the experimental introduction of a second working fluid in an independent cycle supplementing that of the steam.”\(^{13}\) These innovations increased the thermal efficiency of fuel: “In 1928, the same amount of energy was produced with 71 per cent less fuel than would have been required in 1904.”\(^{14}\)

Technical progress in the generation of electricity from coal impacted regions differently depend-

\(^{12}\)National Electric Light Association (1931, page 43).
\(^{13}\)Census of Electric Light and Power Stations (1927, page 82)
\(^{14}\)Electrical Research Statistics (1929). See also Sleight (1930, page 57) for a similar finding.
ing on their initial dependence on this technology. Regions with access to hydroelectric power, such as Minnesota or California, have cheap electricity but the price of electricity is roughly constant. Regions without hydroelectric power, such as North Dakota or New Jersey, have initially more expensive electricity but the price of electricity decreases. Figure 3 illustrates the pattern of convergence across states. Figure 4 shows the first-stage of the instrument at the state-level: states with initially larger dependence on coal power also had a decrease in the relative price of electricity. The two measures of the price of electricity in this paper are:

\[
\Delta \log (p_{E,k,t}) = \frac{1}{10} \log \left( \frac{p_{E,k,1937}}{p_{E,k,1927}} \right), \quad \Delta \log \left( \frac{p_{E,k,t}}{w_{k,t}} \right) = \frac{1}{10} \log \left( \frac{p_{E,k,1937}}{p_{E,k,1927}} \right) - \frac{1}{6} \log \left( \frac{w_{k,1935}}{w_{k,1929}} \right),
\]

where the price of electricity is the average price of electricity for ultimate consumers from the Census of Electric Light and Power Stations in 1927 and 1937 and the wage is the industry-wide average wage for wage-earners and salaried workers for all manufacturing firms in 1929 and 1935.

Four arguments support the validity of this instrument. First, concrete plants do not sort geographically depending on the price of electricity: the concrete industry sells a non-traded product and locates near its customers. Second, the instrument should affect electric utilities on the supply side of the electricity market but not concrete plants on the demand side of the market. Third, the instrument is an initial level and the outcome variables are changes. Omitted variables in levels, such as the skill composition of the workforce or the density of the road network, are differenced out in the regressions. Fourth, using ratios at the plant-level, such as labor productivity or the labor share of income, implies the absence of that plant-level shocks that affect the numerator and denominator similarly, such as TFP shocks.

A possible violation of the exclusion restriction concerns omitted variables that change through time. For example, cities high in hydroelectric power may attract more government programs for dam construction, which would increase demand for concrete in regions with hydroelectric power compared to regions with coal power. This increase in demand may be met with the more adjustable factors, such as labor or materials. To address this concern, I run a falsification test with the materials share of income and also run a robustness test by dropping states with dam construction from the sample.
Figure 2: The non-linear relationship in the model is close to a linear one for short periods of time.
The vertical line corresponds to a decrease in the price of electricity of $\phi = 7\%$.

Figure 3: The price of electricity converged across states between 1927 and 1937.
The two neighboring states of Minnesota and North Dakota have a different color and a larger font. The outlier states of Mississippi and Arizona are omitted.
4 Results

This section presents the evidence for $\sigma > 1$ and for the causal link between electricity and labor market outcomes: the labor share of income, labor productivity, and employment. Concrete plants with access to cheaper electricity also reduce their labor share of income, increase labor quantity productivity, reduce employment, and have a higher electric capital-labor ratio. The results are robust to several alternative specifications and the coal instrument is not correlated to banking failures or to the growth in construction over the 1920s.

4.1 Baseline results

Table 2 shows the baseline results in instrumental variables and Table 3 shows the results in reduced-form. The exogenous decrease in the price of electricity caused a decrease in the labor share of revenue, an increase in labor quantity productivity, a decrease in employment, and an increase in electrical intensity. The regression of labor quantity productivity (the number of concrete tons divided by employment) suggests that the results are not due to deflation or other price channels. The regression of the labor share of revenue supports the crucial assumption in the model. The coefficient for the labor share is proportional to $\sigma - 1$: it should be positive under the assumption $\sigma > 1$ and zero under $\sigma = 1$. The IV regression of electrical intensity traces the demand curve and finds a negative coefficient: cheaper electricity induces more horsepower per worker. The theory predicts that the coefficients on electric capital-labor ratios should be smaller than -1 and the regressions confirm that prediction. The coefficients are economically and statistically significant. The standard errors in all plant-level regressions are clustered at the state-level and all variables are "winsorized" at the 1% level.

A back-of-the-envelope calculation with the point estimates in reduced form suggest that technical progress in the coal technology may explain the decrease in the labor share of revenue of the concrete industry: it decreased on average 1.6% per year, while the reduced-form regression predicts a decrease of 1.9% (equal to the reduced-form coefficient of 0.0247 times the average coal dependence in the sample of 0.78). That is, technical progress over-predicts the decrease in the
Figure 4: First-stage regression: an initially higher share of coal in power generation in 1927 causes a subsequent decrease in the relative price of electricity.
Larger circles represent states with more plants but the regression has the same weight for all states.

Table 2: Baseline results in IV: the decrease in the price of electricity caused a decrease in the labor share of revenue, an increase in labor quantity productivity, a decrease in employment, and an increase in electrical intensity.
labor share of revenue for continuing plants. This thought experiment assesses the net contribution of electricity and holds constant other factors, such as wages that may have national-level shifters such as the National Recovery Act of 1933.

To ensure that the results are in line with the theory, which predicts that the relevant variable is the price of electricity relative to wages, Table 4 shows the IV regressions with the price of electricity relative to wages in all of manufacturing. The coefficients have similar magnitudes and lose some statistical significance.

4.2 Falsification tests

Tables 5 shows four falsification tests, or placebo regressions. The first two test an alternative channel of a demand shock: if the coal instrument were correlated with a demand shock, it could explain both a decrease in production and in employment. The first two columns of Table 5 suggest that such is not the case: the coal instrument is not a statistically significant predictor of the change in value or quantity of output. The last two test the effect of the instrument on the materials and fuel share of revenue. One might be concerned that, since revenue shares sum to one, the effect of electricity on the labor share may be a arithmetic consequence of the increase in the share of materials or fuel. The last two rows of Table 5 suggest that such is not the case either: the IV regressions have statistically insignificant coefficients.

4.3 Geography of the coal share of power

Using state-level geography as an instrument has the drawback that the instrument corresponds to inland regions as opposed to the coasts. Figure 5 shows that the mountains in the West and East Coast provide the altitude differentials necessary for hydroelectric power while the Great Plains need to use coal power. Some variation persists within region, such as the neighboring states of North Dakota with 100% coal power versus Minnesota with 36% coal power, or the neighboring states of Florida with 98% coal power versus Georgia with 13% coal power. Nevertheless, the within-region variation is not sufficient to confirm the baseline results. Hydroelectric
### Table 3: Baseline results in reduced-form: initially higher coal dependence caused a decrease in the labor share of revenue, an increase in labor quantity productivity, a decrease in employment, and an increase in electrical intensity.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$\Delta \log \frac{w_iL_{i,t}}{p_iY_{i,t}}$</th>
<th>$\Delta \log \frac{Y_{i,t}}{L_{i,t}}$</th>
<th>$\Delta \log (L_{i,t})$</th>
<th>$\Delta \log \frac{K_{E,i,t}}{L_{i,t}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{coal}_{k,1927}$</td>
<td>-0.0247***</td>
<td>0.0625***</td>
<td>-0.0435***</td>
<td>0.0935**</td>
</tr>
<tr>
<td>(state-level)</td>
<td>(0.0121)</td>
<td>(0.0229)</td>
<td>(0.0141)</td>
<td>(0.0361)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.00345</td>
<td>-0.0928***</td>
<td>-0.00849</td>
<td>-0.00738</td>
</tr>
<tr>
<td></td>
<td>(0.00926)</td>
<td>(0.0185)</td>
<td>(0.0108)</td>
<td>(0.0308)</td>
</tr>
<tr>
<td>Observations</td>
<td>620</td>
<td>551</td>
<td>620</td>
<td>474</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.005</td>
<td>0.009</td>
<td>0.007</td>
<td>0.021</td>
</tr>
<tr>
<td>Number of states / clusters</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>39</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

### Table 4: The baseline results are robust to using the relative price of electricity instead of the absolute price.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$\Delta \log \frac{w_iL_{i,t}}{p_iY_{i,t}}$</th>
<th>$\Delta \log \frac{Y_{i,t}}{L_{i,t}}$</th>
<th>$\Delta \log (L_{i,t})$</th>
<th>$\Delta \log \frac{K_{E,i,t}}{L_{i,t}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \log (p_{E,k,t}/w_{k,t,mfg})$</td>
<td>1.320*</td>
<td>-3.482**</td>
<td>2.333*</td>
<td>-4.801*</td>
</tr>
<tr>
<td>(state-level, instrumented)</td>
<td>(0.747)</td>
<td>(1.441)</td>
<td>(1.218)</td>
<td>(2.765)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.0398***</td>
<td>0.0199</td>
<td>-0.0849***</td>
<td>0.153***</td>
</tr>
<tr>
<td></td>
<td>(0.0133)</td>
<td>(0.0316)</td>
<td>(0.0236)</td>
<td>(0.0498)</td>
</tr>
<tr>
<td>Observations</td>
<td>620</td>
<td>551</td>
<td>620</td>
<td>474</td>
</tr>
<tr>
<td>Number of states / clusters</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>39</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
power requires falling water and is close to the map of mountains in the United States, a consequence of using geography as an instrument for the change in the price of electricity depending on the source of power. If plants in the mountain regions are affected differently during the Depression, it may invalidate the exclusion restriction of the Instrumental Variable approach. One possibility is that mountain regions have government programs for building dams. Table 6 shows that the baseline results are robust to dropping counties within 50 miles of dams under construction, giving confidence that the instrument is valid and the results are not due to government demand for concrete products.

Several other correlations suggest that the coal instrument is not picking up alternative channels: the instrument does not predict the previous growth in housing construction over the 1920s, it does not predict the subsequent bank failures across states. Another threat to identification occurs if the share of coal in electric power generation reacts to changes in electricity demand and in aggregate demand. Figure 7 suggests that the change in coal capacity is uncorrelated with the change in housing construction over the 1920s.

4.4 Jobless recovery

The last prediction of jobless recoveries finds some support in the data. Table 7 shows the results for employment and productivity between 1933 and 1935, in reduced-form, for plants that report both employment and physical output. The decrease in the price of electricity caused a slower recovery of employment and strong productivity gains, both in IV and in reduced-form, with a magnitude twice as large as the coefficients for 1929-1935. Nevertheless, these results should be taken with a grain of salt: they are not entirely robust to other specifications, such as the aggregation of all plants.

4.5 State-level results for all plants

The predictions of the model for the labor share and labor productivity are also valid at the state-level for all plants, not just continuing plants. To run state-level regressions, I aggregate
### Table 5: Falsification tests in instrumented variables: the decrease in the price of electricity has no effect on the materials share of revenue.

As the fuel share of revenue is small, around 1%, this regression uses the percentage point change instead of the log-change.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$\Delta \log (p_{E,k,t})$</th>
<th>$\Delta \log (Y_{i,t})$</th>
<th>$\Delta \log \frac{\text{materials}<em>{i,t}}{p</em>{i,t}Y_{i,t}}$</th>
<th>$\Delta \frac{\text{fuel}<em>{i,t}}{p</em>{i,t}Y_{i,t}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(state-level, instrumented)</td>
<td>1.971 (1.587)</td>
<td>-1.647 (2.395)</td>
<td>1.288 (0.830)</td>
<td>-0.162 (0.115)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.0492 (0.0359)</td>
<td>-0.123** (0.0545)</td>
<td>0.0316* (0.0181)</td>
<td>-0.00284 (0.00242)</td>
</tr>
<tr>
<td>Observations</td>
<td>629</td>
<td>558</td>
<td>598</td>
<td>629</td>
</tr>
<tr>
<td>Number of states / clusters</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>First-stage $F$-statistic</td>
<td>19.15</td>
<td>19.15</td>
<td>19.15</td>
<td>19.15</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 5: Map of the share of coal power in 1927 (darker blue implies higher coal share).
Dependent variable: $\Delta \log \frac{w_{i,t} L_{i,t}}{Y_{i,t}}$ $\Delta \log \frac{Y_{i,t}}{L_{i,t}}$ $\Delta \log (L_{i,t})$ $\Delta \log \frac{K_{E,i,t}}{L_{i,t}}$

<table>
<thead>
<tr>
<th></th>
<th>$\Delta \log (p_{E,k,t})$</th>
<th>$\Delta \log \frac{Y_{i,t}}{L_{i,t}}$</th>
<th>$\Delta \log (L_{i,t})$</th>
<th>$\Delta \log \frac{K_{E,i,t}}{L_{i,t}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(state-level, instrumented)</td>
<td>1.952*</td>
<td>-5.172*</td>
<td>2.587*</td>
<td>-8.176*</td>
</tr>
<tr>
<td></td>
<td>(1.126)</td>
<td>(3.089)</td>
<td>(1.526)</td>
<td>(4.420)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0297</td>
<td>-0.165**</td>
<td>0.0137</td>
<td>-0.123</td>
</tr>
<tr>
<td></td>
<td>(0.0266)</td>
<td>(0.0713)</td>
<td>(0.0345)</td>
<td>(0.104)</td>
</tr>
<tr>
<td>Observations</td>
<td>531</td>
<td>472</td>
<td>531</td>
<td>410</td>
</tr>
<tr>
<td>Number or states / clusters</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>36</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: The baseline results are robust to dropping counties within 50 miles of dams under construction.

Details: The latitude and longitude by city is from Gaslamp Media (2014), which “compiled from a city/county/state database and geocoded with Google Maps.” The list of counties with dam construction is from Hay (1991) for dams completed between 1930 and 1940. The latitude and longitude of a county with dam construction is the average of all cities in that county. The closest distance from county X to a dam under construction is the minimum Haversine distance from all cities in county X to all cities in counties with dam construction.

Figure 6: The coal instrument is unrelated to bank failures across states.

Details: bank failures is the percentage of deposits of all banks in 1930 that were suspended in 1930, 1931, 1932, or 1933.
Figure 7: The change in coal capacity between 1922 and 1927 is uncorrelated with the growth in housing construction from 1925-1929.
Details: housing is the number of dwellings built over each quinquennium (1925-1929 or 1920-1924), kindly provided by Kimbrough and Snowden (2007).

Table 7: A higher loading on the coal technology caused a weaker recovery of employment and strong productivity gains.
employment, total output value, wage bill, and electric horsepower at the state-level, and then I compute annualized changes. Table 8 suggests that the results persist for the labor share and productivity with similar magnitudes as the plant-level regressions. The effects on employment and horsepower per worker become statistically insignificant: this could be due to compositional bias and the creative destruction of concrete plants, one avenue for future research.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$\Delta \log \frac{w_{k,t}L_{k,t}}{p_{k,t}Y_{k,t}}$</th>
<th>$\Delta \log \frac{Y_{k,t}}{L_{k,t}}$</th>
<th>$\Delta \log (L_{k,t})$</th>
<th>$\Delta \log \frac{K_{E,k,t}}{L_{k,t}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \log (p_{E,k,t}/w_{k,t,mfg})$</td>
<td>1.141**</td>
<td>-3.371**</td>
<td>1.103</td>
<td>-2.548</td>
</tr>
<tr>
<td>(state-level, instrumented)</td>
<td>(0.527)</td>
<td>(1.644)</td>
<td>(0.917)</td>
<td>(2.375)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.0448***</td>
<td>0.104***</td>
<td>-0.150***</td>
<td>0.110***</td>
</tr>
<tr>
<td></td>
<td>(0.0111)</td>
<td>(0.0403)</td>
<td>(0.0205)</td>
<td>(0.0420)</td>
</tr>
<tr>
<td>Observations</td>
<td>46</td>
<td>45</td>
<td>46</td>
<td>44</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: State-level results in IV: the decrease in the price of electricity caused an increase in labor productivity (value or quantity) and a decrease in the labor share of value added.
Details: the regression is weighted by initial employment in each state. Output value $p_{k,t}Y_{k,t}$ at the state-level is value added instead of revenue.
5 Conclusion

This paper tests the model of labor market changes based on capital-labor substitution in the context of electricity and provides two contributions. First, it uses a plant-level dataset from the concrete industry during the 1930s, digitized for the first time for this project. This plant-level dataset has finer detail than the Census of Manufactures state-level publications for the concrete industry and allows a more precise test of the model, e.g. by considering continuing plants and by excluding plants near dam construction. Second, the identification strategy uses a new instrument—a state’s initial loading on the coal technology—to isolate the exogenous shift in the electricity supply curve. Consistent with the predictions of the model, a decrease in the price of electricity caused a decrease in employment, an increase in productivity, and a decrease in the labor share of income. The results imply that the elasticity of substitution between electricity and labor is greater than 1. Some occupations may be more replaced by electrical machinery than others, such as the routine, dexterity-intensive occupations described by Gray (2013).

Two questions arise for future research. First, this paper used electricity prices at the state-level and ignored within-state variation in electricity prices. As an example of within-state variation, plants in Buffalo use hydroelectricity from Niagara Falls while plants in New York City use coal electricity. Further data digitization from the Census of Manufactures could produce electricity prices for industrial consumers at the county or city level, which would allow researchers to leverage the plant-level variation of this dataset. Second, the model’s predictions for employment find support for continuing plants but not for all plants. An investigation of the characteristics of entry and exit in the concrete industry would provide a more accurate description of aggregate-level employment during the Great Depression. These questions are left for future research.

It is a surprising conclusion that the model, designed to explain labor market changes with the adoption of computers since the 1980s, can also explain labor market changes in the concrete industry with the adoption of electricity in the 1930s. By emphasizing the parallels between two eras of rapid technology adoption, this paper relates to the literature on general purpose technologies throughout history: ‘whole eras of technical progress and growth appear to be driven by a few ’General Purpose Technologies,’ such as the steam engine, the electric motor,
and semiconductors.” (Bresnahan and Trajtenberg, 1995). A recent debate has focused on the importance of recent General Purpose Technologies compared to previous ones. Jovanovic and Rousseau (2005) think that “electricity and information technology [are] probably are the two most important General Purpose Technologies so far.” Gordon (1999) disagrees and suggests that we may face decreasing returns in the invention of new technologies: “electricity . . . was a much more profound creator of productivity growth than anything that has happened recently . . . this was a unique event that will not be replicated in the lifetimes of our generation or that which follows us.” It is an open question whether the next General Purpose Technology will be as important as previous ones and whether the historical patterns of the output and labor markets will repeat themselves.
References


Ziebarth, Nicolas. 2011. “Misallocation and Productivity during the Great Depression.” *Northwestern University manuscript (accessed 14 February 2012).*

### Data sources


A Census of Manufactures for the concrete industry

A.1 Matching across years

I matched plants between years 1929 and 1935 according to a similar procedure as Bresnahan and Raff (1991). Some plants sent two schedules to the Census Bureau, such as one by the plant and another by the general office; on two occasions, I aggregated them into a new plant by either averaging their responses if the two schedules covered the same period of operation, or by summing their results if they covered different periods. I considered that two plants were a match if:

1. one plant is from 1929 and the other from 1935,

2. the two plants are located in the same state, county, and city,

3. one of the following conditions hold:

   (a) the name fields coincide (name of plant, name of owner, or their change) and the location fields coincide (same street location in both years, or the street location in a year coincides with the general office location in another year),

   (b) the name fields coincide, one of the plants did not report a street location, and they are the only plants in that state, county, and city,

4. no other plants match criteria (1-3).
As an example of condition 2, I considered small cities included in larger cities to be the same, such as Flushing and New York. I also considered nearby cities to be the same, such as Edina and Minneapolis, since concrete plants sometimes reported the location of the plant and sometimes the post office address of the general office. As an example of condition 3 (a), it is verified between a plant in 1935 with name “Gehirs” and address “23 Conklin St,” and a plant in 1929 with owner “Gehirs” and address “Conklin street and Liberty Avenue.” As an example of condition 4, if two plants in Rockford, Illinois, share the name “Rockford plant” in 1929, then none is matched to the “Rockford plant” in 1935.

This procedure produces 629 plants merged between 1929 and 1935. Out of the 2,435 concrete plants operating in 1929, more than two thirds exited the market; out of the 1,108 concrete plants operating in 1935, a third entered the market.

The schedules changed slightly across plants. Some concrete plants in 1929 filled a schedule for the Census of Mines and Quarries, which omitted questions about electricity consumption and the quantity of output. Some plants filled other schedules and reported their output in different units, e.g. the number of laundry trays instead of their weight.
A.2 Data for the Census of Manufactures in other years

The schedules before 1929 and after 1935 were lost. The Census Bureau used them to compile information for the Statistical Abstracts and publications of the manufacturing industry. After such compilation, an Act of Congress gave the right to destroy the schedules. A 1971 letter by Dennis Rousey, Acting Chief of the Industrial and Social Branch, mentioned that “Since 1900, the schedules of agriculture censuses have been disposed of under Congressional authorization,” with the manufacturing schedules possibly having a similar fate. An archivist told me that he was surprised that the schedules for 1929 to 1935 even survived, which he attributed to the relevance of the economic downturn. I searched for earlier or later schedules extensively and found only one surviving schedule from 1925, for the Crow Indian Mill in Colorado and kept at the National Archives in Denver, and one surviving schedule from 1939, for a German-owned company and the German American Bund that was seized during World War II. The schedules for the 1947 Census of Manufactures were transferred to non-safety microfilm, are disintegrating, and are “unavailable to researchers [because of] preservation issues and concerns.”

A.3 Categories of employment

The Census asked about two categories of employment, wage-earners and salaried workers, described in detail below. Wage-earners are present in all years and represent around 90% of employment. Officers of the corporation were sometimes reported on a special administrative schedule that is absent from the Census of Manufactures. In 1929, the Census seems to have included engineers and other technical employees as wage-earners. In 1935, technical employees had a separate category. This chapter considers all categories of employment, excluding proprietors, who had no salary, and salaried officers of the corporation, who were sometimes reported on a different form. The details of employment categories suggest that the two types of employment are different from skilled/unskilled and from routine/nonroutine occupations.

15Electronic correspondence with the National Archives at College Park, Maryland.
• Categories of employment in 1929:

  – Proprietor or firm members

  – Principal officers of corporations

  – “Managers, superintendents, and other responsible administrative employees; foremen and overseers who devote all or the greater part of their time to supervisory duties; clerks, stenographers, bookkeepers, and other clerical employees on salary.”

  – Wage-earners: “Skilled and unskilled workers of all classes, including engineers, firemen, watchmen, packers; also foremen and overseers in minor positions who perform work similar to that done by the employees under their supervision.”

• Categories of employment in 1935:

  – Proprietor or firm members

  – Salaried officers of the corporation

  – Supervisory employees: “managers, superintendents, and other responsible administrative employees (including plant foremen whose duties are primarily supervisory but not including foremen and overseers in minor positions who perform work similar to that of the employees under their supervision”

  – Technical employees: “trained technicians, such as chemists, electrical and mechanical engineers, designers, who hold responsible positions requiring technical training and whose supervisory duties, if any, are only incidental”

  – Clerical employees: “clerks, stenographers, bookkeepers, timekeepers, and other clerical employees (including laboratory assistants, draftsmen), whether in the office or in the factory”
— Wage-earners: “all time and piece workers employed in the plant (including the power plant and the maintenance, shipping, warehousing, and other departments) covered by this report, not including employees reported above. Include here working foremen and gang and straw bosses, but nor foremen whose duties are primarily supervisory.”

A.4 Measurement of plant-level variables and industry background

The histograms in Figure 8 suggest that the labor share of income have bell-shaped frequency curves with accurate measurement. The Census Bureau checked thoroughly these variables and mailed the plant for more information when it found outliers. In contrast, Figure 9 suggests that the average price of electricity has considerable variation, up to 1 dollar per kilowatt-hour, at a time when the average price for the United States was 2.6 cents per kilowatt-hour.

![Histograms showing labor share of income in 1929 and 1935](image)

*Figure 8: The labor share of revenue of concrete plants in 1929 and 1935 has a bell-shaped distribution.*
This chapter considers the income $p_{i,t}Y_{i,t}$ to be revenue instead of value added. Revenue is a more robust measure and contains fewer outliers: for example, some plants during the Depression were operating at a loss and had negative value added (see Berman, Bound and Griliches (1994, page 383) for a similar approach).

Tennessee Valley Authority (1947) details the production of concrete for the Tennessee Valley Authority projects. It consists of mixing cement (often portland cement) with water and an aggregate (crushed stone, sand, or gravel). Production of concrete starts with collecting the aggregate, for example the sand of a river or the stone from a quarry. If concrete plants own a quarry (in 1929, many plants were included in the Census of Mines and Quarries rather than the Census of Manufactures), they may crush the stone to obtain a finer aggregate. Otherwise, plants may buy the aggregate already crushed. Plants mix the ingredients—cement, the aggregate, and water—to obtain a fluid substance that they pour onto a mold. The substance hardens with time. Plants sometimes vibrate the mold to achieve a more compact product. They cure the concrete product with water, as cement requires a moist environment to harden further and increase strength. Plants may also polish the concrete product with sandblasting—a jet of water mixed with sand under high pressure to remove superficial irregularities. If plants convey the concrete product over a long distance to the delivery location, the product bears the risk of un-mixing.
Proof of equations (2) and (3). This proof omits the plant index $i$. The firm maximizes intertemporal profits

$$
\sum_{t=0}^{\infty} D_{0,t} \left( A_{i,t} K_{NE,t}^{\alpha} L_{NR,t}^{\beta} (K_{E,t}^{\rho} + L_{R,t}^{\rho})^{\frac{\gamma}{\rho}} - w_t (L_{NR,t} + L_{R,t}) - r_{NE,t} K_{NE,t} - r_{E,t} K_{E,t} \right),
$$

where $\rho = (\sigma - 1) / \sigma$. The firm has no accumulation constraints on capital or labor and the intertemporal maximization problem collapses to a sequence of static maximization problems. The first-order conditions for profit-maximization, taking prices as given, are:

$$
MPK_{NE,t} = \frac{\alpha Y_t}{K_{NE,t}} = r_{NE,t},
$$

$$
MPL_{NR,t} = \frac{\beta Y_t}{L_{NR,t}} = w_t,
$$

$$
MPK_{E,t} = \gamma Y_t L_{R,t}^{\rho-1} (K_{E,t}^{\rho} + L_{R,t}^{\rho})^{-1} = r_{E,t},
$$

$$
MPL_{R,t} = \gamma Y_t L_{R,t}^{\rho-1} (K_{E,t}^{\rho} + L_{R,t}^{\rho})^{-1} = w_t,
$$

where $MPF$ is the marginal product of factor $F$. The ratio of electric capital to employment in routine occupations is:

$$
\frac{K_{E,t}}{L_{R,t}} = \left( \frac{r_{E,t}}{w_t} \right)^{-\sigma}.
$$
The labor share of income is:

\[
\frac{w_t L_t}{Y_t} = \frac{w_t L_{NR,t}}{Y_t} + \frac{w_t L_{R,t}}{Y_t},
\]

\[
= \beta + \gamma L_{R,t}^\rho \left( \frac{K_{E,t}}{L_{R,t}} + L_{R,t}^\rho \right)^{-1},
\]

\[
= \beta + \gamma \left( 1 + \left( \frac{K_{E,t}}{L_{R,t}} \right)^\rho \right)^{-1},
\]

\[
= \beta + \gamma \left( 1 + \left( \frac{r_{E,t}}{w_t} \right)^{-\sigma} \right)^{-1},
\]

\[
= \beta + \gamma \left( 1 + \left( \frac{r_{E,t}}{w_t} \right)^{1-\sigma} \right)^{-1}.
\]

The routine share of labor is:

\[
\frac{L_{R,t}}{L_t} = \frac{L_{R,t}}{L_{NR,t} + L_{R,t}},
\]

\[
= \left( 1 + \left( \frac{L_{NR,t}}{L_{R,t}} \right) \right)^{-1},
\]

\[
= \left( 1 + \frac{\beta r_{E,t}^{1-\sigma} + w_t^{1-\sigma}}{\gamma} \right)^{-1}.
\]

The electric capital-total labor ratio is:

\[
\frac{K_{E,t}}{L_t} = \frac{K_{E,t} L_{R,t}}{L_{R,t} L_t},
\]

\[
= \left( \frac{r_{E,t}}{w_t} \right)^{-\sigma} \left( 1 + \frac{\beta}{\gamma} + \frac{\beta}{\gamma} \left( \frac{r_{E,t}}{w_t} \right)^{1-\sigma} \right)^{-1},
\]

\[
= \left( \frac{r_{E,t}}{w_t} \right)^{-\sigma} \left( \frac{\beta}{\gamma} + \left( 1 + \frac{\beta}{\gamma} \right) \left( \frac{r_{E,t}}{w_t} \right)^{1-\sigma} \right)^{-1}.
\]

In short, the labor share of income \( w_t L_t/p_t Y_t \) is increasing in \( r_{E,t} \), electrical intensity \( K_{E,t}/L_t \) is decreasing in \( r_{E,t} \), and labor productivity \( Y_t/L_t \) is decreasing in \( r_{E,t} \).
C Electricity data and background

C.1 Other measures of the price of electricity

Other measures of the price of electricity exist during this period but they are inferior to the state-level price of electricity used in the baseline regressions. First, the price of electricity paid by ice plants (Ziebarth, 2011) covers cities that coincide with only 200 concrete plants. Second, the city-level price of electricity for residential consumers for a typical bill of 25, 100, or 250 kilowatt-hours (Federal Power Commission, 1937) is a survey with measurement error due to retrospective questions asked in 1936, concerns residential consumers instead of industrial consumers, and has a significantly lower amount than the average demand by concrete plants in 1929 (1400 kilowatt-hours per month for concrete plants versus 250 kilowatt-hours for residential consumers), and they are also on different rate schedules (see the next section). Third, the price of electricity by municipal utilities from the Census of Electric Light and Power Stations in 1927 and 1937 concerns a small market (5% of total kilowatt-hours).\footnote{Census of Electric Light and Power Stations, 1927, page 71.} Fourth, the Census of Electric Light and Power Stations published the price of electricity from both public and private utilities to industrial consumers, split by “small” (retail) and “large” (wholesale), but the “wholesale” numbers exist only half of the states to prevent disclosure of establishment information. To the best of my knowledge, there are no other measures for the price of electricity that are disaggregated geographically over this period.

To show how the price of electricity at the plant-level is plagued with fixed costs, figure 10 shows a scatter plot of the change in the state-level price of electricity and a Paasche index of the change in the price of electricity at the plant-level aggregated at the state-level: the two measures should be positively related but are negatively related.
Figure 10: The change in the Paasche index of the price of electricity is negatively related to the change in the state-level price of electricity.

C.2 Pricing of electricity

Electric utilities offered many rate schedules, detailed by the Federal Power Commission in a published glossary in 1936. All rates have a component of capacity, in kilowatts or horsepower, and of energy, in kilowatt-hours or Joules.
An electric bill consists of three types of charges: a customer charge, a demand charge, and an energy charge. The Federal Power Commission defines “customer charge” or “service charge” as “a component part of a rate schedule providing that a customer must pay a certain definite sum in a specified period (usually 1 month) without regard to the consumption of energy or the demand, for which he can use no energy or demand.” It defines a “demand charge” as “a component part of a rate schedule which provides for a charge based upon the customer’s demand or equivalent, without regard to the consumption of energy.” It defines “energy charge” as “a component part of a rate schedule that provides for a charge based upon the amount of energy consumed.” In short, the customer pays a service charge for connecting to the grid, a demand charge for the right to use a given capacity from the grid, and an energy charge for consumption of electricity.

Most rate schedules also define “maximum demand,” which is often the aggregate capacity of electric appliances commonly used. For example, a plant may have a primary motor and a stand-by motor, each with a capacity of 100 kW. The plant may normally use only the primary motor and contracts for a maximum demand of 100 kW. If the plant happens to use both motors at the same time, it will have to pay a higher price for using more capacity than the maximum demand.

Electric utilities offered up to eight different schedules. The flat rate schedule “provides for a specified charge per unit of time, irrespective of the amount of electric energy taken. For example: $2 per month per customer up to and including 6-50 watt lamps.”

The straight line meter rate schedule “provides for a constant charge per unit of energy regardless of the amount consumed. For example: 5 cents per kilowatt-hour.”

The flat demand rate schedule “bases the billing either on the demand or on some fixed characteristic indicative of demand but provides no charge for energy. For example: $50.00 per year per horsepower of demand.”
The **flat and meter rate** schedule is a two-part tariff with “two components, the first of which is a customer (or service) charge and the second of which is a price for the energy consumed.”

The **block meter rate** schedule “divides the total amount of energy to be consumed during a definite period into prescribed blocks and provides a different rate for each.”

The **Hopkinson demand rate** schedule has “two components, the first of which is a charge for demand, and the second a charge for the energy consumed.”

The **block Hopkinson demand rate** schedule has “either the demand charge or the energy charge or both are arranged in blocks. For example, a demand charge of $1.25 for the first 50 kilowatts of maximum demand per month, and $1.00 per kilowatt for all above 50 kilowatts of maximum demand per month. Plus: an energy charge of 3 cents per kilowatt-hour for the first 1,000 kilowatt-hours used per month, and 1 cent per kilowatt-hour for all energy used in excess of 1,000 kilowatt-hours per month.”

The **step meter rate** schedule has “a charge per unit of energy [that] is constant for all kilowatt-hours consumed during the billing period, the charge per unit depending upon the total consumption. For example: if 1 to 25 kilowatt-hours are used in a month, 5 cents per kilowatt-hour; if 26 to 50 kilowatt-hours are used in a month, 3 cents per kilowatt-hour (for all the energy including the first 25 kilowatt-hours).”

The **three-part rate** schedule “provides three components for determining the total bill: customer charge, demand charge, and energy charge. For example: 50 cents per month per meter. Plus: a demand charge of $1.25 per month per kilowatt for the first 25 kilowatts of maximum demand in the month; 90 cents per month per kilowatt for the excess of the maximum demand over 25 kilowatts. Plus: an energy charge of 1.5 cents per kilowatt-hour.”

Furthermore, rate schedules may have clauses providing for additional charges in the event of large increases in the price of coal, the price of commodities, or wages.
C.3 Technical progress in the generation of electricity

Figure 11 illustrates the exponential decrease in the price of electricity over the first half of the 20th century. Gordon (1992, Table 1) estimates the rate of decrease in the price of electricity at 7% per year between 1899 and 1948. The real price of electricity increased slightly during the Great Depression because of deflation in the consumer price index. In a more general model with irreversible investment, firms would have difficulty adjusting their capital stock to cyclical changes in the price of electricity and would react to the trend in the price of electricity rather than to the fluctuations. Furthermore, the nominal price of electricity decreased by 0.02 log-points in the sample of concrete plants (see Table 1).

![Figure 11: The real price of electricity decreased exponentially in the first half of the 20th century. The price of electricity is in cents per kilowatt-hour from the Historical Statistics of the United States, series Db234, Db235, and Db237. The price deflator is the consumer price index from the BLS, series Cc1. The rate of decrease of the price of electricity for residential consumers is 5.8%.](image)

The technology to produce electricity from coal improved over the first half of the 20th century, but hydroelectric technology did not:
In generating electricity from coal even the largest and most modern electric power stations are able to utilize only about 25 per cent of the heat units available in the coal. ... On the other hand, modern hydro-electric machinery now transforms into electricity more than 90 per cent of the energy in falling waters, leaving little opportunity for radical improvements in present-day hydro-electric practice. (The electric light and power industry, 1931, page 43)

Hughes (1993) describes another source of technical progress with economies of scale. The interested reader is referred to his account of electrification in Western Society over the period 1880-1930.