

# Fall and Rise of Labor after Technological Revolutions: Substitutability and Scalability since 1800

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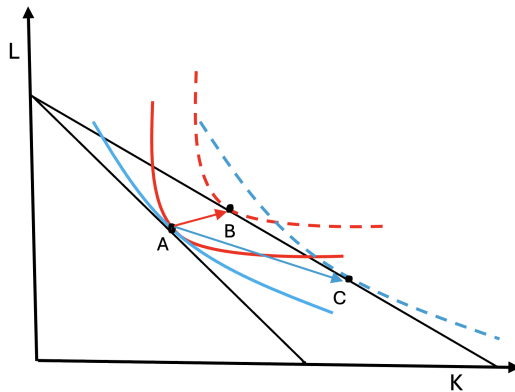
# Motivation

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- Rising concerns about the *future* of labor due to the disruption of new technology (Acemoglu and Restrepo 2019, Autor et al. 2020, Karabarbounis and Neiman 2013)
- Literature largely focuses on aggregate labor demand and supply (e.g. will tasks be performed by K or L?)
- In practice occupations are affected differently by technological change (e.g. Autor and Dron 2013) → substitutability vs scalability.

**Q** We revisit this important question (substitutability vs. scalability) in a context which witnessed among the largest technological disruptions and structural transformations ever observed in human history: the US during the Technological Revolution

# Substitutability and Scalability



**Figure 1:** Isoquants from a CES production function for a complementary (red) and substitutable (blue) occupation in response to a fall in the price of capital  $r$ .



# What We Do

- Build new database: arrival & diffusion of tech. innovations across time & space:
  - ▷ Source: Digitized *local* newspapers in the U.S. (1820-1960) (Library of Congress)
  - ▷ *Equipment ads* with pricing and *Job ads*
- Document the dynamic response of labor to new technology and the evolution of county level aggregates:
  - ▷ Labor: rise and fall of occupations
    - high frequency data; potentially more granular occ. than HISCO/Census.
    - cross-validated with population census data.
  - ▷ County level aggregates: using the census of manufacturing we quantify the effect of technological shocks on productivity, wages, capital, employment and the labor share.

# What We Find

- New technologies between 1860–1950 reshaped labor markets by **substituting** and **scaling** occupations.
  - **Heterogeneous** Effects on occupations: fall (e.g. coachmen) and rise (e.g. drivers).
    - ▷ Staggered DID (Time  $\times$  Space Diffusion in LOC and Population Census)
    - ▷ Instrumenting (TBD)
  - Focusing on Manufacturing Census: On average, new technologies:
    - ▷ **Increase** employment, wages, and productivity
    - ▷ **Unaffected** labor share in manufacturing
- Build a model that rationalizes these effects (TBD)
- Help-wanted ads (demand) respond faster Census: (Lack of) Adaptability?
  - ▷ Counties with **higher adaptability**: Are richer and more employed in 2000
  - ▷ Show lower high–low skill polarization
- Overall: technologies **reallocate** labor rather than **replace** it.

# **A New Historical Database of Technology and Occupations**

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# A New Database

We use two data sources:

1. Library of Congress: *Chronicling America*

- Public domain repository of over 21 million newspaper pages published between 1756 and 1963.
- National coverage.
- ▷ We extract approximately 400 thousand pages containing equipment ads and 550 thousand pages containing help wanted ads.

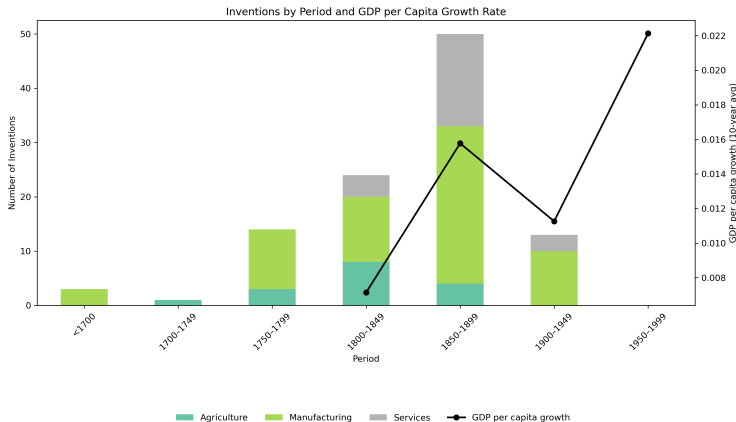
2. Census of population, manufacturing and agriculture for 1850-1960:

- Data on employment, wages, output and capital for the manufacturing sector.
- Detailed information on occupations and industry from the Census of population.

# Technological Innovations Overview

- **Overview:** 123 technologies spanning 3rd century BCE –early 20th century
  - Force Pump (3rd c. BCE) to the Television (1927).
- **Sectors:**
  - Manufacturing: Steam Engine, Airplane, Assembly Line
  - Agriculture: Seed Drill, Combine Harvester, Steel Plow
  - Services: Telegraph, Telephone, Phonograph
- **Origins:** Europe (England, Germany, France) → USA (19th–20th century.)
- **Trends:**
  - Manual/water power → steam → internal combustion
  - Advent of electricity: Light Bulb, Electric Motor
  - Rise of mass production: Assembly Line, Punch Press

# Why this Time Period?



**Figure 2:** Number and sector of inventions for 50 year time periods shown together with the average GDP per capita growth rate. Data sources: data on inventions is from author's calculations using the Library of Congress (LOC), data on GDP per capita is from Maddison 2023.

# Examples: Technology Ad

**One Man Saws 40 Cords a Day**

**At a Cost of 1¢ a Cord!** Send today for Big Special Offer and Low Direct Price on the OTTAWA, the One-Man Saw, the first made and sold direct from factory to user. Greatest labor saver and money-maker ever invented. Saws any size log at the rate of a foot a minute. Does the work of ten men. As easily moved from log to log or cut to cut as any wheelbarrow. 4-Cycle Frost Proof Engine has balanced crank shaft—pulls over 4 H.P. Magneto equipped; no batteries needed. **Special Clutch** lever controlled enables you to start and stop saw with engine running. Automatic Speed Governor. Easy to move, costs less to operate. When not sawing, engine runs pumps, feed mills and other machinery. Pulley furnished.

**OTTAWA LOG SAW**  
Cuts Down Trees—Saws Logs By Power  
Patent Applied For

**Strictly a One-Man Outfit**

**FREE** Write at once for Free Book and Low Price.

**Cash or Easy Payments** Shipped direct from factory. **30 Days Trial** No waiting—no delay. Let the OTTAWA saw your logs and pay for itself as you use it. **10-YEAR GUARANTEE.** See the OTTAWA at work on your farm once and you will never give it up. Thousands in use, every owner a booster. Out-saws any other on the market. Send today for FREE BOOK and Special Offer.

**OTTAWA MFG. CO., 2435 Wood St., Ottawa, Kans.**

(a) Saw Replaces 10 Men

Every Ford Tractor becomes a Power Shovel with this Dearborn Heavy Duty Loader—a Ford Farming Team that **does the work of 40 Men and Shovels!**

An exceptional worker might load 10 cubic feet of dirt, sand, gravel or manure in 20 minutes. This power loader will load 10 cubic feet of dirt, sand, gravel or manure in one quick scoop. It **does the work of more than 40 men and shovels.**

**One Dearborn Loader equals 40 men with shovels**

**Ritches Power to Many Farm Chores**  
This time-saving, money-making power tool will remove and move dirt, lift and stack hay, rock and feed manure, shovel and deliver grain. Merely changing attachments makes it a handy hoist, a power crane, or a hydraulic platform—all on wheels—then makes a multitude of daily farm chores simple and surer.

Easy to install, it has its own hydraulic system, leaving the tractor's hydraulic system and one power-take-off available for scrapers, mowers, plows, scrapers, or other tools.

**Ford Farming Means Less Work...More Income Per Acre**

**See for Yourself—Make This Test**

1. Fill the bucket with dirt or gravel.
2. Fill the bucket with dirt or gravel.
3. Fill the bucket with dirt or gravel.
4. Fill the bucket with dirt or gravel.
5. Fill the bucket with dirt or gravel.
6. Fill the bucket with dirt or gravel.
7. Fill the bucket with dirt or gravel.
8. Fill the bucket with dirt or gravel.
9. Fill the bucket with dirt or gravel.
10. Fill the bucket with dirt or gravel.

See Your Nearest Ford Tractor Dealer for Complete Details and Demonstration. He Will Be Pleased To Serve You.

(b) Loader Replaces 40 Men

**Figure 3:** Source: (left) The St. Mary banner. (Franklin, Parish of St. Mary, La.), November 20, 1920.; (right) Montana farmer-stockman. [volume] (Great Falls, Mont.), December 15, 1948.

## Examples: Technology Ad (AI-Like)

See the Wonderful Electric Loom Weaving

**The Famous Moneybak Fine Black Silk**

...Trade Mark...

Introducing  
**Long Wearing Moneybak Silk.**  
Making a Taffeta That Will Not Cut

Two representatives from the York Manufacturing Co. will be here to explain the working of the loom, and the merits of the silk.

Silk weaving, a most interesting process to anyone interested in silk fabrics, shows perfection of weaving by a combination. Using skilled labor and machine almost endowed with human intelligence, the combination using 400 perfectly pure, strong threads to the inch of every surface, also a double thread to the filling, produces a reliable, long-wearing and lasting taffeta silk.

Exhibit...  
**Five Handsome Gowns**  
Made by a leading New York modiste, from  
**Moneybak Fine Black Silk.**  
On Display in Nicollet Arcade Window.

**Money Back.**

You will see silks woven in our store just as they are woven in the mills. Every yard must be satisfactory to the buyer or money back. That's the trade-mark protection. "Moneybak," woven in every yard on a patented detachable selvage, which is detached from any silk run up to the high standard of perfection required.

**This wonderful loom will be on exhibition in our Silk and Dress Goods Depts. all week.**

(a) Loom (AI-Like)

**Brinly Leverless Cultivator**



The machine with almost human intelligence. No levers—no trouble—the one perfect riding cultivator—managed as easily as a walking cultivator—no extra weight for the horse if you ride.

If you will do justice to yourself you will own a **BRINLY LEVERLESS.**

**FRAUENTHAL & SCHWÄRZ**

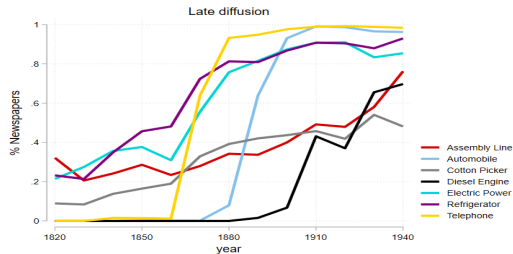
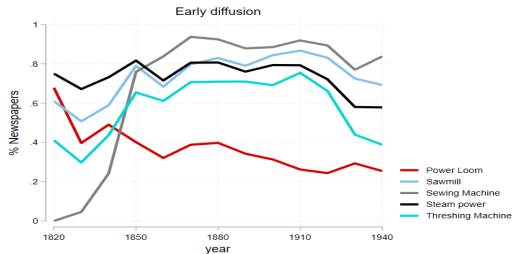
.. Your Credit Is Good. ..

(b) Cultivator (AI-Like)

**Figure 4:** Source: (left) The Minneapolis journal. [volume] (Minneapolis, Minn.), 01 March 1904.; (right) The log cabin Democrat. [volume] (Conway, Ark.), 02 March 1916.



# Source of Variation 1: Technology Diffusion across Time and Space

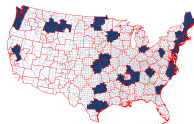


**Figure 5:** Fraction of newspapers mentioning each technology over time. Source: Author's calculations using Library of Congress, *Chronicling America*.

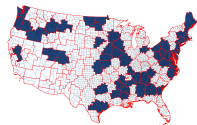
## Source of Variation 2: Technology Diffusion across Time and Space



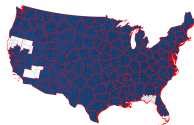
(a) 1892



(b) 1900



(c) 1908



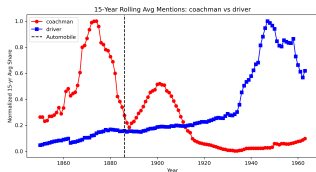
(d) 1916

**Figure 6:** Diffusion of the tractor over time. Newspapers are clustered into 150 groups and each county is assigned to the closest newspaper group. Red lines show the boundaries between groups. Source: Author's calculation using Library of Congress newspapers [chroniclingamerica](http://chroniclingamerica.org).

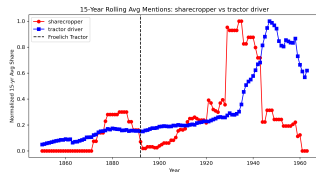
# Help Wanted Ads: Labor Demand

- **Occupations & Triggers:**
  - Start with 1950 census occupations (occ1950)
  - Define for each occupation a set of “trigger” words/phrases
- **Text Mining:**
  - Search pages for instances of the occupation or its trigger words.
- **Counting:**
  - For every occupation, flag ads containing its name or any trigger
  - Aggregate counts by year and location (each county is matched to a newspaper group)

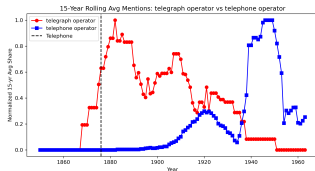
# Help Wanted Ads: Descriptives



(a) Automobile



(b) Tractor



(c) Telephone

**Figure 7:** Normalized 15-year moving average of help wanted ads (1860–1960) for selected professions. Vertical lines show the introduction of relevant technologies. Source: Library of Congress *Chronicling America*.

# Empirics

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We are interested in estimating the following regression model:

$$y_{it} = \alpha_i + \delta_t + \sum_{k=-2}^2 \beta_k D_{t > \tau_i - k} + \epsilon_{it}, \quad (1)$$

Where  $y_{it}$  is a county level outcome variable. We use the Borusyak et al. (2024) estimator to account for staggered treatment.

## Empirical Strategy 2/2

We construct a county level measure of adaptability to technological shocks:

$$M_i = \underbrace{\frac{1}{JT} \left( \sum_j \sum_{o \in S_j} \sum_{t=-k}^k (s_{o,a,t} - s_{o,c,t}) \right) \mid s_{o,a,t} > s_{o,c,t}}_{M_p} - \underbrace{\frac{1}{JT} \left( \sum_j \sum_{o \in S_j} \sum_{t=-k}^k (s_{o,a,t} - s_{o,c,t}) \right) \mid s_{o,a,t} \leq s_{o,c,t}}_{M_n}$$

And correlate it with long-run county level outcomes:

$$y_{i,2000} = \alpha_s + \beta M_i + \Gamma' X + \epsilon_{it} \quad (2)$$

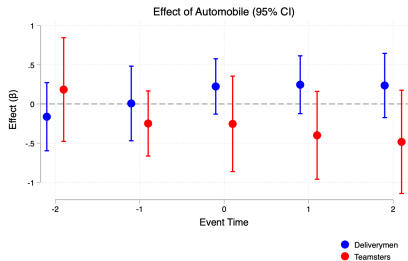
We use copyright registrations between 1840 and 1860 as an IV for  $M$ . [▶ Controls](#)

## Results

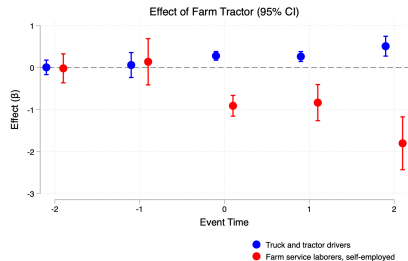
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# Employment: Granular Treatment Events



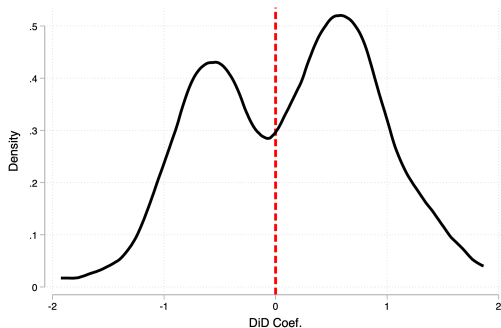
(a) Automobile



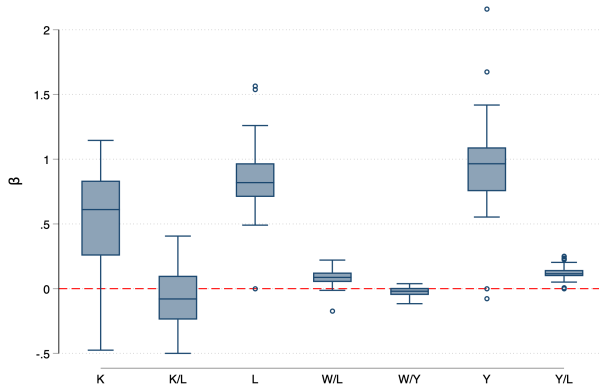
(b) Tractor

**Figure 8:** Event study plots of the effect of an innovation on two occupations. Dependent variable is log of employment for that occupation in the census. Data source: US Census of Population 1860–1940 and author's calculations using Library of Congress *Chronicling America*.

# Employment: Occupation Level Treatment Events

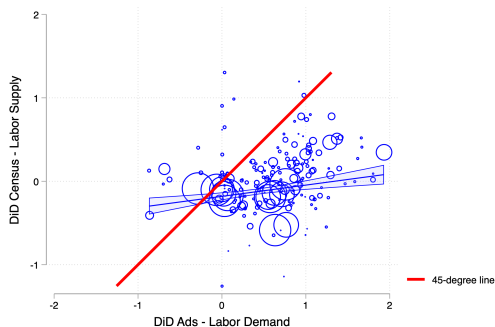


**Figure 9:** Distribution of  $\hat{\beta}$  coefficients estimated from difference-in-differences regressions of model 1. Dependent variable is log of employment at the occupation level. For each innovation we consider 10 relevant occupations which may be negatively or positively affected by the technology. Data source: US census of population 1860-1940 and author's calculations using Library of Congress *Chronicling America*.



**Figure 10:** Distribution of the treatment effects for different outcome variables. Each box plot shows the inter quartile range and outliers of  $\hat{\beta}$  coefficients estimated from difference-in-differences regressions of model 1 using ten-year census intervals.

# Employment: Census vs Ads



**Figure 11:** Scatter plot of treatment effects  $\hat{\beta}$  from difference-in-differences regressions (model 1), with the log of census (labor supply) and help wanted ads (labor demand) as outcomes. Observations are weighted by final-period labor supply. Each innovation includes 10 occupations potentially affected (positively or negatively). Data: US Census 1860–1940 and author’s calculations from Library of Congress *Chronicling America*.

# OLS and IV Results: Long-Run Outcomes

**Table 1:** Effect of Misalignment on Economic Outcomes

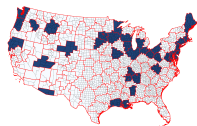
	(1) Log. Income	(2) Unemp.	(3) Share HS	(4) Share College
<i>Panel A: OLS Estimates</i>				
Misalignment	-0.523*** ( -3.89 )	0.003 (0.31)	-0.058*** (-2.85)	0.143*** (3.06)
$R^2$	0.226	0.316	0.513	0.302
<i>Panel B: IV Estimates</i>				
Misalignment	-2.176** (-2.46)	0.148*** (2.67)	-0.470*** (-3.96)	0.700*** (3.61)
N	1087	1087	1087	1087
$R^2$	0.141	0.149	0.276	0.075

$t$  statistics in parentheses. Standard errors computed using the Conley correction with a 100km cutoff.

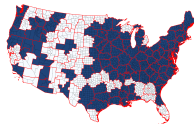
## Conclusion

- We construct a county level dataset of technology diffusion and labor demand for the US over 1800/1960 covering 123 technologies.
- Technological innovations between 1860–1950 displaced and scaled different occupations — **reallocation, not replacement**.
- Average effects on labor markets are **positive**: higher wages, productivity, and employment. Labor share unaffected.
- Regions that adapted faster are richer, more polarized, and less unemployed by 2000.
- From a historical perspective, we offer **cautious optimism** about current technological transitions.

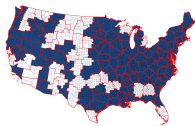
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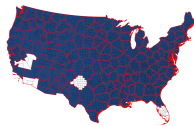
(a) 1876



(b) 1878



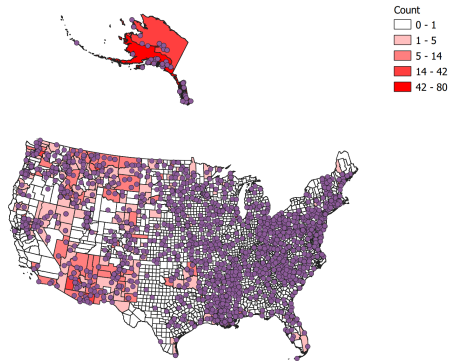
(c) 1880



(d) 1900

**Figure 12:** Diffusion of the telephone over time. Newspapers are clustered into 150 groups and each county is assigned to the closest newspaper group. Red lines show the boundaries between groups. Source: Author's calculation using Library of Congress newspapers [chroniclingamerica](http://chroniclingamerica.org).

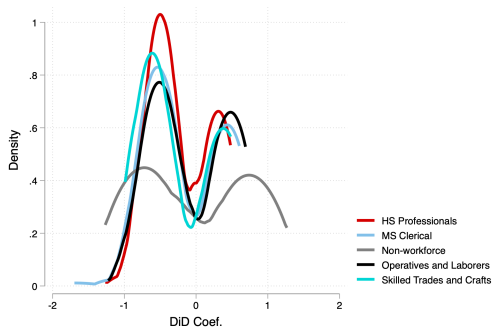
# Map of Newspaper Coverage



**Figure 13:** Map of newspapers at the county level. Data source: Library of Congress *Chronicling America*.

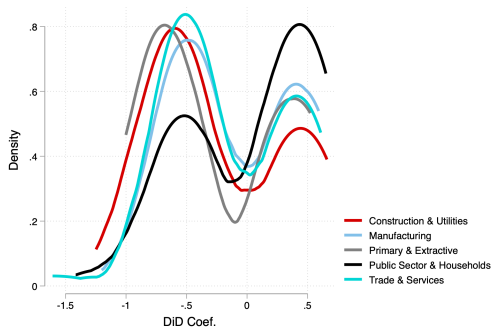


# Employment: Occupation Level Treatment Events



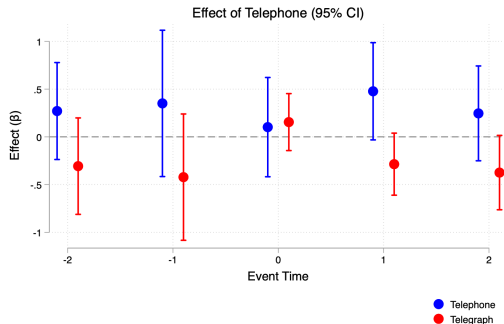
**Figure 14:** Distribution of  $\hat{\beta}$  coefficients estimated from difference-in-differences regressions of model 1. Dependent variable is log of employment at the occupation level. For each innovation we consider 10 relevant occupations which may be negatively or positively affected by the technology. Data source: US census of population 1860-1940 and author's calculations using Library of Congress *Chronicling America*.

# Employment: Occupation Level Treatment Events



**Figure 15:** Distribution of  $\hat{\beta}$  coefficients estimated from difference-in-differences regressions of model 1. Dependent variable is log of employment at the occupation level. For each innovation we consider 10 relevant occupations which may be negatively or positively affected by the technology. Data source: US census of population 1860-1940 and author's calculations using Library of Congress *Chronicling America*.

# Employment: Granular Treatment Events



**Figure 16:** Event study plot showing the effect of the tractor on employment in a selected occupation. Dependent variable is log employment from the census. Data: US Census of Population 1860–1940 and author’s calculations using Library of Congress *Chronicling America*.

Table 2: Summary of Control Variables

Type of Control	Variables
Geographic	Potential yields Average rainfall Average temperature Distance to oceans and the Great Lakes Terrain ruggedness
Human Capital (measured in 1850)	Literacy rate School enrollment rate
Spatial Controls	Third-degree polynomial of longitude and latitude