Scale-Biased Technical Change and Inequality*

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October 6, 2023

Abstract

Scale bias in technical change is the degree to which technical change increases the productivity of large relative to small firms. I propose that this dimension of technical change is important for inequality. I first develop a tractable framework with heterogeneous households choosing to work for wages or earn profits as entrepreneurs. Entrepreneurs choose from a set of available production technologies, defined by a fixed and a marginal cost. Large-scale-biased technical change lowers entrepreneurship rates and leads to larger firms on average. With fewer and larger firms, top entrepreneurs are capturing a larger share of the profits which increases top income inequality. Small-scale-biased technical change has the opposite effects. I test the theoretical predictions by identifying the effects of adoption of two technologies that vary in scale bias, but are otherwise similar: steam engines (large-scale-biased) and electric motors (small-scale-biased). Using newly collected data from the United States and the Netherlands, I verify that these two technologies had opposite effects on firm sizes and inequality. Steam engines increased firm sizes, while electric motors decreased them. Steam engines led to increased inequality, electric motors did not. Consistent with scale bias (rather than skill bias), I find that adopting entrepreneurs were the main drivers of inequality increases after steam engine adoption.

*I am grateful to my advisors Ethan Ilzetzki, Camille Landais, Ben Moll, and Ricardo Reis for their continued guidance and support. I also thank Lukas Althoff, Leah Boustan, Jeremiah Dittmar, Matthias Doepke, Wouter den Haan, Jonathon Hazell, Jane Olmstead-Rumsey, Maarten de Ridder, Richard Rogerson, and Caterina Soto Vieira for insightful comments. I am furthermore indebted to many employees of archives in the Netherlands, in particular those at Brabants Historisch Informatie Centrum, Drents Archief, Gelders Archief, Historisch Centrum Overijssel, the National Archives, Noord-Hollands Archief, Statistics Netherlands and Zeeuws Archief. This work was financially supported by The Suntory and Toyota International Centres for Economics and Related Disciplines and the Centre for Macroeconomics at the London School of Economics.

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1 Introduction

Income and wealth inequality has significantly increased in many countries in recent decades. Between 1980 and 2014, the United States saw a 21% growth in the incomes of the bottom half of the distribution, while the top ten percent experienced more than double this growth during the same period (Piketty et al., 2018). Skill-biased technical change is a common explanation for the increase in inequality: if new technologies more strongly complement high-skilled labor, this may exacerbate wage inequality (Katz and Murphy, 1992; Krusell et al., 2000). Similarly, if "low-skill tasks" are more susceptible to automation technologies, this increases the skill-gap and may even reduce absolute wages for low-skilled workers (Autor et al., 2003; Acemoglu and Autor, 2011; Acemoglu and Restrepo, 2018, 2022).

I propose *scale* bias in technical change — the degree to which technical change affects the relative productivity across firms of different sizes — as another important determinant of inequality. If technical change is large-scale-biased, it skews productive resources towards larger firms. As a result, profits are also redistributed to larger firms. Since the ownership of any given firm tends to be concentrated, the redistribution of economic activity and profits across firms implies a redistribution of income across households. In this paper, I first develop a tractable general equilibrium framework to illustrate the mechanism. I then empirically demonstrate the relevance of scale bias by studying the effect of two of the most important general purpose technologies (GPTs) in history: the steam engine and the electric motor.

To formalize the theory of scale-biased technical change and inequality, I develop a tractable model where households that are heterogeneous in productivity can choose to either work for wages or be an entrepreneur. Entrepreneurs have access to a set of available technologies — defined by a marginal and a fixed cost — and adopt the one that maximizes profits. I show that technical change is large-scale-biased if it increases fixed costs sufficiently relative to previously adopted technologies. If technical change is large-scale-biased, it lowers entrepreneurship rates and leads to larger firms on average. With fewer and larger firms, top entrepreneurs are capturing a larger share of the profits which increases top income inequality. If technical change is small-scale-biased, it has the opposite effects.

To empirically test the theory, I compare the effects of the adoption of steam engines and electric motors. These two GPTs provide an appropriate and useful comparison because i) their adoption was widespread and transformative so that it could be reasonably expected to have a meaningful impact on inequality ii) they were similar in their capability and purpose — converting energy into rotary motion in manufacturing —, and iii) their technological characteristics were so that the technical change induced by them varied strongly in scale bias. Steam engines entailed high fixed costs of purchase and operation. The annualized cost of using a 50 horsepower steam engine (exclusive of fuel) was equal to the *yearly* wage of around 3 to 4 unskilled workers.[1] For an electric motor with the same capacity, these costs were only slightly more than one *weekly* wage, about two hundred times lower than for steam engines.[2] Also, for reasons of technological efficiency, steam engines came in much larger sizes than electric motors.[3] As a result, the adoption rates of the two technologies across the firm size distribution were different. Large establishments were much more likely to adopt steam engines than small establishments (see also Atack et al., 2008). In stark contrast, electric motors were adopted uniformly across the firm size distribution.

To measure the steam engine's and electric motor's effect, I construct a rich data set on technology adoption, firm sizes, and inequality through digitization of various archival sources from the Netherlands as well as the United States. For the United States, I draw on the Census of Manufactures that provides information such as the number of establishments, employment, value added, and power adoption by state and industry. I digitized and compiled these data for each decade year between 1850 and 1940 and 1947. The industry classification in the Census of Manufactures was highly granular, yielding over 50 thousand state-industry observations. Using these data, I investigate the role of steam engines and electric motors in shaping the firm size distribution in manufacturing in the United States.

The first main empirical result is that, consistent with the theory, steam engines increased the establishment size, while electric motors decreased them. To identify the effects on the establishment size, I use variation in natural resources across the United States that affected the costs of adoption. Specifically, I use historical coal resources and hydropower potential as instruments for steam engine and electric motor adoption, respectively.[4] These natural resources induced variation in adoption of the two technologies. I estimate how, over time, they affected the sizes of firms within the same industry, controlling for unobserved differences between states that are constant over time. High-coal access states experienced a growth in establishment sizes relative to 1850, when steam engines started to be adopted. In contrast, before the widespread adoption of electric motors in the 20$^{\text{th}}$ century, trends in establishment sizes were not different in states with high hydropower potential. After the introduction of electric motors around 1900,

[1] Computations based on the United States in 1874. The total annualized cost was \$1404 (see Table E.3 in Appendix E) and the *yearly* wage of an unskilled worker was around \$400 Abbott (1905).

[2] Computations based on the United Kingdom, around 1925. Total annualized cost of an electric motor of 50 hp in 1925 was £2.46 (see Table E.3 in Appendix E) and the weekly wage was around £2.00 (Bank of England, 2017).

[3] In the United States in 1910, the average steam engine had a capacity of 93.4 horsepower, more than 10 times that of the average electric motor (8.5 hp).

[4] Data to construct the instruments are from the Coal Resources Data System (coal resources) and Young (1964) (hydropower potential).

high-hydropower states experience a decrease in establishment sizes. To provide further evidence that these trends reflect the effects of scale-biased technical change, I show that the estimated effects on establishment sizes are driven by industries that are adopting the respective technologies.

I next study how the technologies affected inequality. While the Census of Manufactures provides high-quality data on American manufacturing, granular data on income or wealth inequality in the United States during steam engine and electric motor adoption is not available. Therefore, to study the two technologies' effects on inequality, I turn to the Netherlands, for which I digitized and compiled unique data on income and wealth inequality over the course of industrialization. First, I build a dataset that includes micro-level information on names, demographics, occupation, and, importantly, wealth of each decedent between 1878 and 1927 in five major provinces in the Netherlands, covering over a million decedents and more than half of the national population. Building this dataset involved digitizing around 130,000 scans of (handwritten) tables enumerating decedents and their wealth. Importantly, the period between 1878 and 1927 covers most of the introduction of the steam engine and the subsequent adoption of electric motors. The second dataset contains detailed income and wealth distributions by municipality tabulated from administrative data for years between 1946 and 1975. The geographical granularity of the data is its main strength relative to sources on inequality available for other countries.

Using the Dutch dataset, I verify the second main prediction of the theory: that large-scale-biased (small-scale-biased) technical change increases (decreases) inequality. Using municipality-by-industry level data from the Dutch Census of Companies in 1930, I compute the share of employees that work in establishments with steam engines, with electric motors, and without power for each municipality. I then show how wealth inequality evolved in municipalities that saw strong steam-engine adoption, controlling for municipality fixed effects. I find that municipalities that ended up adopting steam engines became significantly more unequal over time, especially from around 1910 onward. In contrast, municipalities with high electric motor adoption saw a slight decrease in inequality after 1900. Furthermore, I use an industrial census from 1816 — long before industrialization — to create a measure of "exposure" to steam engines as well as electric motors, based on the industrial composition. Municipalities that were by their industrial composition in 1816 exposed to steam engines showed a strong increase in inequality between 1880 and 1930, while those exposed to electric motors experienced a slight decrease in wealth inequality. The effects on inequality are primarily driven by the very top of the distribution, while the rest of the distribution was not much affected.

The third prediction of scale-biased technical change is that its effects on top inequality manifests itself through entrepreneurs that adopt the technology. To test this prediction, I zoom into the major industrializing city of Enschede, in the east of the Netherlands. The pre-existing textile industry made this city particularly exposed to the introduction of the steam engine. Even though wealth inequality decreased in most areas, it increased sharply in Enschede, from around 70% in 1880 to 87% in 1920. I find that the rise in top inequality was solely driven by the textile entrepreneurs that adopted the technology. I do not find any meaningful increase in inequality after excluding the textile entrepreneurs and their spouses from the sample. This finding shows that the important rise in inequality was driven by entrepreneurial income — not by wage — so that it can not be explained by by standard theories of skill-biased technical change, which only consider wage inequality. The proposed theory of *scale*-biased technical change does offer an explanation: the large-scale-biased technical change in textile manufacturing meant that firm concentration increased strongly, which in turn concentrated business income into the hands of a small set of entrepreneurs.

Related literature First and foremost, this paper contributes to our understanding of the effect of technical change on income and wealth inequality. Scale-biased technical change offers a view on the distributional effects of technology that is complementary to the existing theories of skill bias (e.g., Katz and Murphy, 1992; Acemoglu and Autor, 2011). The case of the electric motor illustrates that the two theories can have opposite predictions. Goldin and Katz (1998) argue that the electric motor increased the relative demand for skilled workers, thereby exerting upward pressure on (wage) inequality.[5] I claim that electric motors reduced scale bias and pushed inequality between entrepreneurs and workers *down*. During the first half of the twentieth century, the time of electric motor adoption, almost every industrialized country witnessed a large decline in inequality (Lindert and Williamson, 2016, p. 194). The empirical findings in this paper suggest that electric motors contributed to this trend.

Another large literature relates increased firm concentration to technical change, especially a move toward high fixed cost technologies (e.g., Autor et al. (2020); Hsieh and Rossi-Hansberg (2023); Kwon et al. (2023)). Intangible inputs such as software have been posited as an example of this (De Ridder, 2019). So far, it has been hard to establish credible causal evidence of technical change on the firm size distribution. Furthermore, because most modern technologies vary on many dimensions other than their cost structure, it is difficult to isolate the role of specific characteristics in driving their concentrating effect. The benefit of comparing steam engines and electric motors is that the two technologies were close to identical otherwise, allowing to single out the role of economies of scale in shaping the firm size distribution. I show empirically that the cost structure of a technology is crucial in shaping entrepreneurship rates and the firm size

[5] Goldin and Katz (1998) argue, however, that an increase in the supply of high-school graduates kept the skill premium in check.

distribution. The theory of scale-biased technical change also provides an additional motive to study business patterns: their implications for economic inequality.[6]

This paper also relates to studies highlighting the role of entrepreneurship in income and wealth inequality (Quadrini, 2000; Cagetti and De Nardi, 2006; Buera and Shin, 2013). Accounting for entrepreneurship in models of wealth accumulation allows to match the high concentration of wealth observed in the data. In contrast to previous work, I focus on the role of the production technology in shaping inequality. For this purpose, I provide a simple and tractable framework in which entrepreneurs face a technology adoption decision. The tractability of the model allows to characterize in closed-form how entrepreneurship and the income distribution depend on the set of technologies available in the economy. Furthermore, I provide empirical evidence on the effect of technology on inequality through entrepreneurship.

Lastly, this paper also speaks to the patterns of inequality during industrialization. Kuznets (1955) hypothesized that inequality rises in the early stage of industrialization and later decreases, because of a shift away from the agricultural sector to the more productive, but potentially more unequal, manufacturing sector. Interestingly, he explicitly related inequality to scale: "inequalities [in manufacturing] might be assumed to be far wider than those for the agricultural population which was organized in relatively small individual enterprise." This paper provides a theoretical foundation and empirical evidence for that argument.

The remainder of the paper is organized as follows. Section 2 lays out the theory of scale-biased technical change and inequality formally. Section 3 describes the historical background of, and differing scale bias between, steam engines and electric motors. In Section 4, I discuss how the data is constructed. The methodology and results on the effect of technology on scale and inequality are shown in Sections 5 and 6, respectively. Section 7 shows evidence that inequality between workers and entrepreneurs was the main channel through which steam engines increased inequality. Section 8 concludes.

[6]See De Loecker et al. (2022) for other reasons to study the firm size distribution.

2 Model

There is a continuum of households with unit measure that differ in their entrepreneurial productivity ψ. I assume that ψ has a probability density function $f(\cdot)$ with semi-infinite support on $\mathbb{R}^+$, i.e., $\{\psi \mid f(\psi) > 0\} = [\psi_m, \infty)$ for some $\psi_m \geq 0$.[7] In a first stage, before observing their entrepreneurial productivity ψ, each household decides whether to be a worker or to be an entrepreneur. A household knows that by choosing entrepreneurship, it is foregoing the wage w.

Once this opportunity cost is sunk, in the second stage, entrepreneurs observe their productivity ψ and choose whether to enter business or not.

An entrant chooses, in a third stage, chooses from an exogenous set of available production technologies $T \equiv \{t_1, .., t_J\}$. Each technology $t_j \in T$ is a tuple $\{\alpha_j, \kappa_j\}$ where α_j is the marginal labor cost and $\kappa_j > 0$ is its fixed cost in terms of the final good.[8] I assume that T does not contain trivially dominated technologies. That is, if $t_j, t_k \in T$ and $\alpha_j < \alpha_k$, then $\kappa_j > \kappa_k$.[9] Technologies are arranged in order of increasing fixed costs ($\kappa_1 < .. < \kappa_J$).

Finally, in stage four, after adopting technology j, entrepreneurs maximize profits given their productivity ψ, yielding $\pi_j(\psi)$. Figure 1 visualizes the decision process and pay-offs. I characterize optimal behavior and derive equilibrium conditions by backward induction.

Stage 4: Profit maximization

Each entrepreneur produces a differentiated good. Given technology t_j and entrepreneurial productivity ψ, their production function is

$$y_j(\psi) = \frac{\psi l}{\alpha_j} \tag{1}$$

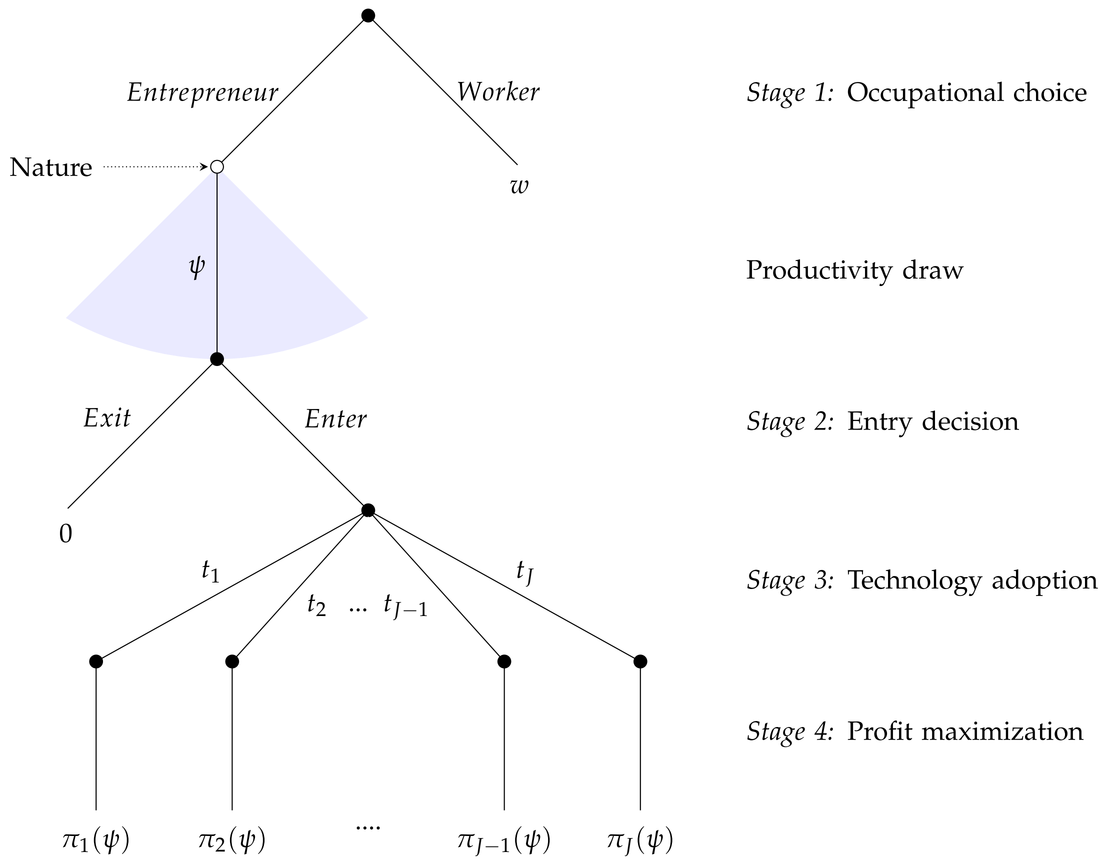
where l is labor and α_j is the marginal labor cost for technology t_j. The total cost to produce y given t_j and ψ is $C_j(y \mid \psi) = \frac{\alpha_j w}{\psi} y + \kappa_j$ where κ_j is the fixed cost in terms of the final good. Each household's utility is characterized by a constant elasticity of substitution σ over a continuum of these differentiated goods indexed by ω (Dixit and

[7]To derive a closed-form solution of the equilibrium, I will later assume that $\psi \sim \text{Pareto}(\psi_m, \xi)$.

[8]This can be seen as a generalization of the binary technology choice in (Yeaple, 2005; Bustos, 2011), who are concerned with the connection between trade and technology adoption.

[9]This assumption does not affect any equilibrium outcome as such trivially dominated technologies would not be adopted.

FIGURE 1: Pay-off tree



Stiglitz, 1977; Melitz, 2003):

$$U \equiv Y = \left[\int_{\omega \in \Omega} y(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}. \tag{2}$$

The demand for good ω is thus $y(\omega) = Y \left(\frac{p(\omega)}{P} \right)^{-\sigma}$ where $p(\omega)$ is the price of good ω and $P \equiv \left[\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$. Hereafter, I use the normalization that $P = 1$. Profit maximization conditional on technology and productivity then yields the pricing rule

$$p_j(\psi) = \frac{\alpha_j w}{\rho \psi} \tag{3}$$

where $\rho \equiv \frac{\sigma-1}{\sigma}$. This is a standard pricing rule (e.g., Melitz, 2003, eq. (3)), but with a marginal cost that may vary across producers. In equilibrium, this yields (conditional) profits $\pi_j(\psi)$ equal to

$$\pi_j(\psi) = \frac{Y}{\sigma} \left(\frac{\rho \psi}{\alpha_j w} \right)^{\sigma-1} - \kappa_j. \tag{4}$$

Stage 3: Technology adoption

An entrepreneur that chooses to produce can use any of the J available technologies in the set T. She therefore adopts the technology j that yields largest profits, so the profits of an entrepreneur with productivity ψ are:

$$\pi(\psi) = \max_{j \in \{1,2,..,J\}} \{\pi_j(\psi)\}. \tag{5}$$

An important property of this profit function is that more productive entrepreneurs choose higher fixed costs technologies. To see this, note that for an entrepreneur with productivity ψ, the difference in profits between technologies t_j and t_k are:

$$\Delta\pi_{jk}(\psi) \equiv \pi_j(\psi) - \pi_k(\psi) = \frac{Y}{\sigma}\left(\frac{\rho\psi}{w}\right)^{\sigma-1}\left(\alpha_j^{1-\sigma} - \alpha_k^{1-\sigma}\right) - (\kappa_j - \kappa_k). \tag{6}$$

Recall that since $j > k$, $\kappa_j > \kappa_k$ and $\alpha_j < \alpha_k$. It then follows from the expression that $\Delta\pi_{jk}(\psi)$ is strictly increasing in ψ. That is, the more productive an entrepreneur is, the larger their profits under technology j (higher fixed, lower marginal cost) relative to technology k (lower fixed, higher marginal cost). A corollary of this result is that prices are strictly decreasing in ψ (see equation (3)), such that entrepreneurs with higher productivity face more demand and, hence, produce more.

Stage 2: Entry decision

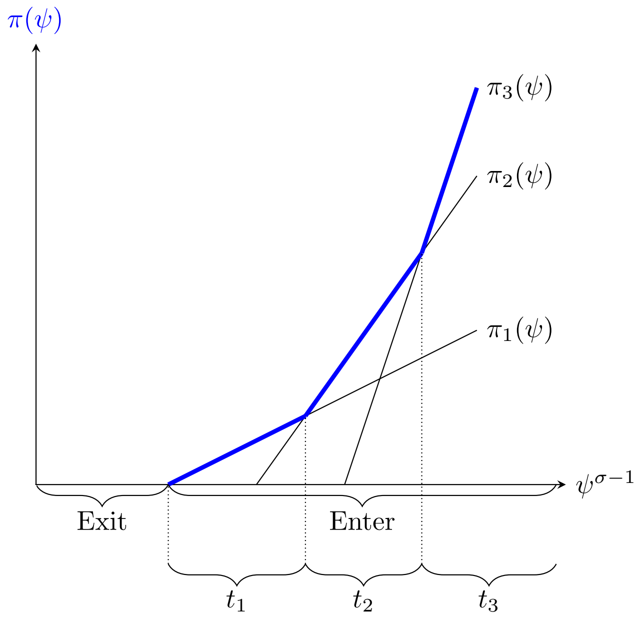
After observing their entrepreneurial productivity ψ, each entrepreneur decides whether or not to exit or enter. Since the opportunity cost is zero (as the opportunity cost of not working is already sunk), they decide to enter if and only if $\pi(\psi) \geq 0$.

There is a unique $\bar{\psi} > 0$ such that an entrepreneur enters if and only if $\psi \geq \bar{\psi}$. To see this, note that equation (4) implies that $\pi_j(\psi)$ is strictly increasing in ψ for each $j \in \{1, 2, .., J\}$. Therefore, $\pi(\psi)$ is the maximum of J strictly increasing functions and is thus also strictly increasing. Finally, $\pi(0) = -\kappa_1 < 0$ and $\pi(\psi) \to \infty$ as $\psi \to \infty$. It thus follows that there is a unique $\bar{\psi}$ implicitly defined by

$$\pi(\bar{\psi}) = 0. \tag{7}$$

To solve for this threshold, note that profits under each technology are strictly increasing in $\pi_j(\psi)$. Therefore, each technology j has itself a zero profit cut-off $\bar{\psi}_j$ above which

FIGURE 2: Profit $\pi(\psi)$ and productivity ψ in case of three adopted technologies



Notes: The braces indicate the optimal action in Stage 2 and 3 given productivity ψ. The elasticity of substitution σ is larger than one so that $\psi^{\sigma-1}$ is increasing in ψ.

profits are positive. From equation (4), this threshold is defined by

$$\bar{\psi}_j = \alpha_j \kappa_j^{\frac{1}{\sigma-1}} \left(\frac{\sigma}{Y}\right)^{\frac{1}{\sigma-1}} \frac{w}{\rho}.$$

Since an entrepreneur enters if and only if at least one technology yields positive profits, the entry decision is governed by the technology for which the entry threshold $\bar{\psi}_j$ is lowest. Combining equations (4), (5), (7) gives a solution for $\bar{\psi} > 0$:

$$\bar{\psi} = \min_{j \in 1,2,..,J} \bar{\psi}_j = \min_{j \in 1,2,..,J} \left\{\alpha_j \kappa_j^{\frac{1}{\sigma-1}}\right\} \left(\frac{\sigma}{Y}\right)^{\frac{1}{\sigma-1}} \frac{w}{\rho}. \tag{8}$$

Figure 2 shows the profit function $\pi(\psi)$ and the optimal decision in Stage 2 and 3. It illustrates that the entry cut-off $\bar{\psi}$ is the productivity level for which the technology with the lowest entry threshold gives positive profits.

Stage 1: Occupational choice

Free entry into entrepreneurship (and risk-neutrality) implies that in equilibrium the expected profits of entering must be equal to the wage. That is,

$$\int_{\bar{\psi}}^{\infty} \pi(\psi) dF(\psi) = w. \tag{9}$$

Defining average profits of producing entrepreneurs as $\bar{\pi} \equiv \frac{1}{1-F(\bar{\psi})} \int_{\bar{\psi}}^{\infty} \pi(\psi) dF(\psi)$, equation (9) can be written as

$$(1 - F(\bar{\psi})) \, \bar{\pi} = w.$$

The probability of entry times the average profits after entry should equate the wage. Were the wage lower (higher) than the expected profits, no one would decide to work (be an entrepreneur).

2.1 Which technologies are adopted?

Answering this question requires defining some notation. First, it follows from optimal behaviour in Stages 2 and 3 that a technology is adopted in equilibrium if there is a set of entrepreneurs that both i) decides to enter and ii) finds it profit-maximizing to produce with that technology. I define the *adopting set* for technology j as the set of productivity levels for which both conditions are satisfied:

$$\Psi_j \equiv \{\psi \mid \pi(\psi) \geq 0\} \cap \left\{\psi \mid \pi_j(\psi) = \max_{k \in \{1,2,..,J\}} \pi_k(\psi) \equiv \pi(\psi)\right\}. \tag{10}$$

A technology j is adopted if the probability measure of the adopting set Ψ_j is strictly positive. Let $T^* \subseteq T$ be *the set of adopted technologies*, so that

$$t_j \in T^* \iff \Pr\left(\psi \in \Psi_j\right) > 0 \text{ for any } j = 1, 2, ..J.$$

For simplicity of notation, I call $t_j^* = \{\alpha_j^*, \kappa_j^*\}$ the technology in T^* with the jth-lowest fixed cost κ_j^*. Let $J^* \equiv |T^*|$ denote the number of adopted technologies. Proposition 1 shows which technologies are adopted in equilibrium.

Proposition 1 (Adopted technologies)**.** *The set of technologies adopted in equilibrium, $T^* = \left\{t_1^*, .., t_{J^*}^*\right\}$, is such that*

(a) the adopted technology with the highest marginal (lowest fixed) cost $t_1^* = (\alpha_1^*, \kappa_1^*)$ is such that

$$\alpha_1^* (\kappa_1^*)^{\frac{1}{\sigma-1}} = \min_{j \in 1,2,..,J} \left\{\alpha_j \kappa_j^{\frac{1}{\sigma-1}}\right\} \text{ and;}$$
$$\alpha_1^* = \min_{j \in 1,2,..,J} \left\{\alpha_j \mid \alpha_j \kappa_j^{\frac{1}{\sigma-1}} = \min_{l \in 1,2,..,J} \left\{\alpha_l \kappa_l^{\frac{1}{\sigma-1}}\right\}\right\}$$

(b) the adopted technology with the lowest marginal (highest fixed) cost $t_{J^*}^* = (\alpha_{J^*}^*, \kappa_{J^*}^*)$ is such

that

$$\alpha^*_{J^*} = \min_{j \in 1,2,..,J} \{\alpha_j\} \text{ and;}$$
$$\kappa^*_{J^*} = \min_{j \in 1,2,..,J} \left\{\kappa_j \mid \alpha_j = \min_{l \in 1,2,..,J} \{\alpha_l\}\right\}$$

(c) *any technology with fixed cost* $\kappa^*_1 < \kappa_j < \kappa^*_{J^*}$ *is adopted if and only if for any* $k \in \{1, .., j-1\}$ *and* $l \in \{j+1, .., J\}$

$$\frac{\alpha_l^{1-\sigma} - \alpha_j^{1-\sigma}}{\alpha_j^{1-\sigma} - \alpha_k^{1-\sigma}} < \frac{\kappa_l - \kappa_j}{\kappa_j - \kappa_k}.$$

Proof of Proposition 1. See Appendix C. □

Proposition 1(a) indicates which technology is the adopted technology with highest marginal cost (and thus lowest fixed cost). Since the profit gain of a marginal cost reduction is increasing in productivity ψ, this is the technology that is adopted by the marginal entrepreneur ($\psi = \bar{\psi}$). Also, the marginal entrepreneur must use the technology j with the lowest *entry threshold* $\bar{\psi}_j$ (in Figure 2, the technology with the leftmost intersection with the zero-profit axis). The first condition in Proposition 1(a) then follows from equation (8). The second condition in Proposition 1(a) states that — in knife-edge cases where there is more than one technology that minimizes the entry threshold — only the technology with the lowest marginal cost among those that minimize the entry threshold are adopted because all but the marginal entrepreneur would strictly prefer that technology.

Proposition 1(b) shows that the technology with the lowest marginal cost is always adopted, regardless of its fixed cost. The result follows from the unbounded support of the productivity distribution. Since the gains from lowering marginal cost are strictly increasing in productivity, the gains from lowering marginal cost are unbounded. Therefore, no matter how high the fixed cost, there is always a strictly positive measure of entrepreneurs willing to incur it to reduce marginal cost. Of course, if there are multiple technologies that minimize marginal cost, only the technology with lowest fixed cost among them is adopted. It follows from combining Propositions 1(a) and 1(b) that only one technology is adopted in equilibrium if and only if the technology in T with the lowest marginal cost also comes with the lowest entry threshold. Th

Lastly, Proposition 1(c) covers all remaining adopted technologies, if any. Intuitively, for a technology to be adopted by an entrepreneur, their productivity must be *high enough* to make the technology more profitable than any other technology with higher marginal cost (and lower fixed cost), but also *low enough* to make the technology more profitable than adopting any other technology with lower marginal cost (and higher fixed cost).

Proposition 1(c) sets out the conditions under which the set of productivities that satisfy these conditions has a strictly positive probability measure. To illustrate the condition, consider Figure 2: there is an intermediate set of productivity levels, for which technology t_2 yields higher profits than both t_1 and t_3. For such a set of productivity levels to exist, the lower bound above which t_2 higher profits than t_1 must be smaller than the upper bound below which it yields higher profits than t_3.

2.2 Equilibrium

Definition (Competitive equilibrium). Given an exogenous technology set $T = \{t_1, .., t_J\}$, a *competitive equilibrium* consists of a price w, profits $\{\pi(\psi)\}$, output Y, productivity threshold $\bar{\psi}$, adopting sets $\{\Psi_j\}_{j=1}^J$, and a share of entrants L such that

- profits $\pi(\psi)$ are as defined in (4) and (5);
- the adopting set of technology j, Ψ_j, is as defined in (10);
- the free entry condition in (9) holds;
- the labor and goods markets clear, so that

$$L = (1-L)Y\left(\frac{\rho}{w}\right)^{\sigma}\sum_{j=1}^{J}\alpha_j^{1-\sigma}\int_{\psi\in\Psi_j}\psi^{\sigma-1}dF(\psi), \tag{11}$$

$$Y = Lw + (1-L)\left(\sum_{j=1}^{J}\kappa_j\int_{\psi\in\Psi_j}dF(\psi) + \sum_{j=1}^{J}\int_{\psi\in\Psi_j}\pi(\psi)dF(\psi)\right); \tag{12}$$

- the pricing by entrepreneurs is consistent with a price index equal to 1, so that

$$1 = (1-L)\left(\frac{w}{\rho}\right)^{1-\sigma}\sum_{j=1}^{J}\alpha_j^{1-\sigma}\int_{\psi\in\Psi_j}\psi^{\sigma-1}dF(\psi). \tag{13}$$

Having defined the equilibrium in general, in order to get more concrete results, form now on I assume that the distribution of productivity ψ is Pareto. With this assumption, the model has closed-form analytical solutions reported in Appendix C.

Proposition 2 (Closed-form equilibrium). *Suppose that the distribution of productivity ψ is Pareto with shape parameter ξ and a minimum productivity level of $\psi_m > 0$ such that $\xi > 1$ and $\xi > \sigma - 1$. Then, the closed-form solutions to the competitive equilibrium for L, $\bar{\psi}$, Y, w, and $\bar{\pi}$ are given by equations (28), (29), (30), (31), and (32) in Appendix C.*

Proof of Proposition 2. See Appendix C. □

Proposition 1 and 2 together fully characterize the equilibrium in closed form. In the next subsection, I use these results to study the effect of scale-biased technical change on entrepreneurship, firm concentration, wages, output, profits, and inequality.

2.3 Scale bias and testable implications

Large-scale-biased technical change is technical change that favors large over small firms by increasing their relative productivity. This definition is analogous to that of *skill*-biased technical change as increasing skilled workers' productivity relative to unskilled labor (Katz and Murphy, 1992; Violante, 2008). Krusell et al. (2000) provide a micro-foundation for skill-biased technical change by considering that the relative productivity changes could be caused by capital-skill complementary. In the same vein, I provide an explicit mechanism for relative productivity increases of large firms in terms of the available technologies.

To formalize scale-biased technical change, I first define the *total factor productivity* of a firm as the idiosyncratic productivity of the entrepreneur ψ divided by the marginal cost of the technology in T that it adopts:

$$TFP\left(\psi \mid T\right) = \begin{cases} \frac{\psi}{\alpha(\psi|T)} & \text{if } \psi \geq \bar{\psi}\left(T\right) \\ 0 & \text{otherwise} \end{cases}$$

where $\bar{\psi}\left(T\right)$ is the entry threshold given the technology set T (derived in closed-form in Proposition 2), so that total factor productivity is zero for entrepreneurs that do not produce.

Technical change is an addition of a new technology, say t_{new}, to the technology set T_{old} such that $T_{new} = T_{old} \cup \{t_{new}\}$. From there, I define scale-biased technical change formally.

Definition (Scale-biased technical change)**.** Technical change is *large-scale-biased* if and only if there exists some $k > \min\left\{\bar{\psi}(T_{new}), \bar{\psi}(T_{old})\right\}$ such that it increases TFP for $\psi > k$ and does not increase it for $\psi < k$:

$$\begin{aligned} &TFP\left(\psi \mid T_{new}\right) > TFP\left(\psi \mid T_{old}\right) \quad \forall \psi > k \text{ and;} \\ &TFP\left(\psi \mid T_{new}\right) \leq TFP\left(\psi \mid T_{old}\right) \quad \forall \psi \in \left(\min\left\{\bar{\psi}(T_{new}), \bar{\psi}(T_{old})\right\}, k\right). \end{aligned} \tag{14}$$

It is *small-scale-biased* if and only if there exists some $k > \min\left\{\bar{\psi}(T_{new}), \bar{\psi}(T_{old})\right\}$ such that it increases TFP for $\psi < k$ and does not increase it for $\psi > k$:

$$\begin{aligned} &TFP\left(\psi \mid T_{new}\right) > TFP\left(\psi \mid T_{old}\right) \quad \forall \psi \in \left(\min\left\{\bar{\psi}(T_{new}), \bar{\psi}(T_{old})\right\}, k\right) \text{ and;} \\ &TFP\left(\psi \mid T_{new}\right) \leq TFP\left(\psi \mid T_{old}\right) \quad \forall \psi > k. \end{aligned} \tag{15}$$

In other words, technical change is large-scale-biased if it increases the productivity of firms above some minimum level of entrepreneurial productivity, while it does not increase the productivity of other firms.

Proposition 3 below lays out the conditions under which technical change is scale-biased if a new technology is added to the set of adopted technologies.

Proposition 3 (Scale-biased technical change)**.** *Suppose that the assumptions in Proposition 2 (Pareto distribution) hold, that $\sigma > 2$, and that $T^*_{new} = T^*_{old} \cup \{t_{new}\}$ (the new technology is adopted alongside the previously adopted technologies). Then,*

(a) the technical change is large-scale-biased if and only if

$$\kappa_{new} > \max_{(\alpha,\kappa)\in T^*_{old}} \kappa;$$

(b) and the technical change is small-scale-biased if and only if

$$\kappa_{new} < \min_{(\alpha,\kappa)\in T^*_{old}} \kappa.$$

Proof. See Appendix C. □

Proposition 3 shows that the addition of a technology constitutes large- or small-scale biased technical change if and only if the new technology comes with either lowest or highest marginal cost.

The intuition behind the "if" is that a technology on the extreme end of the technology set would be adopted by the most productive or least productive entrepreneurs. Also, under the assumptions in Proposition 3, if a new technology is adopted, it *reduces* profitability of all other technologies. Therefore, entrepreneurs that do not adopt the new technology do not reduce marginal cost through a change to a third technologies. If anything, some may decide to "downgrade" their technology in response to other entrepreneurs using the new technology. Thus, if a new technology has largest fixed cost, it reduces the productivity of the top entrepreneurs relative to the rest. Vice versa, if it comes with lowest fixed cost, it increases the relative productivity of small entrepreneurs.

If a technology is adopted that has neither the highest or the lowest fixed cost, it will be used by a set of intermediate entrepreneurs. This means that both the largest and the smallest firms do not adopt this technology. Hence, by the same reasoning as above, this type of technical change does not increase the productivity of either small or large firms and is thus neither large- nor small-scale-biased.

The condition that $\sigma > 2$ is the empirically relevant case for at least two reasons. First, it is consistent with estimates of σ around 6 for US manufacturing data (Bernard et al., 2003) and with the calibration of $\sigma = 4$ by Melitz and Redding (2015). Second, $\sigma \leq 2$ implies a labor share of a half or lower, while the labor share has been consistently larger than a half in the US and other countries.

Using Propositions 2 and 3, I generate three main predictions of the theory. First, large-scale biased technical change increases average firm sizes, while small-scale-biased technical change decreases them. Second, large-scale biased technical change increases top income inequality. Small-scale-biased technical change decreases inequality. Third, scale bias affects inequality mostly through inequality between workers and entrepreneurs.

Proposition 4 (Theoretical implications of scale-biased technical change)**.** *Suppose the assumptions in Proposition 3 hold. Then, large-scale-biased (small-scale-biased) technical change*

(a) increases (decreases) the average firm size as measured by employment;

(b) increases (decreases) the income share of the top k% of income earners for any $k \in (0, 100)$

(c) increases (decreases) income inequality between workers and entrepreneurs.

Proof of Proposition 4. See Appendix C. □

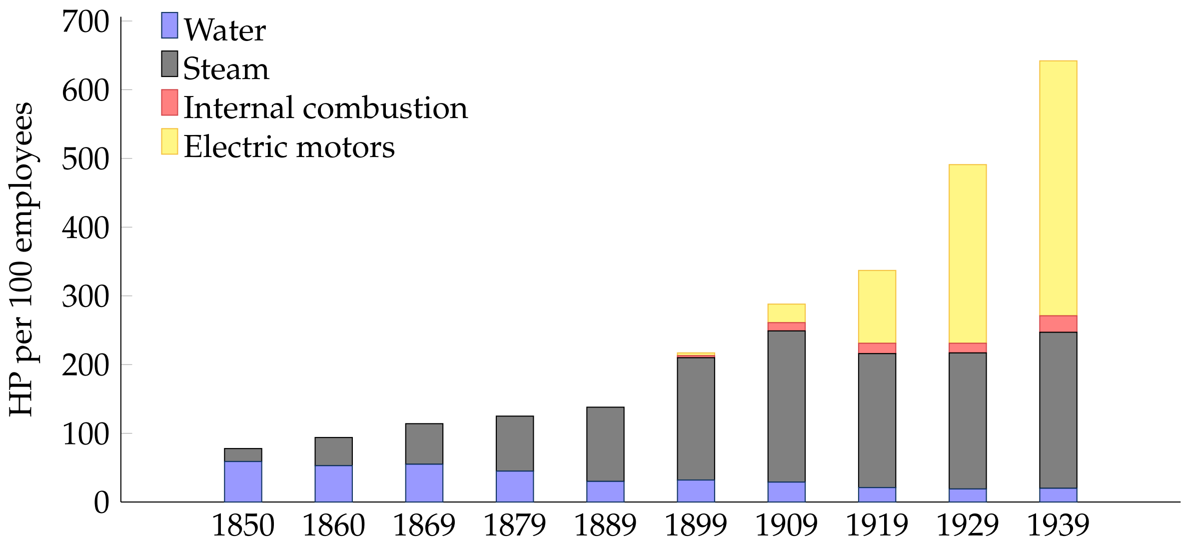
The remainder of the paper is devoted to testing the theoretical predictions above. I will use the case of steam engines and electric motors. In the next section, I show that steam engines are large-scale-biased and electric motors are small-scale-biased.

3 Steam engines and electric motors

To test the theory of scale-biased technical change, I compare the effects of steam engine and electric motor adoption. I argue that the comparison of these two technologies is uniquely appropriate to test the theory for three main reasons. First, the steam engine and the electric motor are two of the most important general purpose technologies in human history. Second, they served a similar purpose: the conversion of energy into rotary motion in manufacturing. Third, as I will argue in this section, they varied crucially on scale bias: steam engine adoption constituted large-scale-biased technical change, while electric motor adoption constituted small-scale-biased technical change.

I first briefly describe the history of steam engine and electric motor adoption. Figure 3 illustrates the timing and degree of adoption of each type of primary power. Three main patterns jump out. First, the waterwheel was slowly replaced by the steam engine in the second half of the 19th century. Second, steam engines, and later the electric motor, were the dominant power source from around 1870 onward. Third, electric motors were adopted from around 1900 and their superiority meant that internal combustion engines were never adopted on a large scale (Du Boff, 1967). Fourth, electric motors driven by purchased electricity started to become dominant around the 1930s, but steam engines remained an important source of primary power until at least 1939. Figure A.1 shows the same patterns for the Netherlands.[10] Below, I lay out the features of the technologies that make steam engine adoption large-scale-biased and electric motor adoption small-scale-biased.

FIGURE 3: Capacity of primary power by type in horsepower per 100 employees in manufacturing in the United States



Notes: Electric motors refer to primary electric motors, i.e., electric motors driven by purchased electricity, only. Electric motors driven by energy generated in the plant are covered under steam engines. *Sources*: (Atack, 1979, Table 1) for the number of steam engines and waterwheels in 1850 and 1860; (Atack et al., 1980, p. 285) for their average size (21 and 15 hp, respectively); Census of Manufactures 1860 for the total number of employees in 1850 and 1860; Census of Manufactures 1939, Power equipment and energy consumption, Table 3 for all years after 1860.

First, steam engines come with much higher fixed costs of purchase, renewal, and op-

[10] A distinction can be made between the primary source of power (from the perspective of the plant) and the system to deliver that power. Many electric motors in manufacturing were not driven by purchased electricity, but by electricity generated in the plant. Such "secondary movers" are excluded from Figure 3 to avoid double counting of capacity. The share of non-electric primary power, such as steam engines, that served to generate electricity for intra-plant use grew strongly over time: from 14.8% percent in 1909 to 65.8% in 1939 (Du Boff, 1979, Table 15). Hence, electricity as a system of power delivery was more dominant than suggested by considering only the primary source of power. For the remainder of this paper, I focus on the primary source of power as the key distinction between "steam engines" and "electric motors".

eration than electric motors. The price of a steam engine (including boiler) of average capacity was around $5331 in 1874, more than 13 times the yearly wage of an unskilled manufacturing worker (Emery, 1883; Abbott, 1905).[11] On top of that, it required an engineer and a firemen, supplies, oil, and repairs. In total, I estimate the annualized cost of purchase, renewal, maintenance, and operation of a 50 horsepower steam engine to be around $1378, about 3 to 4 times the yearly unskilled wage. In other words, for the cost of operating an average-sized steam engine excluding fuel, one could hire around 3 to 4 unskilled workers. In comparison, the equivalent annualized fixed costs of an electric motor of that size were negligible: the fixed cost amounted to only 2 percent of the yearly wage of an unskilled worker (Bolton, 1926). In Appendix E, I provide more details on computations and sources.

Second, larger steam engines were considerably more efficient in converting energy into motion than small ones (Atack, 1979; Devine, 1983). In contrast, electric motors' efficiency does not vary nearly as much with size. In the words of the contemporaneous engineer Bell (1891): "With the electric motor the case is very, very different [from steam engines]; an eight horse-power motor may be as completely worked out in detail as one of a hundred times its power, and may be only slightly less efficient." Figure A.2 illustrates the efficiency of steam engines and electric motors for different sizes (horse-power capacity) relative to a 100 h.p. equivalent based on estimates by Emery (1883) and Bolton (1926). A steam engine of 10 h.p. required more than twice as much coal per horse-power of energy output than a 100 h.p. steam engine. Coal-efficiency was an important consideration given that coal accounted for between a half and two-thirds of the total operating costs for the larger engines.

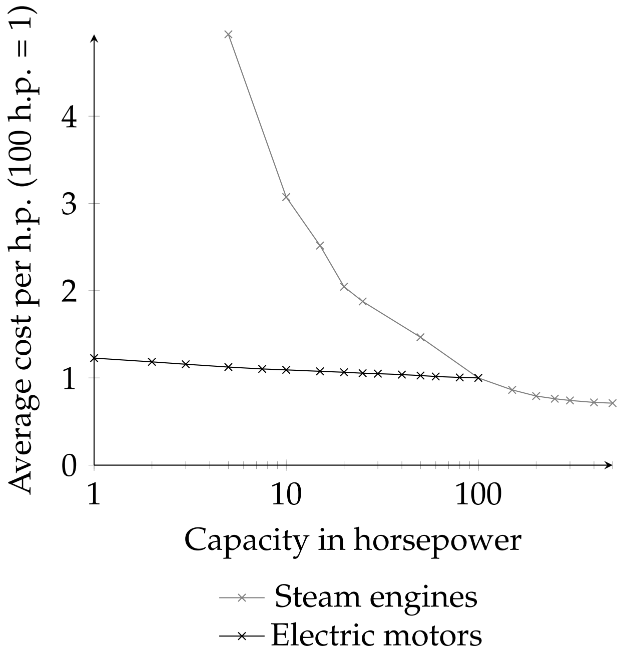
The marginal and fixed costs of steam engines and electric motors can be combined to estimate an average cost curve by rated capacity for the electric motor and the steam engine. Figure 4 shows the results.[12] Clearly, steam engines were much more cost-efficient on a large scale. For electric motors, scale was close to irrelevant as almost all costs were marginal, coming from the purchase of electricity, and the efficiency loss of small motors was minor.

Lastly, there were reasons for steam engine adoption to be skewed to large establishments that are less easily quantified, but no less important. A steam engine occupied a large amount of space and fuel storage, water supply, and mitigation of fire hazard fur-

[11] The average steam engine in the United States in 1889 had a capacity of 50.1 horsepower (Du Boff, 1979). The daily wage of an unskilled worker was $1.29 Abbott (1905), which I multiplied by 309 days as in (Emery, 1883).

[12] I have assumed an interest rate of 5 percent, depreciation rates as estimated by Emery (1883); Bolton (1926) and a price of electricity as reported by Hannah (1979) and of coal as Emery (1883). In Appendix E, I explain the assumptions and computations underlying Figure 4 in further detail. Consistent with my estimates based on Emery (1883), (Kapp, 1894, p. 234) reports that the cost per horsepower hour of a "small" steam engine was about four times the cost of that of a "large" engine.

FIGURE 4: Average cost per horsepower per year of steam engines and electric motors of different capacities relative to its 100-horse power equivalent



Notes: Author's computation based on contemporaneous price and efficiency data. *Sources*: (Emery, 1883) for steam engines and coal; (Bolton, 1926; Hannah, 1979) for electric motors and electricity. See Appendix E for further details.

ther increased the fixed costs of operating steam engines (Hunter and Bryant, 1991, p. 56). Also, the "notoriously wasteful" steam engine had to be run at full capacity even if only small doses of power were required, a feature likely to be specifically uneconomical for small establishments (Du Boff, 1967).

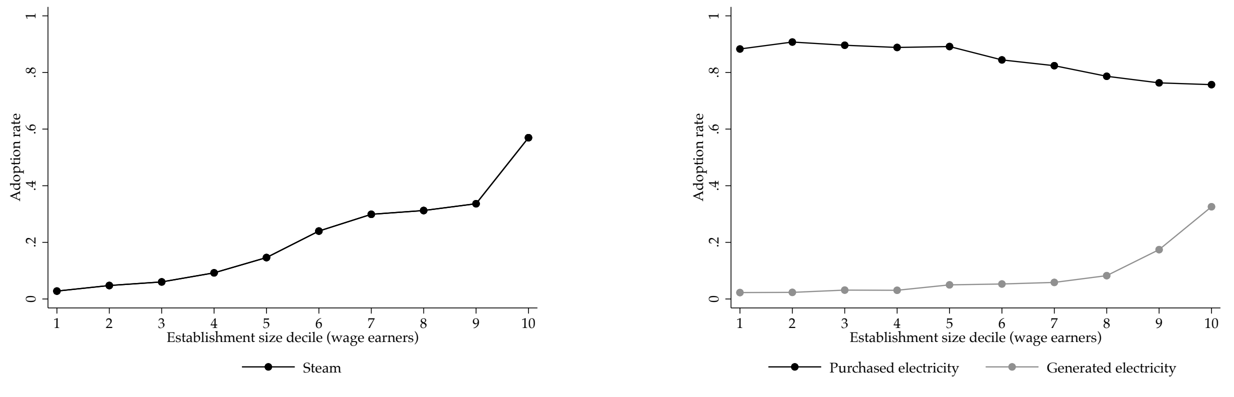
The adoption rates by plant size reflect the considerations above. Figure 5(A) shows that large plants are much more likely to adopt steam engines, as documented before by Atack et al. (2008). In contrast, Figure 5(B) indicates that electric motors driven by purchased electricity were almost uniformly adopted across the establishment size distribution. In fact, larger firms were slightly less likely to use purchased electricity while they were much more likely to use self-generated electricity. This further confirms, that for the purpose of studying scale bias, the relevant distinction is the primary source of power, not the system of delivery.

4 Data construction

This paper uses newly collected and digitized data from the United States as well as the Netherlands. In this section, I discuss the sources and construction of the data for both countries.

FIGURE 5: Adoption rates by establishment size

(A) Steam engines (1880) (B) Electric motors (1929)



Notes: This figure indicates the share of establishments using steam engines in 1880 (panel A) and electric motors in 1929 (panel B) by establishment size as computed from micro-samples of the Census of Manufactures. *Sources*: for 1880, the national random sample of the Census of Manufactures (Atack and Bateman, 1999); for 1929, the Census of Manufactures for selected industries (Vickers and Ziebarth, 2018). I left out the concrete industry as data on electric motors driven by generated electricity is not available for that industry.

4.1 United States

For the United States, I most heavily rely on the tabulations of the decennial Census of Manufactures by state and industry. I digitized and compiled these data for each decade year between 1850 and 1940 and 1947. The information in the Census of Manufactures varied somewhat from year to year, but key variables such as the number of establishments, employment, and value added are always available. Furthermore, from 1870 onward, the tabulations reported the adoption of power technologies such as water wheels, steam engines, and, later, electric motors. The industry classification is detailed; in the average year, there are around three to four hundred different manufacturing industries. In total, the data comprise of 51,263 state-industry-year observations.

Since industry classifications changed over time, I created two crosswalks that allow to compare industries over time. The first covers all industries between 1860 and 1900, the period of most rapid steam engine adoption and consists of 182 industries. This crosswalk is an extension of the 1860 to 1880 crosswalk published by Hornbeck and Rotemberg (2021). The second crosswalks consists of 211 harmonized industries across the five censuses between 1890 and 1930. To create this second crosswalk, I used tabulations by industries over time published in the Census of Manufactures.[13] The final crosswalk can be found in Appendix D.2.

[13]In particular, I mostly used "comparative summaries" and descriptions of industry classifications in the appendices in the Census of Manufactures.

To construct instrumental variables for technology adoption, I use data on coal resources and hydropower potential by state. Data on historical coal resources by county are taken from the National Coal Resources Data System from the United States Geological Survey (USGS).[14] The dataset contains information on the "rank" (i.e., type) of coal, the estimated tonnage available, the thickness of the field, and the "overburden" (i.e. the depth of the material that lies above the coalfield). The estimates refer to the tonnage available prior to mining. Using this information, I compute the total coal resources in British thermal units (Btu) for each county.[15] Recognizing that coal was traded across counties, I compute a measure of "coal access" by county similar to the measure of market access used by Donaldson and Hornbeck (2016). That is, for destination county c in state s, coal access is given by

$$\mathrm{COAL}_c^s = \sum_o \tau_{oc}^{-\theta} \mathrm{BTU}_o \tag{16}$$

where $\tau_{oc} \geq 1$ is the "iceberg cost" of transporting coal between counties o and c in 1830, θ is the trade elasticity, and BTU_o is the total amount of coal resources in county o measured in Btu.[16] Intuitively, the coal resources in county o more strongly count towards county d's coal access if the transportation costs between these counties is low. Importantly, I use transportation costs before the introduction of the railroads to avoid capturing infrastructure investments. Figure A.3 shows the spatial distribution of coal access.

Hydropower potential is defined as the total horsepower of energy that can be feasibly generated by waterpower given the topographic characteristics of the area. Importantly, it covers both developed and undeveloped sites. Estimates of hydropower potential of each state were published by USGS at various points in time. I use the estimates of hydropower potential published in (Young, 1964, Table 10). Since water flow may vary seasonally, hydropower potential may not be constant over time. I use estimates of hydropower potential available 50 percent or more of the time. Figure A.4 shows a map of hydropower potential across the United States.

[14]The source file can be downloaded from `https://www.usgs.gov/media/files/uscoal`.

[15]Following Averitt (1975), I convert the tonnage of coal of different ranks to Btu using the following ratios: Anthracite, 12,700 Btu per pound; bituminous coal, 13,100 Btu per pound; subbituminous coal, 9,500 Btu per pound; lignite, 6,700 Btu per pound. I include the coal resource only if the overburden is less than 3,000 feet and the thickness is more than 14 inches for anthracite and (sub)bituminous coal or more than 28 inches for lignite (Averitt, 1975).

[16]Specifically, as in (Donaldson and Hornbeck, 2016; Hornbeck and Rotemberg, 2021), $\tau_{oc} = 1 + t_{oc}/\bar{P}_{coal}$. I set $\bar{P}_{coal} = 6.08$ to the average dollar per ton anthracite coal price in 1830, Philadelphia (Chandler, 1972, Table 2). t_{oc} is the transportation cost per ton-mile between counties o and c in 1830 as estimated by Donaldson and Hornbeck (2016). The trade elasticity θ is set to 8.22 as estimated by (Donaldson and Hornbeck, 2016).

4.2 Netherlands

For the Netherlands, I measure income and wealth inequality using two new datasets. The first dataset contains the names, occupation, residence, birth place, and wealth at death for all individual s who died in selected provinces between 1879 and 1927. The provinces cover around a half to two-thirds of the national population. The second dataset contains digitized tabulations of income and wealth distributions for each municipality and for around every five years between 1946 and 1975. Furthermore, I collected data on manufacturing on the local level for selected years. In all data, each municipality is coded to their "Amsterdamse code", an identifier for each historical Dutch municipality.[17]

4.2.1 Inheritance tax data (1879-1927)

The data on wealth at death derive from the inheritance tax administration. The tax was levied nationally since 1818. All source data up to 1927 is publicly available in regional archives in the Netherlands. Before 1878, the inheritances were only subject to tax if not all recipients were descendants in the direct line. After 1878, all inheritances above *ƒ*1000 (a thousand Dutch guilders) were taxed. However, the value of many estates worth less than *ƒ*1000 were assessed and recorded. The source files are printed tables that were filled in by hand indicating decedent's name, occupation, place of residence, marital status, date of death, and importantly, the value of their estate. The tables were referred to contemporaneously as "Tafels V-bis". Figure D.1 is an example of a source image. It also contains decedents whose inheritance were not subject to taxation. De Vicq and Peeters (2020) have digitized the Tafels V-bis for decedents who were subject to taxation in 1921. For more information on the source, I refer to their paper.

I cover the entire period between 1879 and 1927. I included all areas for which the source files were available online as scanned images, namely the provinces Noord-Holland, Zuid-Holland, Noord-Brabant, Gelderland, and Overijssel.[18] In 1900, these five provinces contained 70 percent of the population.[19] For Zuid-Holland, scanned images were only available up to around 1900. The source files are printed tables that were filled in by hand indicating decedent's name, occupation, place of residence, marital status, date of death, and importantly, the value of their estate. Figure D.1 is an example of a source image. The tables were digitized using Transkribus, an AI-powered platform specialized in digi-

[17]See Huijsmans (2020) for a database of all historical municipalities.

[18]The archival sources are: Noord Hollands Archief, record group 178 (for Noord-Holland); Nationaal Archief, record group (i.e. "inventarisnummer") 3.06.05 (for Zuid-Holland); Brabants Historisch Informatie Centrum, record group 82 (for Noord-Brabant); Gelders Archief, various record groups (for Gelderland); Collectie Overijssel, record group 136.4 (for Overijssel).

[19]See `http://www.volkstelling.nl` for data on population by province. The four provinces for which the entire period is covered contained 47 percent of the population in 1900.

tization of historical records.[20] In total, more than 130 thousand images were transcribed in this way.

I mitigate noise coming from automatic digitization of the data in two ways. First, the wealth of all observations with wealth recognized to be larger than ƒ100,000 (19,178 observations) were checked by hand. Second, I link the digitized dataset to existing high-quality hand-collected information from the civil death registry by (fuzzy) matching based on name, place and date of death, and age.[21] Around 80 percent of the observations can be linked to a record in the civil death registry.

Using the data, I create a panel of distributional wealth measures on a granular local level. I use the smallest geographical unit, the municipality, as the unit of analysis. To create a sufficient amount of observations per time period, I compute the distributional statistics by decade.[22] As reported above, all estates worth more than the taxable threshold of ƒ1000 were assessed and taxed, but many estates were assessed to be below the threshold. Which estates were assessed may have varied somewhat across tax offices and over time: the exact criteria under which an estate was assessed are to my knowledge unknown. The need to avoid that variations in assessments affect the measures of inequality, would suggest to only include decedents with an assessed wealth above ƒ1000 (as they should always have been assessed). However, to reduce variance in the measures of inequality, we would like to include as many people as possible. I balance these interests by using every decedent with an assessed wealth above ƒ300 to compute measures of the wealth distribution.

The resulting dataset on wealth over the period of industrialization is unique in its size and geographic scope. The existing literature has focused on documenting national trends in the wealth distribution. For instance, Lindert (1986) (UK) samples 12,581 for four regions and six dates between 1670 and 1875, Piketty et al. (2006) (France) cover a random sample of Parisian estates in selected years in the 19$^{\text{th}}$ century, and Bengtsson et al. (2018) (Sweden) collect information on samples of around 5000 probate inventories between 1750 and 1900. This dataset is an illustration of the value of using newly available technologies for scalable digitization of handwritten historical records. With more than 1.5 million decedents — of which 550,966 had their wealth assessed and recorded — and coverage across the country, it allows for a detailed look on the wealth distribution. Furthermore, and importantly for the purpose of this paper, it provides complete coverage between 1879 and 1927, the period where first steam engines and then electric motors were adopted in the Netherlands.

I assess the reliability of the data by comparing the measures of inequality with data

[20] For more information, see `https://readcoop.eu/transkribus/`.
[21] The civil registry data can be downloaded in bulk at `https://www.openarch.nl/exports/csv/`.
[22] Since the dataset starts in 1879, I assign that year to the 1880s too.

TABLE 1: Correlations between top decile shares based on inheritance data and alternative data sources

	Wealth, inheritance data				
	1880	1890	1900	1910	1920
Income, 1883	**0.86**	0.77	0.73	0.62	0.54
Income, 1926	0.38	0.33	0.54	0.60	**0.71**
Wealth, 1926	0.48	0.56	0.66	0.72	**0.76**

Notes: This table shows the correlations between the measures of municipality-level top wealth inequality for each decade derived from the inheritance data and measures of income and wealth inequality from other sources. Observations are weighted by the number of individuals on which the inheritance wealth inequality measure is based. *Sources*: local income tax data for income inequality in 1883; national income (wealth) tax data for income (wealth) inequality in 1926.

from two other sources that I have digitized. First, I uncovered a parliamentary document that recorded in large detail the distribution of income by municipality in 1883 for 79 municipalities.[23] These data were derived from the local income tax administrations. I also collected data on income distributions of 8 additional cities with a local income tax whose distribution was not included in the parliamentary study.[24] The second source of the data are income and wealth distributions derived from national taxation for the largest 45 municipalities for 1926 in (Centraal Bureau voor de Statistiek, 1928). Table 1 shows that the correlations are strong, and importantly, they are strongest for the relevant time period. For instance, the top decile share of income in 1883 correlates strongly with the top decile wealth share in 1880, but much less strongly with that in 1920. These correlations provide evidence that the data is accurate both in the cross-section and over time. Furthermore, Table 1 shows that wealth inequality among decedents (as measured by the inheritance data) correlates strongly with wealth (and income) inequality among the living population.

4.2.2 Income and wealth distributions by muncipality (1946-1975)

From 1946 onward, Statistics Netherlands published detailed income and wealth distributions for each municipality. The tabulations indicated the number of inhabitants in specific income (wealth) brackets as well as total bracket income (wealth).[25] Figure D.2 shows an example of the source data for one municipality. The data originate from the

[23] Tweede Kamer (*House of Representatives*) 1883-1884 kamerstuknummer (*document number*) 172.13. The source file can be found on `https://zoek.officielebekendmakingen.nl/0000397139`.

[24] The cities are: Breda (1880), Vlissingen (1883), Enschede (1880), Utrecht (1888), Delft (1893), Eindhoven (1885), Hilversum (1880), Nijmegen (1880). The sources for these extra cities are documented in Appendix D.3.

[25] The relevant publications are (Statistics Netherlands, 1953, 1954b, 1959b, 1965, 1967b, 1976b, 1979b) for wealth and (Statistics Netherlands, 1952, 1954a, 1959a, 1962, 1964, 1967a, 1970, 1976a, 1979a) for income.

national income and wealth tax administration. Since 1941, the national income tax covered almost the entire active population.[26] In line with Hartog and Veenbergen (1978), I therefore treat the units subject to income tax in a municipality as the target population for which I estimate the distribution of income and wealth.

To estimate the income and wealth distribution by municipality from the tabulations, I use the generalized Pareto interpolation method (Blanchet et al., 2022).[27] For income, since the target population is the taxed population, I perform this method directly on the source data. For wealth, the tax exemption limit was such that only around the wealthiest 10 percent of households subject to income tax were covered. I therefore first estimate the average wealth of a household below the threshold, using log-normal extrapolation. After this imputation, I estimate the overall wealth distribution using the generalized Pareto interpolation method.

4.2.3 Manufacturing

I use newly digitized data on manufacturing by municipality for the years 1816-1819 and 1930. The first official Census of Companies ("Bedrijfstelling") in the Netherlands was performed in 1930. It offers a high-quality snapshot of manufacturing by industry by municipality.[28] This source provides information on the number of establishments and workers by size class by industry by municipality and the adoption of motive power (in horsepower).[29] Importantly, it breaks down motive power by electric motors driven by purchased energy and other motive power (i.e., steam engines or electric motors driven by steam engines in the plant). Figure D.3 provides an example of a source page. In total, the data consists of 33,134 municipality-by-industry observations.

The data for the years 1816-1819 derive from two government surveys from which the results are compiled and published in print by (Brugmans, 1956; Damsma et al., 1979).[30] I digitized the data from that source and coded the establishment types to a 2-digit ISIC industry code.[31] Where data is available for both 1816 and 1819, I use the data for 1819. Furthermore, I added the results for the municipality of Rotterdam and neighbouring municipalities — that were excluded by (Brugmans, 1956; Damsma et al., 1979) — from (Korteweg, 1926). The inquiry contains, by municipality, information on the number of

[26]The coverage rose over time from around 85 to 99 percent (Schultz, 1968).

[27]The R-package `gpinter` implements the method.

[28]While it also provides information on non-manufacturing firms, I have digitized the data only for manufacturing firms. Source images can be downloaded from https://doi.org/10.17026/dans-xqs-5q6e.

[29]The establishments are broken down by those employing none or one person, 2 to 5 persons, 6 to 10 persons, or 11 or more persons.

[30]The source images can be downloaded from https://resources.huygens.knaw.nl/nijverheid.

[31]Specifically, I coded the establishment types to the International Standard Industrial Classification of All Economic Activities, Rev. 4.

establishments for each type of establishment (e.g. tannery or cotton factory) and the number of workers. Brugmans (1956); Damsma et al. (1979) were not able to retrieve the survey results of all municipalities in three out of eleven provinces (Zuid-Holland, Overijssel, and Groningen). The final data contain 3,658 municipality-by-industry observations in 539 distinct municipalities.[32] The data includes nearly all large cities and other places with a strong manufacturing presence.

Lastly, to estimate firm sizes in manufacturing in 1889, I use the Census of Occupations, which enumerated by municipality-by-industry the number of business owners and employees for the largest 285 municipalities. The data was digitized and made available by Mourits et al. (2016). I approximate the firm size in a municipality by dividing the number of employees by the number of business owners in manufacturing.

For comparability across years, I coded each industry or establishment type to its relevant 2-digit ISIC industry code for all the Dutch manufacturing data.

5 The effect of scale-biased technical change on firm size

This section documents the impact of the adoption of steam engines — large-scale-biased technical change — and the adoption of electric motors — small-scale-biased technical change on establishment sizes. The first prediction in Proposition 4 is that steam engine adoption increased the average establishment size, while electric motor adoption decreased it. Using geographical variation within the United States in the relative costs of the technologies, I verify this prediction.

5.1 Large-scale-biased technical change

The theory combined with the evidence in Section 3 suggests that large firms have an advantage over small firms in the adoption of steam power. Such selective adoption means that a correlation between firm sizes and steam engine adoption does not necessarily imply a causal effect of steam engine adoption. We therefore need exogenous variation to distinguish the effect of steam power adoption on the firm size from reverse causal effects and potential other confounders. I argue that differences in access to the natural coal reservers across the United States provides such quasi-experimental variation. As the most important input to steam engines, the availability of affordable coal affected the adoption of steam engines. Figure A.5 shows a strong negative correlation between coal

[32] Around 1200 municipalities existed at the time. For eight out of eleven provinces, (Brugmans, 1956; Damsma et al., 1979) retrieved the complete returns of the surveys so that any "missing" municipalities are likely to not have had any significant manufacturing presence. For the remaining three provinces, some municipalities may be missing despite some manufacturing industry.

TABLE 2: The effect of coal access on steam engine adoption (1890)

	Steam HP per worker (asinh, 1890)			Steam as share of total HP (1890)		
Coal access (logs)	0.027***	0.027***	0.026***	0.024***	0.024***	0.023***
	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Hydro-potential		X	X		X	X
Firm size			X			X
Observations	3890	3890	3890	3238	3238	3238

Standard errors in parentheses are clustered at the state-level. Industry fixed-effects included.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

prices and "coal access" ($\rho = -0.58$).

I first test the hypothesis that coal access affected the adoption of steam engines. That is, I estimate for $t = 1890$

$$\text{STEAM}_{ist} = \delta_i + \theta \ln\left(\text{COAL}_s\right) + \epsilon_{ist} \tag{17}$$

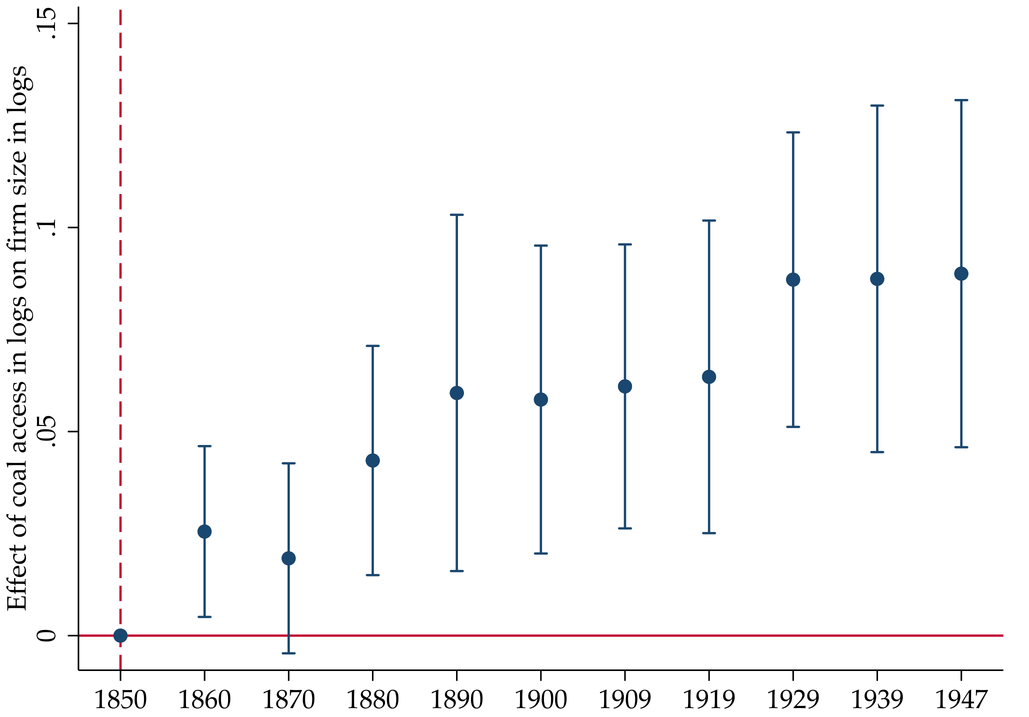
where the subscripts i, s, and t refer to industry, state, and year, respectively. STEAM_{ist} refers to measures of steam engine adoption, i.e., steam engines' horsepower per employee and the share of steam engines in total horsepower. COAL_s is the measure of state s's coal access, computed as the average coal access of the counties in state s as given by equation (16). Standard errors are clustered at the state-level and the regression is weighted by the total number of establishments in industry i, state s, and year t. Table 2 shows that coal resources strongly predicted steam engine adoption, both relative to employment and relative to other power sources (mostly water wheels). This relationship is robust to — and if anything strengthened by — controlling for hydropower potential of state s (see Section 5.2) and the average firm size (in employment) in industry i and state s.

I estimate the reduced form effect of access to coal on the firm size using the following regression equation:

$$\ln\left(y_{ist}\right) = \alpha_s + \eta_{it} + \sum_{k \in T} \beta_k \left(\ln\left(\text{COAL}_s\right) \times D_{tk}\right) + \boldsymbol{\lambda}' \mathbf{X}_{ist} + \varepsilon_{ist} \tag{18}$$

where the subscripts i, s, and t refer to industry, state, and year, respectively. D_{tk} is a dummy that is 1 if $t = k$ and 0 otherwise and T contains all but one reference census year (1850). y_{ist} is the average firm size (in terms of employment). Standard errors are clustered at the state-level and the regression is weighted by total employment in industry i, state s, and year t. $\mathbf{X}_{ist}$ is a vector of controls: it contains the density of the population in state s at time t, and interactions between time and hydropower potential in state s

FIGURE 6: The reduced-form effects of coal access on the firm size



and "market access" in state s.[33] Controlling for market access ensures that the estimated effect of access to coal does not reflect low-cost access to consumer markets.

Figure 6 shows the estimates and 95% confidence intervals for β_t for each period. I find that firm sizes started to grow in states with high access to coal from 1850 onward relative to other states, consistent with the notion that steam engines increased establishment sizes.

I then study *which* industries are most affected by coal access. If coal access affects firm sizes through steam engine adoption, one would expect to see that its effects are most pronounced in industries that eventually adopt steam engines. To test this hypothesis, I use the industry-crosswalks between 1860 and 1900 described in Section 4.1. Specifically, I run the same regression as in equation (18) for the years between 1860 and 1900, now including state $\times$ industry fixed effects. Furthermore, I estimate this for two groups of industries: "placebo" industries that used little to no steam engines nationally, and "adopting" industries.[34] Figure A.8 shows that the result is driven by the adopting industries and that coal access had neither an economically nor statistically significant effect on the placebo industries.

[33]Market access is computed by county for the year 1830 (before railroads) as in (Donaldson and Hornbeck, 2016) and then averaged to the state-level.

[34]Placebo-industries are in the bottom quartile in terms of steam engine horsepower per employee in 1890 nationally.

TABLE 3: The effect of hydropower potential on purchased electric energy use (1939)

	MwH per employee (1939)			Electricity as share of fuel (1939)		
Hydropower potential	0.659***	0.654***	0.646***	0.020***	0.019***	0.017***
	(0.175)	(0.191)	(0.194)	(0.004)	(0.005)	(0.004)
Coal resources		X	X		X	X
Firm size			X			X
Observations	5029	5029	5029	5008	5008	5008

Standard errors in parentheses are clustered at the state-level. Industry fixed-effects included.
* p< 0.10, ** p< 0.05, *** p< 0.01.

5.2 Small-scale-biased technical change

The methodology to estimate the impact of electric motors on the firm size distribution is analogous to that for steam engines in Section 5.1. The early feasibility of electric motor adoption depended on the price of electricity. The price of electricity, in turn, depended strongly on the "hydropower potential" that an area had to offer. Figure A.6 shows the state-level correlation between hydropower potential and electricity prices ($\rho = -0.56$). I thus use hydropower potential as an instrumental variable for electric motor adoption.[35]

I proceed analogously to Section 5.1. I first estimate the effect of the instrument (hydropower potential) on the adoption of the technology (electric motors). That is, I estimate for the year 1939:

$$\text{ELEC}_{ist} = \delta_i + \theta \ln\left(\text{HYDRO}_s\right) + \boldsymbol{\lambda}'\boldsymbol{X}_{ist} + \epsilon_{ist}.^{36} \tag{19}$$

ELEC_{ist} refer to two measures of electric motor adoption: the total kilowatt hour of purchased electric energy per employee and the cost of purchased electric energy as a share of total fuel costs. $\ln\left(\text{HYDRO}_s\right)$ refers to the logarithm of the hydropower potential of state s. Table 3 shows the results. Hydropower potential caused firms to adopt more electric energy, relative to employment as well as relative to other fuels.

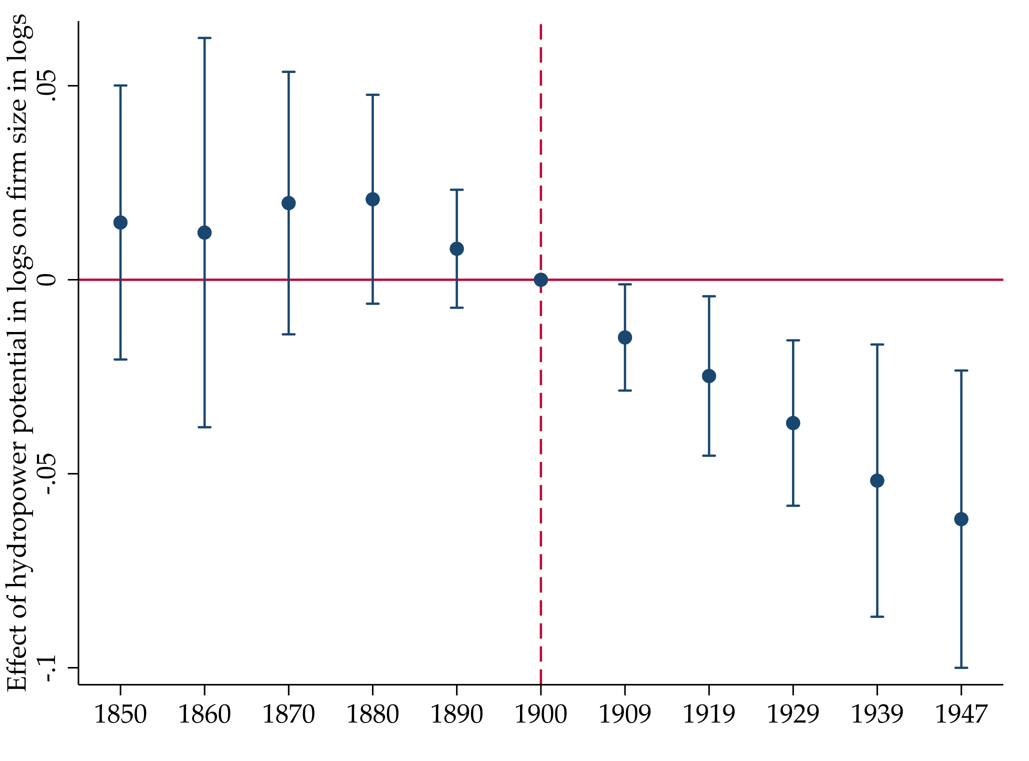
I then estimate the reduced form effect of the exposure to electric motors on the firm size:

$$\ln\left(y_{ist}\right) = \gamma_s + \eta_{it} + \sum_{k \in T} \beta_k \left(\ln\left(\text{HYDRO}_s\right) \times D_{tk}\right) + \boldsymbol{\lambda}'\boldsymbol{X}_{ist} + \varepsilon_{ist}.^{37} \tag{20}$$

Figure 7 shows that exposure to electric motors lowered the average firm size relative to the pre-electric period. Before the adoption of electricity (between 1890 and 1900) there

[35] See e.g., Gaggl et al. (2021); Severnini (2022) for other applications of this instrument.
[36] For simplicity, I chose notation identical to (17). Of course, the parameters in (17) and (19) are different.
[37] For simplicity, I chose notation identical to (18). Of course, the parameters in (18) and (20) are different.

FIGURE 7: The reduced-form effects of hydropower potential on the firm size



is a parallel trend between high- and low-hydropower states. Over the course of the twentieth century, firm sizes start to decrease in high hydropower states relative to other states.

Similar to in Section 5.1, I use crosswalks between the Census of Manufactures industries between 1890 and 1929 to understand which industries drive the effect. I again, split the sample up into placebo industries and adopting industries.[38] Consistent with hydropower potential affecting the firm size only through electric motor adoption, Figure A.8 shows that hydropower potential only affected the firm size in industries that adopted electric motors nationally.

6 The effect of scale-biased technical change on inequality

The previous section's results demonstrated that large-scale-biased technical change concentrates increases establishment sizes, while small-scale-biased technical change does the opposite. In this section, I study the second prediction of the theory: that large-scale-biased technical change increases inequality. To answer this question, I use the newly created dataset on Dutch wealth during the period of steam engine and electric motor adoption. The detail, accuracy, and consistency of the Dutch data provides a unique

[38]Placebo industries are the industries in the bottom quartile in terms of the share of horsepower driven by purchased energy in total horsepower.

opportunity to test the theory's implication on inequality.

6.1 Main analysis

I use the digitized Dutch inheritance tax data to create various measures of local inequality for the period between 1879 and 1927. With this dataset, I first study how wealth inequality evolved across municipalities with varying rates of adoption of steam engines and electric motors. I use wealth inequality, not income inequality as suggested by the theory, for reasons of data availability. Table 1 shows, however, that income and wealth inequality are strongly correlated. Furthermore, in Section 6.3, I also show the effects on income inequality using the more fragmentary data available.

As a measure adoption, I use the share of local manufacturing employment that works in establishments using these technologies. I measure this using the newly digitized 1930 Census of Dutch Companies. Particularly, I divide establishments in three groups: 1) those using prime movers run by energy generated in the plant (steam engines), 2) those only using prime movers run by purchased electricity (electric motors), and 3) those not using any prime movers at all. The measure of local steam engine adoption is the share of workers in the first type of establishments. Similarly, electric motor adoption is measured as the share of workers in the second group of establishments, so that:

$$\text{STEAM}_{1930,m} = \frac{\text{Employment in plants using prime movers run by generated energy in } m}{\text{Total employment in } m} \tag{21}$$

$$\text{ELECTR}_{1930,m} = \frac{\text{Employment in plants using prime movers run by purchased electricity in } m}{\text{Total employment in } m}. \tag{22}$$

The main specifications are as follows:

$$\text{INEQUALITY}_{mt} = \alpha_{1m} + \eta_{1t} + \sum_{k \in T \setminus \{1880\}} \beta_{1k} \left(\text{STEAM}_{1930,m} \times D_{tk}\right) + \varepsilon_{1,mt} \tag{23}$$

$$\text{INEQUALITY}_{mt} = \alpha_{2m} + \eta_{1t} + \sum_{k \in T \setminus \{1880\}} \beta_{2k} \left(\text{ELECTR}_{1930,m} \times D_{tk}\right) + \varepsilon_{2,mt} \tag{24}$$

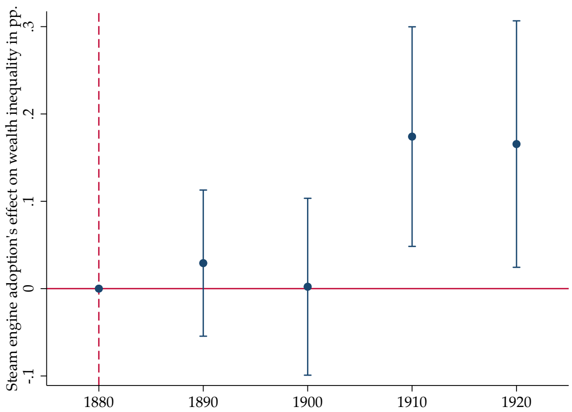
where the subscript $t \in T = \{1880, 1890, 1900, 1910, 1920\}$ refers to the decade, m to the municipality and D_{tk} is a dummy that 1 if $t = k$ and 0 otherwise. INEQUALITY_{mt} is the share of wealth held by the top 1% of decedents with wealth. The coefficients β_{1k} and β_{2k} capture the association between steam engine and electric motor adoption and the change in wealth inequality from 1880, the reference year, to year k.

Figure 8(a) plots the coefficients of β_t for each decade relative to 1880. The coefficient suggest that a 1 percentage point increase in the share of employment exposed to steam engines leads to an increase in the top 1% wealth share of about 0.2 percentage points. This effect is statistically and economically significant. Local steam engine adoption varied strongly: around 10 percent of municipalities adopted no steam engines at all, while in some municipalities more than 90 percent of manufacturing employment was in steam-powered establishments. A one standard deviation increase in steam engine adoption (0.19) increases the top 1% wealth share by around 4 percentage points in 1920. The average top 1% wealth share across municipalities was 21 percent.

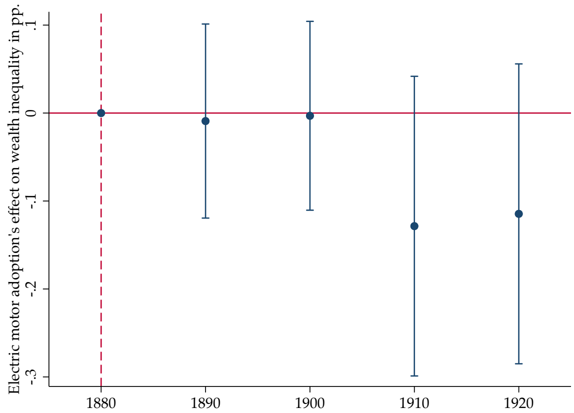
The estimated effects of electric motor adoption on wealth inequality are shown in Figure 8(b). The figure shows that electric motor adoption did not increase wealth inequality. If anything, it decreased it. However, the size of the estimated effect is smaller than for steam engines and not statistically significant on the 95% confidence level.

FIGURE 8: Steam engine adoption increased wealth inequality, electric motors did not

(A) Effect of steam engines



(B) Effect of electric motors



Notes: This figure shows the estimated effects in percentage points of steam engine (in panel A) and electric motor adoption (in panel B) on within-municipality top wealth inequality for each decade relative to 1880. The econometric specifications are detailed in equations (23) and (24). Observations are weighted by the number of individuals on which the inequality measure is based. Bars represent 95% confidence intervals.

The coefficients in Figure 8 reflect the different evolution of wealth inequality in municipalities along one dimension of power usage (steam engine adoption or electric motor adoption). But when electric motor adoption is low, this could be because steam engine adoption was high or because there was little use of power of any sort. To directly compare the effect of steam engine adoption and electric motor adoption, I also estimate equation (23) while controlling for the share of employment in establishments that do not use any power in 1930 (similarly interacted with time dummies).[39] Since $\text{STEAM}_{1930,m}$, $\text{ELEC}_{1930,m}$, and $\text{NOPOWER}_{1930,m}$ sum to one by construction, the coefficient of interest

[39]That is, I estimate:

$$\text{INEQUALITY}_{mt} = \alpha_{3m} + \eta_{3t} + \sum_{k \in T \setminus \{1880\}} \left[\beta_{3k} \left(\text{STEAM}_{1930,m} \times D_{tk}\right) + \gamma_{3k} \left(\text{NOPOWER}_{1930,m} \times D_{tk}\right)\right] + \varepsilon_{3,mt}.$$

in this regression reflects the increase in wealth inequality associated with a 1 percentage point increase in steam engine adoption and a 1 percentage point *decrease* in electric motor adoption. The results are shown in Figure A.9. It shows that holding total power usage constant, when more steam engines were used — and thus less electric motors — wealth inequality increased relative to 1880.

6.2 Instrumental variable analysis

The municipality-fixed effects specifications in equations (23) and (24) control for any time-invariant unobserved heterogeneity across municipalities. Time-varying heterogeneity is a potential remaining threat to causal interpretation of the coefficients in Figure 8. For instance, it is a priori conceivable that changes in local inequality between 1880 and 1920 also affected technology adoption, leading to reverse causality. To assess the quantitative importance of such threats to identification, I employ an instrumental variable strategy.

The identification strategy uses that the local industry composition in manufacturing in 1816 (see Section 4.2.3 for details on the data) is predictive of the local adoption rates of steam engines and electric motors. I assign 2-digit ISIC industry codes to each industry in the manufacturing data in 1930 and 1816. Then, using the 1930 data, I compute industry i's adoption of steam engines and electric motor adoption. The adoption rates are computed analogously to $\text{STEAM}_{1930,m}$ and $\text{ELECTR}_{1930,m}$ in equations (21) and (22), only changing the unit of analysis from municipality m to industry i.

Table B.1 shows the adoption rates for each manufacturing industry. The textile industry, together with the much smaller beverage industry, was the largest adopter of steam engines, with half of employment in establishments using steam. On the other hand, the leather, apparel, tobacco, and printing industries almost did not use any steam engines at all. Using these adoption rates in 1930, I then compute the exposure to steam engines and electric motors in municipality m in 1816 as:

$$\text{STEAM\_EXP}_{1816,m} = \sum_{i \in I} \frac{\text{Employment in industry } i \text{ in } m \text{ in } 1816}{\text{Total employment in } m \text{ in } 1816} \times \text{STEAM}_{1930,i} \tag{25}$$

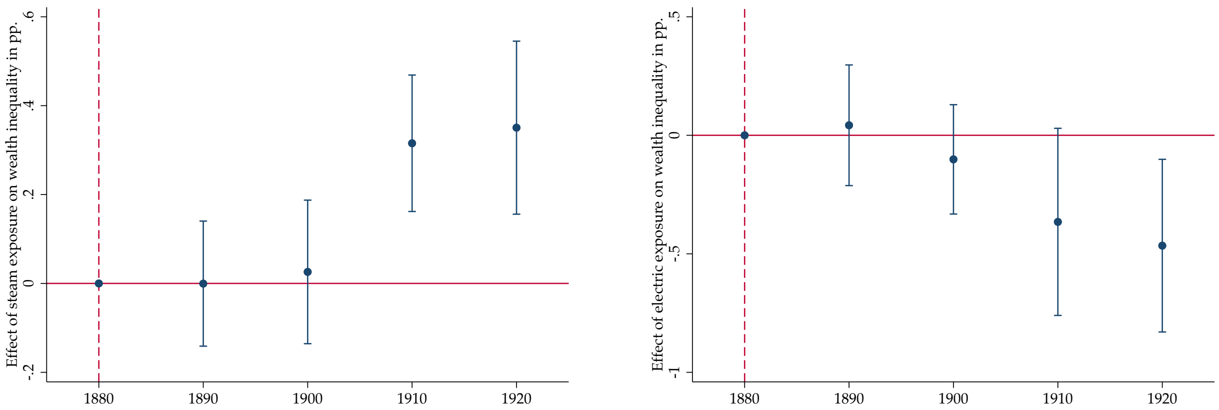
$$\text{ELECTR\_EXP}_{1816,m} = \sum_{i \in I} \frac{\text{Employment in industry } i \text{ in } m \text{ in } 1816}{\text{Total employment in } m \text{ in } 1816} \times \text{ELECTR}_{1930,i}. \tag{26}$$

The exposure measure is a strong predictor of actual adoption in 1930 (see Table B.2 for the correlation).

I estimate the "reduced form" of the instrumental variable analysis equivalently to equations (23) and (24) except that the actual adoption rates are changed for the predicted rates in equations (25) and (26). That is, I estimate how wealth inequality evolved between 1880 and 1927 across municipalities that were more or less exposed to the two technologies.

FIGURE 9: Steam engine adoption increased wealth inequality, electric motors did not

(A) Effect of steam engines (B) Effect of electric motors



Notes: This figure shows the estimated effects in percentage points of pre-industrial exposure to steam engine (in panel A) and electric motor adoption (in panel B) on within-municipality top wealth inequality for each decade relative to 1880. The instrumental variable is exposure to the respective technology which is computed on the basis of the local industry composition in 1816 and adoption rates by industry in 1930. Observations are weighted by the number of individuals on which the inequality measure is based. Bars represent 95% confidence intervals.

Figure 9 shows that places more exposed to steam engines became more unequal, while places more exposed to electric motors became more equal, providing further evidence that steam engines and electric motors had a causal effect on inequality as predicted by the theory.

6.3 Further evidence using income data

The model of scale-biased technical change proposed in this paper relates technical change to income inequality. Since wealth inequality is strongly correlated with income inequality (see Table 1) and consistent time-series data is only available for local wealth inequality, I used wealth inequality for the main analysis. Here, I assess the robustness of the results to studying income inequality instead with the more limited data on the income distribution that is available.

As described in Section 4.2.1, I uncovered and digitized data on the income distribution in 1883 for 87 (mostly large) municipalities. Also, for 1946 income distributions are available for each municipality (see Section 4.2.2 for details). From there, I compute the percentage point change in income inequality (as measured by the income share of the top percentile) between 1946 and 1883 as

$$\Delta \text{INC\_INEQUALITY}_{1946,1883} = \text{INC\_INEQUALITY}_{1946} - \text{INC\_INEQUALITY}_{1883}$$

I then regress the growth in income inequality on $\text{STEAM}_{1930,m}$ and $\text{ELECTR}_{1930,m}$ defined in equations (21) and (22). I do this using ordinary least squares as well as using the respective instrumental variables defined in Section 6.2.

TABLE 4: The effect of steam engine and electric motor adoption on the change in income inequality (1946 - 1883)

	$\Delta \text{INC\_INEQUALITY}_{1946,1883}$			
	OLS		IV	
$\text{STEAM}_{1930,m}$	0.118^{**}		0.353^{***}	
	(0.052)		(0.120)	
$\text{ELECTR}_{1930,m}$		-0.072		-0.876^{*}
		(0.062)		(0.458)
Observations	82	82	78	78
C-D Wald F-stat			24.549	4.895

Notes: Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. This table shows the estimated effects of steam engine and electric motor adoption on the change of within-municipality top income inequality between 1946 and 1883. Exposure is computed on the basis of the local industry composition in 1816 and adoption rates by industry in 1930. Observations are weighted by the number of individuals on which the inequality measure in 1946 is based.

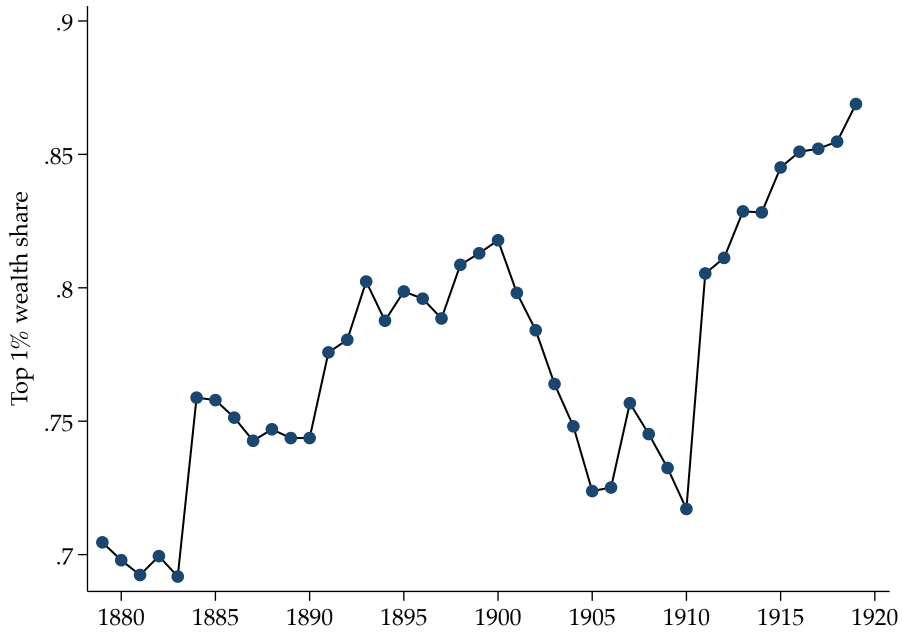
Table 4 shows the results. It verifies the results obtained using wealth inequality as the dependent variable: steam engine adoption increased inequality and electric motors had a marginal negative effect.

7 Scale or skill?

Section 6 showed that steam engine adoption led to increased inequality, while electric motor adoption did not. The last question is then: how did steam engines increase inequality? The third prediction of the theory is that steam engines increase inequality by increasing the gap between the top entrepreneurs and the rest of the population. In this section, I zoom in to Enschede — the major Dutch textile city — to understand *who* was driving the rise in inequality. The findings corroborate the theory: the increased inequality was predominantly due to the textile factory owners amassing wealth at a much higher rate than other households.

I selected Enschede for this case study because, being a major textile producer, it heavily depended on steam engines and witnessed a strong increase in wealth inequality. Figure 10 charts the wealth share of the top 1% over time. Another advantage of studying Enschede is that the history of its textile industry is well documented and the identities of the factory owners are known.

FIGURE 10: Top 1% wealth share in Enschede, Netherlands



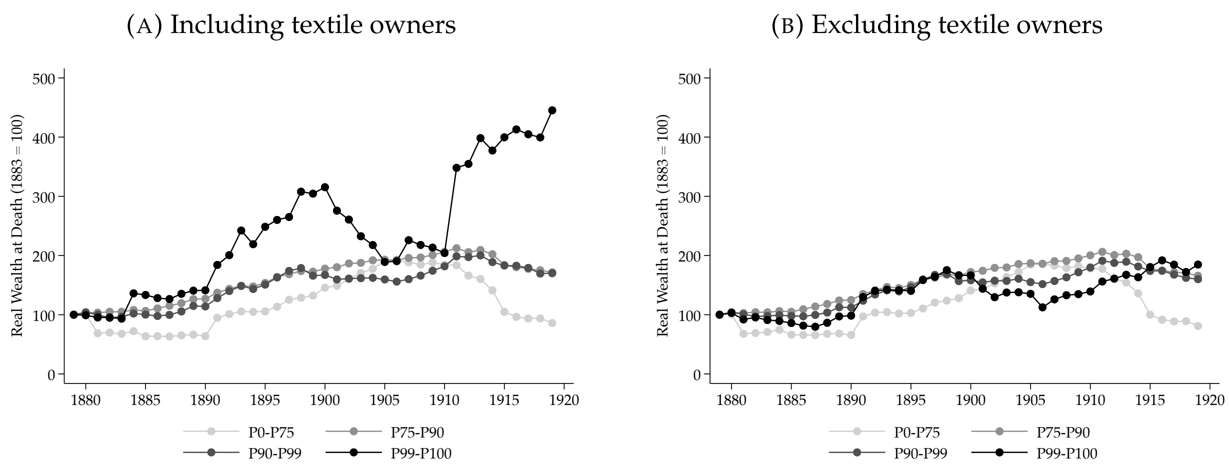
Notes: This figure shows the share of wealth held by the top 1% of decedents aged 20 and over in Enschede between 1879 and 1919. For each year, wealth inequality is computed from the sample of decedents in a 10-year window around it.

The textile industry's roots in Twente, surrounding Enschede, trace back to the 16th century. Flemish entrepreneurs, attracted by Twente's strategic location between Amsterdam and North Germany, had their linen woven there (Schot et al., 2003). By 1750, textiles employed 40

The foundations of the textile industry in Twente, the region around Enschede, already had been laid in the 16th century. At the time, many Flemish entrepreneurs had their linen woven in Twente, due to its attractive position between Amsterdam and North Germany (Schot et al., 2003). In 1728, Enschede had acquired the right to produce *bombazijn*, a textile woven from a combination of linen and cotton threads, and it became the largest producer of this textile halfway into the 18th century (Stroink, 1962). By 1750, 40% of the labor force was occupied in the textile industry. Since textile manufacturing was the industry most exposed to steam engines (see Table B.1), Enschede's rate of steam engine adoption was among the highest in the country.

The theory predicts that large-scale-biased technical change impacts inequality through the profits accrued by entrepreneurs. Therefore, one should expect the see that wealth inequality is driven mostly by them too. To test this prediction, I compute the average wealth at different parts of the wealth distribution separately on a sample including and excluding textile owners. Specifically, I exclude people from the sample if they belong to a family of textile owners. I use the last name as a proxy for being a (spouse of a) factory owner and I exclude people that have one of eight last names.[40]

FIGURE 11: Wealth inequality is driven by entrepreneurs adopting steam engines



Notes: This figure shows the evolution of the top 1 percent wealth share in Enschede when this measure is estimated on the full population (in panel A) and when measured on the sample excluding textile owners (in panel B). For each year, wealth inequality is computed from the sample of decedents in a 10-year window around it.

Figure 11(A) shows the mean wealth at death for different percentile groups. It illustrates that wealth inequality increased through a divergence of the top 1 percent from the rest of the distribution. However, panel (B) indicates that wealth inequality among everyone except the textile families Figure 11(B) did not go up. These pattern indicate the importance of studying inequality in the overall population, not only among wage earners. If technical change is scale-biased, it will most strongly affect the income of top business owners relative to the rest of the distribution.

8 Conclusion

In this paper, I highlight a new channel through which technical change can affect inequality: scale bias. I large-scale-biased technical change as technical change that it increases the relative productivity of large firms. I show that technical change can be large-scale-biased if it increases fixed costs sufficiently. Only large firms would opt to incur the fixed cost to reduce marginal cost, while smaller firms keep using the existing technology or even go out of business. As a result, profits accrue to a smaller set of firms. With fewer

[40]The last names are: Blijdenstein, Cromhoff, Jannink, Gelderman, Heek, Ledeboer, Kuile, and Scholten.

and larger firms, top entrepreneurs are capturing a larger share of the profits, pushing top income inequality up.

I showed that the adoption of steam engines and electric motors offer a unique opportunity to test the theory: the fixed cost of the technologies varied strongly, while the technologies are otherwise similar, the fixed costs of steam engines were an order of magnitude larger. I then tested the theoretical predictions on the effects of steam engine adoption (large-scale-biased) and electric motor adoption (small-scale-biased). I found that the effects of these technologies were in line with the theory's prediction: steam engines increased firm sizes and inequality while electric motors reduced it.

While this research shows that entrepreneurs and their incomes are key for shaping and understanding inequality, existing work primarily focuses on the impact of technical change on wage inequality, not overall income inequality.[41] The effect of technical change on the distribution of business income and inequality between workers and entrepreneurs has, to the best of my knowledge, so far not been studied. This is an important omission, because most "rich" people are entrepreneurs. In the US, 81 percent of individuals in the top 1 percent of the wealth distribution was a business owner or self-employed (Cagetti and De Nardi, 2006). Similarly, more than half of total income for the top 0.1 percentile is business income (Smith et al., 2019).

Trends in roughly the last three decades are consistent with the presence of on-going scale-biased technical change. All three theoretical implications of large-scale-biased technical change are observed in the data. First, firm sizes and concentration are increasing and entrepreneurship is in decline (Autor et al., 2017, 2020; Salgado, 2020; Jiang and Sohail, 2023; Kwon et al., 2023). A large and growing theoretical literature relates these patterns to technical change, specifically the growing importance of scale advantages arising from intangible capital and information technology (Aghion et al., 2019; De Ridder, 2019; Lashkari et al., 2021; Hsieh and Rossi-Hansberg, 2023; Kwon et al., 2023). Second, top income and wealth inequality has increased sharply. For example, between 1980 and 2014, the United States experienced 21% growth in the incomes of the bottom half of the distribution, while the top 10 percent saw their incomes more than double during the same period (Piketty et al., 2018). Third, since the 1990s, business income —not wage income—accounts for the largest part of the rise of top incomes in the United States (Smith et al., 2019, Figure IX). This paper provides a unified framework to understand all these trends.

The quantitative importance of scale bias for inequality depends on the concentration of business ownership. If households hold a perfectly diversified portfolio of firms, the

[41] As a notable exception, Moll et al. (2022) recently expanded the scope beyond wage inequality by studying automation's effect on income (and wealth) derived from both wages and capital: by raising the returns to capital, automation increases income and wealth inequality.

distribution of profits across firms does not determine the distribution of income. The model assumes the other extreme: that a household can only own one firm. In practice, business ownership tends to be strong even today. In the US, "pass-through" businesses account for 51 percent of all business income in 2013 (Nelson, 2016).[42] The typical such business is owned by one to three people (Smith et al., 2019) and 69% of its income accrues to the top 1% (Cooper et al., 2016). The great bulk of the remaining income earned by "C-corporations", businesses who are taxed at the entity level, is earned by a small share of publicly traded firms (Clarke and Kopczuk, 2017). While ownership of publicly traded firms is less concentrated, it is not as diffuse as commonly thought.[43] Even for firms in the Fortune 500, the 500 largest US firms by revenue, founding families alone accounted for 18 percent of outstanding equity between 1992 and 1999 (Anderson and Reeb, 2003). This empirical reality means that the firm size distribution — and the effect technical change has on scale — will likely continue to play an important role in shaping inequality in the future.

[42] Pass-through businesses are businesses that are not subject to corporate tax and whose income instead "pass through" to their owners to be taxed under individual income tax. Specifically, they comprise S-corporations, sole proprietorships, and partnerships.

[43] For instance, among a random sample of US publicly traded firms, 96 percent had shareholders that own at least 5% of the stock, and in 53 percent of firms, the largest shareholder is a family (Holderness, 2009).

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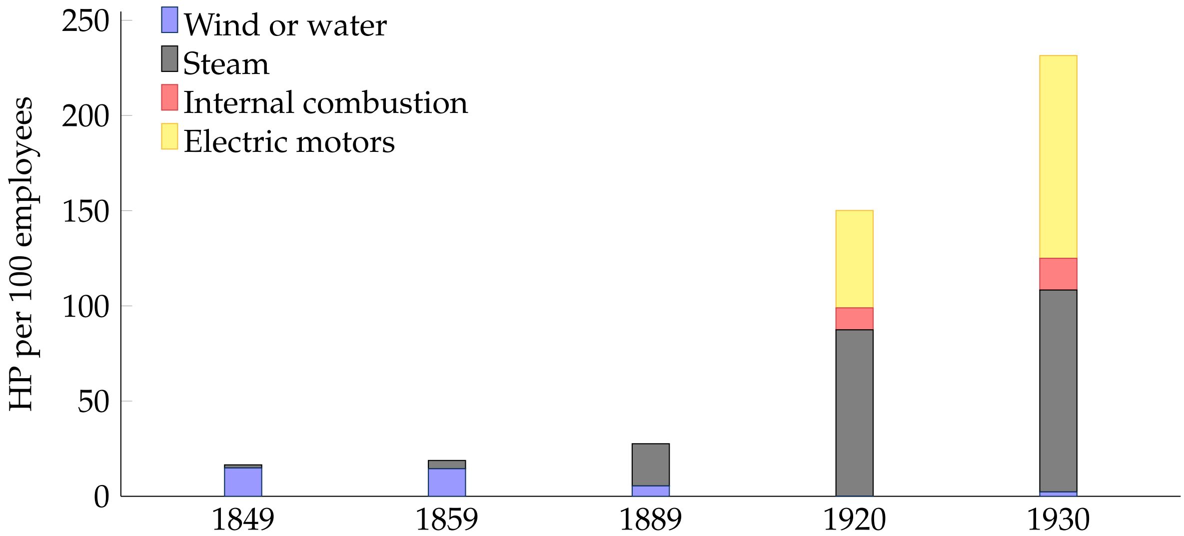
Appendix

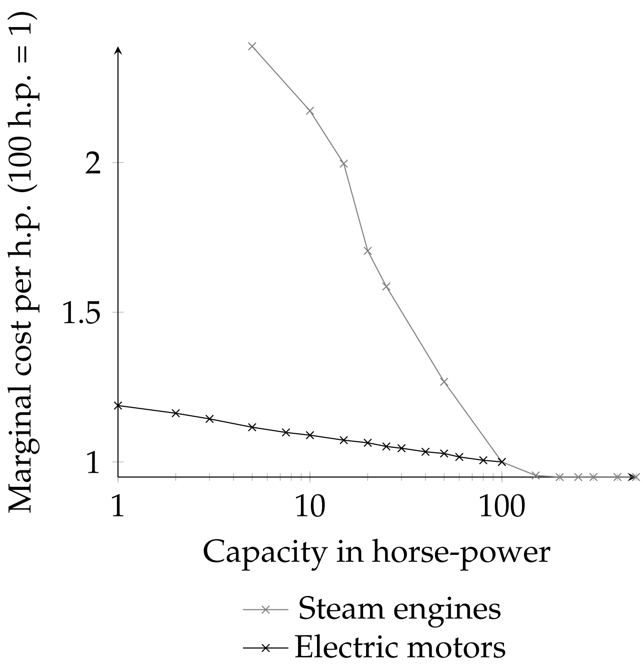
A Figures

FIGURE A.1: Capacity of primary power by type in horsepower per 100 employees in manufacturing in the Netherlands



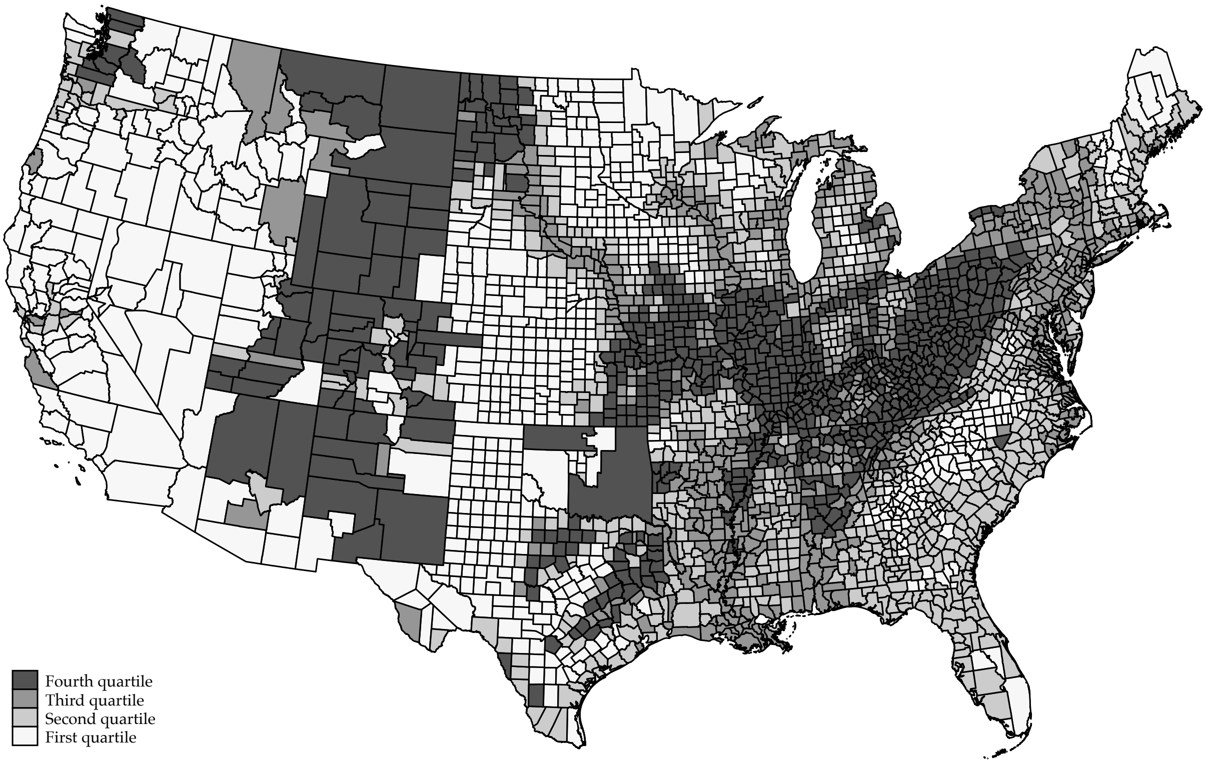
Notes: Electric motors refer to primary electric motors, i.e., electric motors driven by purchased electricity, only. *Sources*: (Blanken and Lintsen, 1981, Table 8) for primary power by type, (Statistics Netherlands, 2001) for employment in manufacturing.

FIGURE A.2: Marginal cost of steam engines and electric motors of different capacities relative to its 100-horse power equivalent



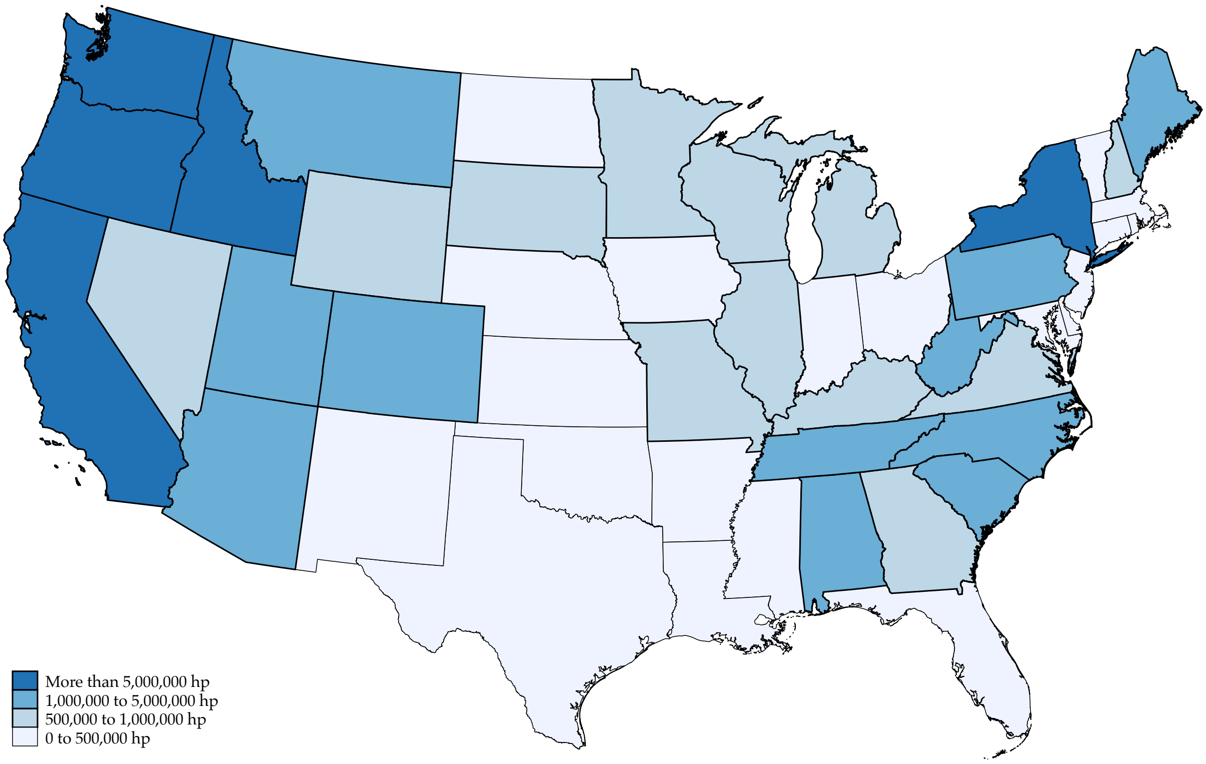
Sources: (Emery, 1883) for coal per horse-power in steam engines; (Bolton, 1926) for full load efficiency of squirrel-cage induction motor.

FIGURE A.3: Coal access by county



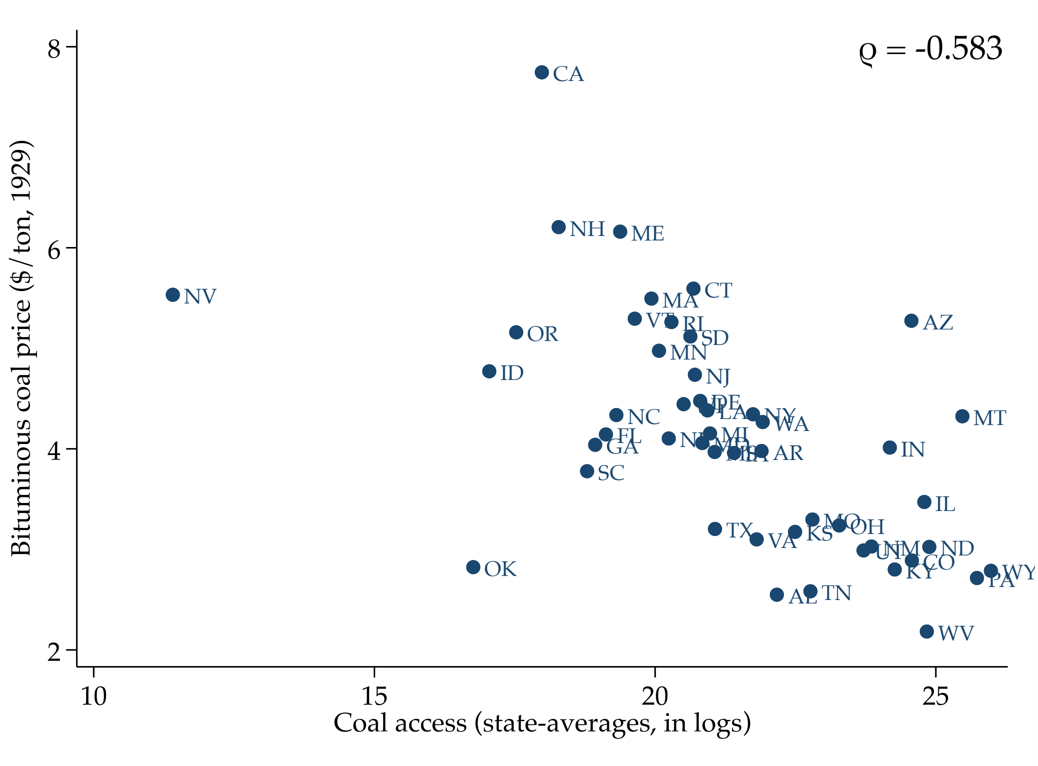
Notes: Coal access is defined in equation (16). *Sources:* US Geological Survey, Coal Resources Data System for the coal resources by county. Donaldson and Hornbeck (2016) for transportation costs by county-pair.

FIGURE A.4: Potential waterpower in horsepower available 50 percent of the time



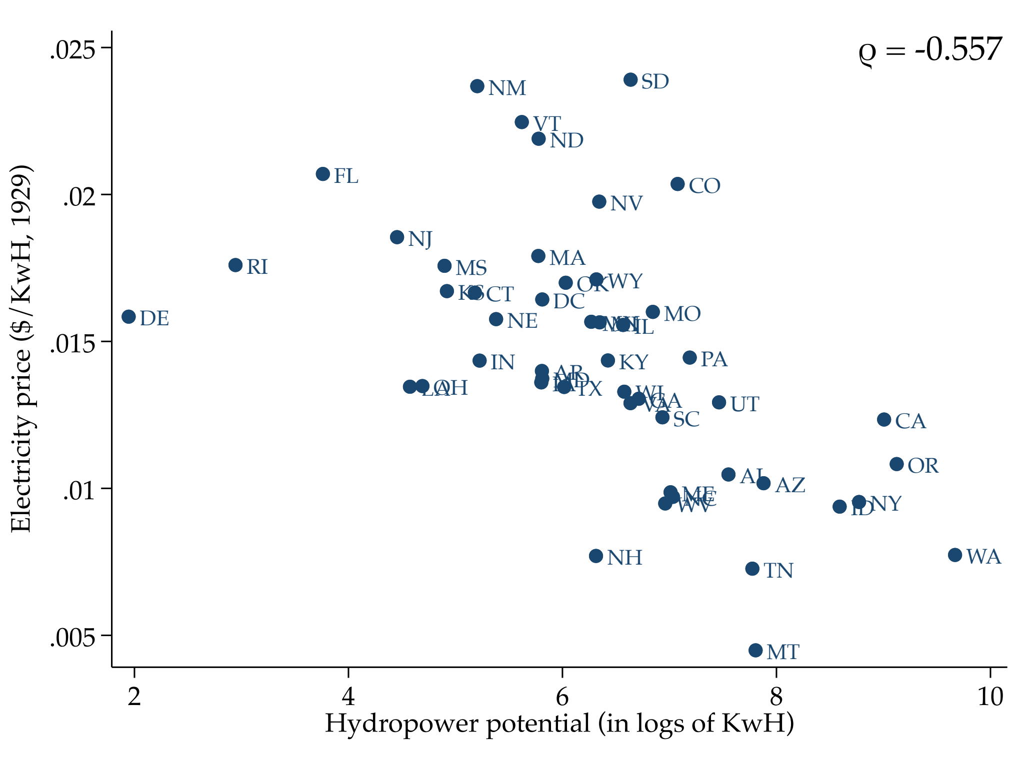
Source: US Geological Survey, (Young, 1964, Table 10).

FIGURE A.5: Correlation between coal access and coal prices



Source: US Geological Survey, (Young, 1964, Table 10).

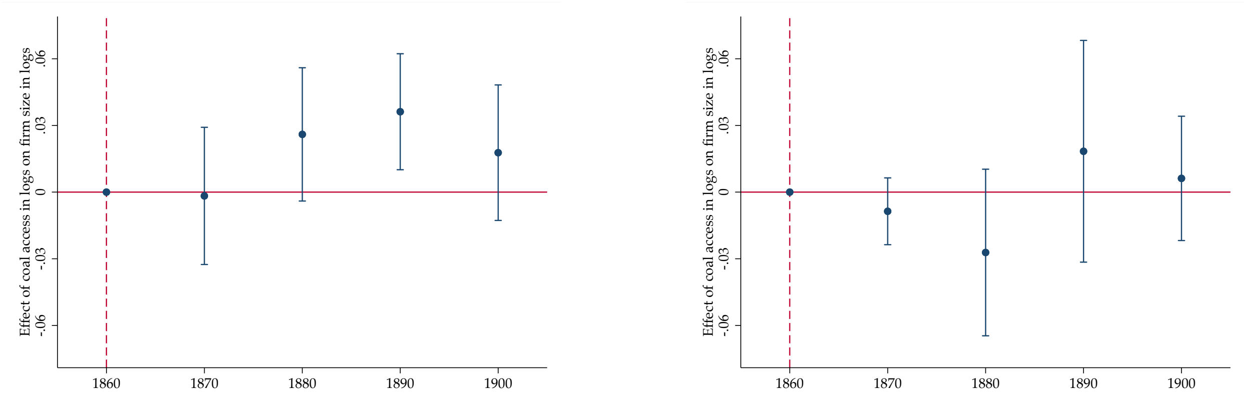
FIGURE A.6: Correlation between hydropower potential and electricity prices



Sources: US Geological Survey, (Young, 1964, Table 10) for hydropower potential and Census of Manufactures 1929 for electricity prices.

FIGURE A.7: Heterogeneous effects of coal access across industries

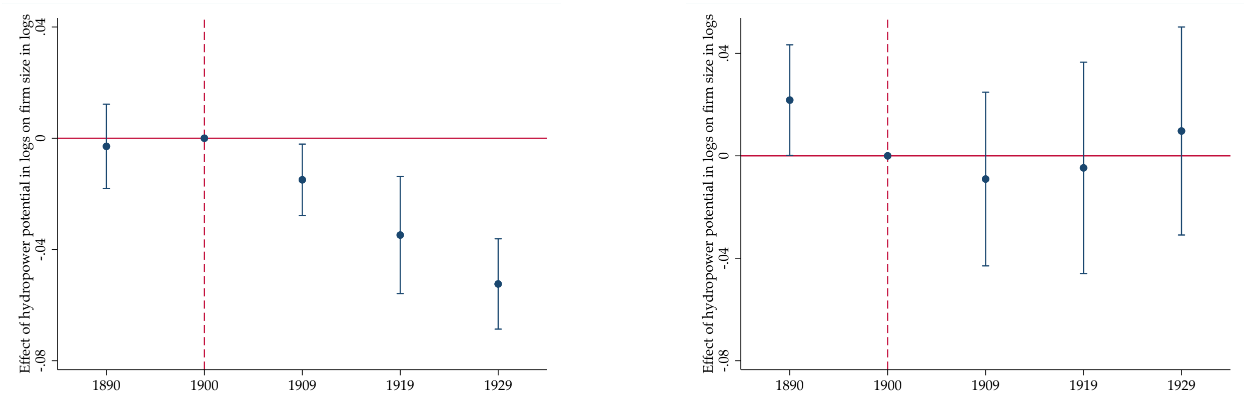
(A) Adopting industries (B) Placebo industries



Notes: Bars represent 95% confidence intervals. Standard errors are clustered at the state-level.

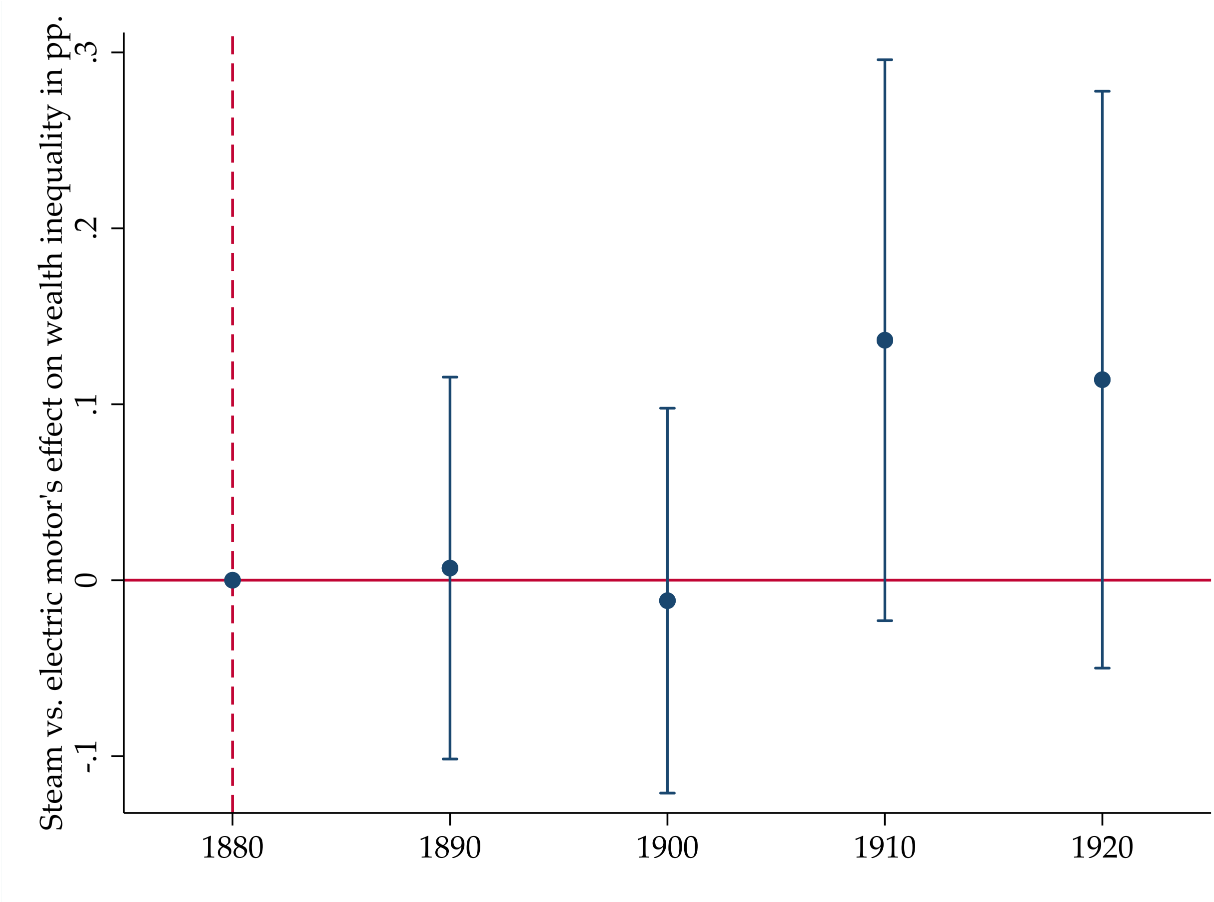
FIGURE A.8: Heterogeneous effects of hydropower potential across industries

(A) Adopting industries (B) Placebo industries



Notes: Bars represent 95% confidence intervals. Standard errors are clustered at the state-level.

FIGURE A.9: Steam engine adoption relative to electric motor adoption increased wealth inequality.



Notes: This figure shows the estimated effects in percentage points of steam engine adoption on within-municipality top wealth inequality for each decade relative to 1880 relative to electric motor adoption. Observations are weighted by the number of individuals on which the inequality measure is based. Bars represent 95% confidence intervals.

B Tables

TABLE B.1: Adoption rates by 2-digit ISIC industry in 1930

ISIC	Name	$STEAM_{1930,i}$	$ELEC_{1930,i}$	Employment
11	Beverages	0.50	0.44	4374
13	Textiles	0.50	0.47	44750
19	Coke and petroleum	0.47	0.42	1129
17	Paper and paper products	0.40	0.57	11000
24	Basic metals	0.35	0.64	6305
23	Other non-metallic mineral products	0.33	0.56	22733
20	Chemicals and chemical products	0.32	0.64	11558
21	Pharmaceuticals	0.29	0.64	1126
22	Rubber and plastics products	0.27	0.71	2540
16	Wood and wood products	0.25	0.40	19081
10	Food products	0.24	0.62	103220
28	Machinery and equipment n.e.c.	0.16	0.82	5313
27	Electrical equipment	0.16	0.84	22380
33	Repair and installation of machinery	0.08	0.89	7030
30	Other transport equipment	0.07	0.87	18723
25	Fabricated metal products	0.07	0.80	34951
15	Leather and related products	0.04	0.40	26855
18	Printing	0.03	0.92	31740
31	Furniture	0.03	0.68	12820
32	Other manufacturing	0.01	0.63	7163
26	Computer and electronic products	0.01	0.32	3748
12	Tobacco products	0.01	0.65	21160
14	Wearing apparel	0.00	0.37	53939

Source: Dutch Census of Companies 1930.

TABLE B.2: First stage: pre-industrial exposure and technology adoption

	$STEAM_{1930,m}$	$ELECTR_{1930,m}$
$STEAM\_EXP_{1816,m}$	0.535***	
	(0.061)	
$ELECTR\_EXP_{1816,m}$		0.497***
		(0.088)
Constant	0.043*	0.254***
	(0.023)	(0.046)
Observations	835	835

Standard errors in parentheses. Observations are weighted by total manufacturing employment in 1930.
* p< 0.10, ** p< 0.05, *** p< 0.01.

C Proofs

Proof of Proposition 1. I prove Proposition 1 by proving its elements (a) to (c) sequentially.
Proposition 1(a): Recall that optimal technology adoption implies that the profit gain of adopting a higher fixed, lower marginal, cost relative to a lower fixed, higher marginal cost technology is increasing in productivity ψ. Formally, $\Delta\pi_{jk}(\psi)$ (defined in equation (6)) is strictly increasing in ψ if $\kappa_j > \kappa_k$ and $\alpha_j < \alpha_k$. This implies that the least productive entrepreneur uses technology with the highest marginal and lowest fixed cost of all adopted technologies. Also, the least productive entrepreneur has productivity ψ equal to the lowest zero-profit cut-off of all available technologies, $\min_{j\in 1,2,..,J} \bar{\psi}_j$. From equation (8), technology t_j is the lowest zero-profit cut-off technology if and only if

$$\alpha_j \kappa_j^{\frac{1}{\sigma-1}} = \min_{k\in\{1,2,..,J\}} \left\{ \alpha_k \kappa_k^{\frac{1}{\sigma-1}} \right\}.$$

The marginal entrepreneur is indifferent between any two technologies t_j and t_k such that $\bar{\psi}_j = \bar{\psi}_k = \bar{\psi}$ as they both give them zero-profit. But since $\Delta\pi_{jk}(\psi)$ in (6) is strictly increasing, any entrepreneur with $\psi > \bar{\psi}$ would strictly prefer the technology with higher fixed cost and lower marginal cost. Therefore, out of any technology t_j that minimizes $\bar{\psi}_j$, only the technology with lowest marginal cost is adopted (in the sense of having a strictly positive probability measure of entrepreneurs adopting the technology).
Proposition 1(b): Note that $\Delta\pi_{jk}(\psi) \to \infty$ in (6) as $\psi \to \infty$ if and only if $\alpha_j < \alpha_k$. This means that if the marginal cost of a technology is lower than that of any another, there exists a productivity level high enough such that it is profitable to adopt this technology. The assumption that the productivity distribution has semi-infinite support implies that for any $C > 0$, $\Pr(\psi > C) > 0$. Therefore, there always exists a strictly positive share of households that adopt the technology with lowest marginal cost. Note that is true regardless of the fixed cost. Of course, in case there is more than one technology that minimizes marginal cost, the technology with lowest fixed costs amongst those will be adopted. Since no technology can be adopted that is trivially dominated, this must also be the adopted technology with highest fixed cost.
Proposition 1(c): A technology t_j with fixed cost κ_j such that $\kappa_1^* < \kappa_j < \kappa_{J^*}^*$ is adopted if and only if there exists a $\psi > \psi_m$ for which it 1) dominates all technologies with lower fixed costs, 2) dominates all technologies with higher fixed cost, and 3) yields positive profits. Note that condition is 3) is redundant given condition 1) since it can only dominate technology t_1^* if $\psi > \bar{\psi}$ and t_1^* yields positive profits for all $\psi > \bar{\psi}$. Also, recall that technologies in T are arranged in order of increasing fixed costs ($\kappa_1 < .. < \kappa_J$) and thus decreasing marginal costs ($\alpha_1 > .. > \alpha_J$). Therefore, technology t_j is adopted if there exists a $\psi > \psi_m$ such that $\Delta\pi_{jk}(\psi) > 0$ for all $k \in \{1, .., j-1\}$ and $\Delta\pi_{jl}(\psi) > 0$ for all

$l \in \{j+1, .., J\}$. Using equation (6), this yields the following two restrictions:

$$\frac{Y}{\sigma}(\rho\psi)^{\sigma-1} > \frac{\kappa_j - \kappa_k}{\alpha_j^{1-\sigma} - \alpha_k^{1-\sigma}} \text{ for all } k \in \{1, .., j-1\} \text{ and;} \tag{27a}$$

$$\frac{Y}{\sigma}(\rho\psi)^{\sigma-1} < \frac{\kappa_l - \kappa_j}{\alpha_l^{1-\sigma} - \alpha_j^{1-\sigma}} \text{ for all } l \in \{j+1, .., J\} \tag{27b}$$

Hence, for (27a) and (27b) to hold for some $\psi > \bar{\psi}$, it is necessary and sufficient that the lower bound in (27a) is strictly lower than the upper bound in (27b). Thus, technology j is adopted if and only if for all $k \in \{1, .., j-1\}$ and $l \in \{j+1, .., J\}$

$$\frac{\alpha_l^{1-\sigma} - \alpha_j^{1-\sigma}}{\alpha_j^{1-\sigma} - \alpha_k^{1-\sigma}} < \frac{\kappa_l - \kappa_j}{\kappa_j - \kappa_k}.$$

□

Proposition 2 (Closed-form equilibrium). Suppose that the distribution of productivity ψ is Pareto with shape parameter ξ and a minimum productivity level of $\psi_m > 0$ such that $\xi > 1$ and $\xi > \sigma - 1$. Then, the competitive equilibrium is given in closed-form by

$$L = \frac{\xi}{1+\xi} \tag{28}$$

$$\bar{\psi} = \bar{B}(\xi, \sigma, \psi_m)\left(\bar{\kappa}^{\frac{\sigma-2}{\sigma-1}} \alpha_1^* (\kappa_1^*)^{\frac{1}{\sigma-1}}\right)^{\frac{\sigma-1}{\bar{A}(\xi,\sigma)}} \tag{29}$$

$$Y = \bar{C}(\xi, \sigma, \psi_m)\left(\frac{\bar{\kappa}^{\frac{1}{\xi}}}{\alpha_1^* (\kappa_1^*)^{\frac{1}{\sigma-1}}}\right)^{\frac{\xi(\sigma-1)}{\bar{A}(\xi,\sigma)}} \tag{30}$$

$$w = \rho\frac{1+\xi}{\xi}Y \tag{31}$$

$$\bar{\pi} = \rho\frac{1+\xi}{\xi}\bar{C}(\xi, \sigma, \psi_m)\bar{B}(\xi, \sigma, \psi_m)^{\xi}\psi_m^{-\xi}\bar{\kappa} \tag{32}$$

where $\bar{A}(\xi, \sigma)$, $\bar{B}(\xi, \sigma, \psi_m)$, and $\bar{C}(\xi, \sigma, \psi_m)$ are strictly positive functions of the exogenous (non-technological) parameters ξ, σ, and ψ_m:

$$\bar{A}(\xi, \sigma) \equiv (1+\xi)(\sigma-1) - \xi$$

$$\bar{B}(\xi, \sigma, \psi_m) \equiv \left(\psi_m^{\xi}(1+\xi)^{\frac{1}{\sigma-1}} \frac{\sigma}{\xi - \sigma + 1}\left(\frac{\xi\psi_m^{\xi}}{\xi - \sigma + 1}\right)^{\frac{1}{1-\sigma}}\right)^{\frac{\sigma-1}{\bar{A}(\xi,\sigma)}}$$

$$\bar{C}(\xi, \sigma, \psi_m) \equiv \bar{B}(\xi, \sigma, \psi_m)^{\frac{-\xi(\sigma-1)}{\bar{A}(\xi,\sigma)}} \frac{\psi_m^{\xi}\sigma}{\xi - \sigma + 1}\frac{\xi}{1+\xi}$$

and $\bar{\kappa}$ is the average fixed cost of all producing entrepreneurs:

$$\bar{\kappa} = \begin{cases} \kappa_1^* & \text{if } J^* = 1 \\ \kappa_1^* + \left(\alpha_1^* \left(\kappa_1^*\right)^{\frac{1}{\sigma-1}}\right)^{\xi} \sum_{j=2}^{J^*} \left(\left(\alpha_j^*\right)^{1-\sigma} - \left(\alpha_{j-1}^*\right)^{1-\sigma}\right)^{\frac{\xi}{\sigma-1}} \left(\kappa_j^* - \kappa_{j-1}^*\right)^{\frac{\sigma-1-\xi}{\sigma-1}} & \text{if } J^* > 1. \end{cases}$$

Proof of Proposition 2. We first derive the adopting set Ψ_j^* for each technology $t_j^* \in T^*$. Note that we can restrict ourselves to technologies that are adopted in equilibrium (see Proposition 1), since the adopting set is empty otherwise.

By definition, if T^* is a singleton set, then Ψ_1^* is $[\bar{\psi}, \infty)$. Now suppose $J^* \equiv |T^*| > 1$. From equation (6), it follows that an entrepreneur with productivity ψ is indifferent between adopting t_j^* and t_{j+1}^* if and only if $G(\psi, t_{j+1}^*, t_j^*) = 0$. Define $\bar{\psi}_{j,j+1}$ implicitly by

$$G(\psi, t_{j+1}^*, t_j^*) = 0$$

which implies that

$$\bar{\psi}_{j,j+1} = \left(\frac{\kappa_{j+1}^* - \kappa_j^*}{\left(\alpha_{j+1}^*\right)^{1-\sigma} - \left(\alpha_j^*\right)^{1-\sigma}}\right)^{\frac{1}{\sigma-1}} \left(\frac{\sigma}{Y}\right)^{\frac{1}{\sigma-1}} \frac{w}{\rho} = \bar{\psi} \frac{\left(\frac{\kappa_{j+1}^* - \kappa_j^*}{\left(\alpha_{j+1}^*\right)^{1-\sigma} - \left(\alpha_j^*\right)^{1-\sigma}}\right)^{\frac{1}{\sigma-1}}}{\alpha_j^* \left(\kappa_j^*\right)^{\frac{1}{\sigma-1}}}. \tag{33}$$

Since $G(\psi, t_{j+1}^*, t_j^*)$ is increasing in ψ (see proof of Proposition 1(a)), the more productive entrepreneur chooses the technology that entails higher fixed cost. Specifically, an entrepreneur would choose t_{j+1}^* over t_j^* if and only if $\psi > \bar{\psi}_{j,j+1}$. This means that all entrepreneurs with productivity between $\bar{\psi}$ and $\bar{\psi}_{1,2}$ choose t_1^*, all entrepreneurs with productivity between $\bar{\psi}_{1,2}$ and $\bar{\psi}_{2,3}$ choose t_2^*, and so on and so forth. Formally,

$$\begin{cases} \Psi_j^* = [\bar{\psi}, \bar{\psi}_{j,j+1}] & \text{if } j = 1 \\ \Psi_j^* = [\bar{\psi}_{j-1,j}, \bar{\psi}_{j,j+1}] & \text{if } 1 < j < J^* \\ \Psi_j^* = [\bar{\psi}_{j-1,j}, \infty) & \text{if } j = J^* \end{cases}$$

Combining equation (8) (definition of $\bar{\psi}$) and equation (11) (labor market clearing) with the Pareto assumption, the probability of being an entrepreneur conditional on entry is

$$1 - F(\bar{\psi}) = \psi_m^{\xi} \bar{\psi}^{-\xi} = \frac{L}{1-L} \frac{\xi - \sigma + 1}{\xi(\sigma - 1)} \frac{w}{\bar{\kappa}} \tag{34}$$

where $\bar{\kappa}$, the average fixed cost across producing entrepreneurs, is

$$\bar{\kappa} = \kappa_1 + \left(\alpha_1^* \left(\kappa_1^*\right)^{\frac{1}{\sigma-1}}\right)^{\xi} \sum_{j=2}^{J^*} \left(\left(\alpha_j^*\right)^{1-\sigma} - \left(\alpha_{j-1}^*\right)^{1-\sigma}\right)^{\frac{\xi}{\sigma-1}} \left(\kappa_j^* - \kappa_{j-1}^*\right)^{\frac{\sigma-1-\xi}{\sigma-1}}.$$

Also, labor market clearing in (11) combined with the aggregate price equation in (13), implies that the labor share is constant and independent of technology:

$$\frac{Lw}{Y} = \rho. \tag{35}$$

Combining the constant labor share with equation (34), shows that the share of output devoted to the fixed costs is constant and independent of technology:

$$\frac{(1-L)\psi_m^{\xi}\bar{\psi}^{-\xi}\bar{\kappa}}{Y} = \frac{\xi-\sigma+1}{\xi\sigma}. \tag{36}$$

Then, by goods market clearing, the profit share must be

$$\frac{(1-L)\psi_m^{\xi}\bar{\psi}^{-\xi}\bar{\pi}}{Y} = 1-\rho-\frac{\xi-\sigma+1}{\xi\sigma} = \frac{\rho}{\xi}. \tag{37}$$

Together with the free entry condition in equation (9) and the labor share in equation (35), the constant profit share implies that the share of entrants is constant and independent of technology too:

$$L = \frac{\xi}{1+\xi}. \tag{38}$$

Lastly, the pricing equation in (13) combined with the Pareto distribution yields

$$\left(\frac{w}{\rho}\right)^{\sigma-1} = (1-L)\left(\frac{\xi\psi_m^{\xi}}{\xi-\sigma+1}\right)\bar{\psi}^{\sigma-1-\xi}\frac{\bar{\kappa}}{(\alpha_1^*)^{\sigma-1}\kappa_1^*} \tag{39}$$

Equations (34), (35), (38), (39) together lead to the closed-form solutions for L, $\bar{\psi}$, Y, and w in equations (28), (29), (30), and (31), respectively. Lastly, the solution for $\bar{\pi}$, the average profits, in (32) result from equations (29), (30), and (31) together with the free-entry condition in (9). □

Lemma 1. Suppose that the assumptions in Proposition 2 (Pareto distribution) hold and that $\sigma > 2$. Then, if a new technology t_{new} is added to the technology set T and it is adopted in equilibrium, it increases output Y, wages w, and total profits $(1-L)\psi_m^{\xi}\bar{\psi}^{-\xi}\bar{\pi}$.

Proof of Lemma 1. Suppose towards contradiction that output Y does not increase. Since Y and wages w are positively linearly related (equation (31)), the profit function can be rewritten as

$$\pi_j(\psi) = \frac{1}{\sigma}\left(\frac{\xi}{1+\xi}\right)^{\sigma-1} Y^{2-\sigma}\left(\frac{\psi}{\alpha_j}\right)^{\sigma-1} - \kappa_j. \tag{40}$$

Given $\sigma > 2$, if Y does not increase, it means that profits can not go down for any productivity level and for any technology choice. Also, given that the technology is adopted, it must yield strictly higher profits for some entrepreneurs. Therefore, total profits must go up. But by equation (37), profits are a fixed share of output. Hence, the increase in total profits implies that output Y *increases*, a contradiction. Therefore, output must increase in response to a new technology that is adopted. Since output, wages, and total profits are positively and linearly related, wages and total profits must also go up in response to an adopted new technology. □

Proof of Proposition 3. I prove Proposition 3 by proving its elements (a) and (b) sequentially.

Proposition 3(a): If t_{new} is adopted and has the highest fixed cost, it must have lowest marginal cost. By the reasoning in Stage 3 (equation (6)), this technology is only adopted by the entrepreneurs above a certain threshold for ψ. The entrepreneurs above this threshold reduce their marginal cost and thus increase their total factor productivity.

Because it becomes the highest fixed cost technology, the average fixed cost among producing entrepreneurs, $\bar{\kappa}$, increases.[44] Since $\bar{\kappa}$ increases, the entry threshold $\bar{\psi}$ increases too (seen from equation (29)). Hence, the technical change would lead some entrepreneurs to no longer produce, i.e., decreasing their total factor productivity to 0. It also means that the thresholds above which an entrepreneur uses technology $j+1$ instead of j increase for each j (see equation (33)): at least some entrepreneurs that do not adopt the new technology "downgrade" their technology, because the increased total output (see Lemma 1) by those using the new technology reduces their demand. Hence, for all entrepreneurs that do not adopt the new technology, the marginal cost either decreases or remains unchanged. This proves that technical change is large-scale-biased *if* the new technology has higher fixed than any other adopted technology.

Now suppose the new technology does not have highest fixed cost of all adopted technologies. Then, entrepreneurs that previously adopted the technology with lowest marginal cost can not decrease their marginal cost. For any $k > \psi_m$, there exists a subset of entrepreneurs with $\psi > k$ that adopts the technology with lowest marginal cost before and after the technical change. Hence, there does not exist a k such that all entrepreneurs with $\psi > k$ strictly increase total factor productivity, so that the technical change can not be large-scale-biased, which proves that technical change can be large-scale-biased *only if* the new technology has higher fixed than any other adopted technology.

Proposition 3(b): If t_{new} is adopted and has the lowest fixed cost, it must have highest marginal cost. First, the entry threshold $\bar{\psi}$ in equation (29) decreases because both κ_1^* (the fixed cost of the lowest adopted fixed-cost technology) and $\bar{\kappa}$ decrease. Therefore, there exists a range of entrepreneurial productivities $[\bar{\psi}_{new}, \bar{\psi}_{old}]$ such that entrepreneurs

[44] To see this formally, note that output increases by Lemma 1. By equation (30), if output increases while the entry technology, i.e. $\alpha_1^*(\kappa_1^*)^{\frac{1}{\sigma-1}}$ remains unchanged, $\bar{\kappa}$ must increase.

within that range exited before the technical change and enter after. Therefore, these entrepreneurs increase their total factor productivity from 0 to a strictly positive value. For any $\psi > \psi_{old}$, none chooses a technology that has lower marginal cost than before the technical change, because the increased total output (see Lemma 1) reduces their demand for any given price. Hence, some entrepreneurs with $\psi > \psi_{old}$ "downgrade" their technology relative to before the technical change and others do not change their adoption choice. This proves that technical change is small-scale-biased *if* the new technology has lower fixed than any other adopted technology.

Now suppose the new technology does not have lowest fixed cost of all adopted technologies. By Lemma 1, output and wages increase as a result of the technical change. Also, output and wages are positively linearly related (equation (31)). Thus, if output goes up while the entry technology remains unchanged, $\bar{\psi}$ must increase by equation (8). That is, $\bar{\psi}(T_{new}) > \bar{\psi}(T_{old})$. This means the range of entrepreneurs with $\psi \in (\bar{\psi}(T_{old}), \bar{\psi}(T_{new}))$ see their TFP decrease. Hence, such technical change can not be small-scale-biased, which proves that technical change can be small-scale-biased *only if* the new technology has lower fixed than any other adopted technology. □

Proof of Proposition 4. I prove Proposition 4 by proving its elements (a), (b), and (c) sequentially.

Proposition 4(a): If technical change is large-scale-biased, it increases average fixed cost: $\bar{\kappa}_{new} > \bar{\kappa}_{old}$ (see the proof of Proposition 3(a)). Since it increases the average fixed cost without affecting $\alpha_1^*(\kappa_1^*)^{\frac{1}{\sigma-1}}$, it increases $\bar{\psi}$ by equation (29). The average employment by firm is the number of workers divided by the number of entrepreneurs. The number of workers L is constant in equilibrium by equation (28). The number of entrepreneurs is $(1-L)(1-F(\bar{\psi}))$ which is decreasing in $\bar{\psi}$. Therefore, the average employment size increases in response to large-scale-biased technical change.

If technical change is small-scale-biased the entry threshold $\bar{\psi}$ in equation (29) decreases because both κ_1^* (the fixed cost of the lowest adopted fixed-cost technology) and $\bar{\kappa}$ decrease. Therefore, the average employment size decreases in response to large-scale-biased technical change.

Proposition 4(b): If technical change is large-scale-biased it decreases the share of entrepreneurs that enter by Proposition 4(a). By Proposition 2, the share of households that choose to work is a constant independent of the technology set (equation (28)). Therefore, the total measure of income earning households decreases (i.e. everyone except entrepreneurs that exit).

Proposition 4(c): □

First, since $Y_{new} > Y_{old}$ by Lemma 1 this term must be smaller than 1 for all entrepreneurs that do not adopt the technology. That is, technical change *reduces* profits for all entrepreneurs that do not adopt the technology. To see To understand the technical change's scale bias, I derive how the relative profit gain depends on productivity. If relative gains are increasing in productivity ψ, it must be large-scale-biased. The derivative of the relative profits with respect to productivity for those entrepreneurs that do not adopt t_{new} is:

$$\frac{\delta\left(\frac{\pi(\psi|T_{new})}{\pi(\psi|T_{old})}\right)}{\delta\psi} = \frac{\frac{\sigma-1}{\sigma}\left(\frac{\xi}{1+\xi}\right)^{\sigma-1}\alpha_{old}^{1-\sigma}\kappa_{old}\psi^{\sigma-2}\left(Y_{new}^{2-\sigma}-Y_{old}^{2-\sigma}\right)}{\pi(\psi \mid T_{old})^2} < 0$$

which is negative because $Y_{new} > Y_{old}$ by Lemma 1 and $\sigma > 2$. Therefore,

Profit gains or losses as a result of technical change be decomposed into:

$$\pi\left(\psi \mid T_{new}\right) - \pi\left(\psi \mid T_{old}\right) = \underbrace{\max\left\{\pi_{new}\left(\psi \mid T_{new}\right) - \pi_{old}\left(\psi \mid T_{new}\right), 0\right\}}_{\text{gains from changing technology } (\geq 0)} + \underbrace{\pi_{old}\left(\psi \mid T_{new}\right) - \pi_{old}\left(\psi \mid T_{old}\right)}_{\text{losses from increased competition } (<0)}.$$

The second term is negative since technical change increases output Y (as proven in Lemma 1), which, in turn, decreases profits for a given productivity level and technology (to see this combine equation (40) and the assumption that $\sigma > 2$). In other words, technical change *reduces* profits for all entrepreneurs that do not adopt the technology. But since total profits go up (Lemma 1), the cumulative profits of entrepreneurs who do adopt the new technology must *increase*.[45]

Case 1: $\kappa_{new} < \kappa_{old}$ and $\alpha_{new} > \alpha_{old}$. Recall that the profit of entrepreneurs with lower productivity is reduced less by an increase in marginal costs (see equation (6)). Therefore, there exists a productivity threshold $\psi_{1,2}$ such that entrepreneurs with productivity $\psi \in [\bar{\psi}_{new}, \psi_{1,2}]$ adopt t_{new} and those with productivity $\psi > \tilde{\psi}$ adopt t_{old} where $\bar{\psi}_{new}$ is the equilibrium entry threshold after the introduction of t_{new} (from equation (29), we know that $\bar{\psi}_{new} < \bar{\psi}_{old}$). Since no entrepreneur with productivity $\psi > k > \psi_{1,2}$ adopts t_{new} their profits must decrease. Therefore,

$$\int_k^\infty \pi\left(\psi \mid T_{new}\right) dF(\psi) < \int_k^\infty \pi\left(\psi \mid T_{old}\right) dF(\psi).$$

[45] Note that this does not necessarily imply that all entrepreneurs that adopt the new technology experience a profit gain.

On the other hand, the new technology increases total profits (by Lemma 1) such that

$$\int_{\bar{\psi}_{new}}^{\infty} \pi(\psi \mid T_{new})dF(\psi) > \int_{\bar{\psi}_{old}}^{\infty} \pi(\psi \mid T_{old})dF(\psi).$$

Together, these two inequalities imply that the technical change is small-scale-biased.

Case 2: $\kappa_{new} > \kappa_{old}$ and $\alpha_{new} < \alpha_{old}$

From the reasoning above, we know that $\int_{\tilde{\psi}}^{\infty} \pi(\psi)dF(\psi)$ decreases and that $\int_{\psi_m}^{\tilde{\psi}} \max\{\pi(\psi), 0\} dF(\psi$ increases. Therefore, it must be that the profit share of entrepreneurs with $\psi > \tilde{\psi}$ increases:

$$\frac{\int_{\tilde{\psi}}^{\infty} \pi(\psi \mid T_{new})dF(\psi)}{\int_{\bar{\psi}_{new}}^{\infty} \pi(\psi \mid T_{new})dF(\psi)} > \frac{\int_{\tilde{\psi}}^{\infty} \pi(\psi \mid T_{old})dF(\psi)}{\int_{\bar{\psi}_{old}}^{\infty} \pi(\psi \mid T_{old})dF(\psi)}$$

Case 1: $\kappa_{new} > \kappa_{old}$ and $\alpha_{new} < \alpha_{old}$. Recall that the benefit of marginal cost reduction is increasing in productivity (see equation (6)). Therefore, there exists a productivity threshold $\tilde{\psi}$ such that entrepreneurs with productivity $\psi \in [\bar{\psi}, \tilde{\psi}]$ adopt t_{old} and those with productivity $\psi > \tilde{\psi}$ adopt t_{new}. From the reasoning above, we know that $\int_{\tilde{\psi}}^{\infty} \pi(\psi)dF(\psi)$ increases and that $\int_{\psi_m}^{\tilde{\psi}} \max\{\pi(\psi), 0\} dF(\psi)$ decreases. Therefore, it must be that the profit share of entrepreneurs with $\psi > \tilde{\psi}$ increases:

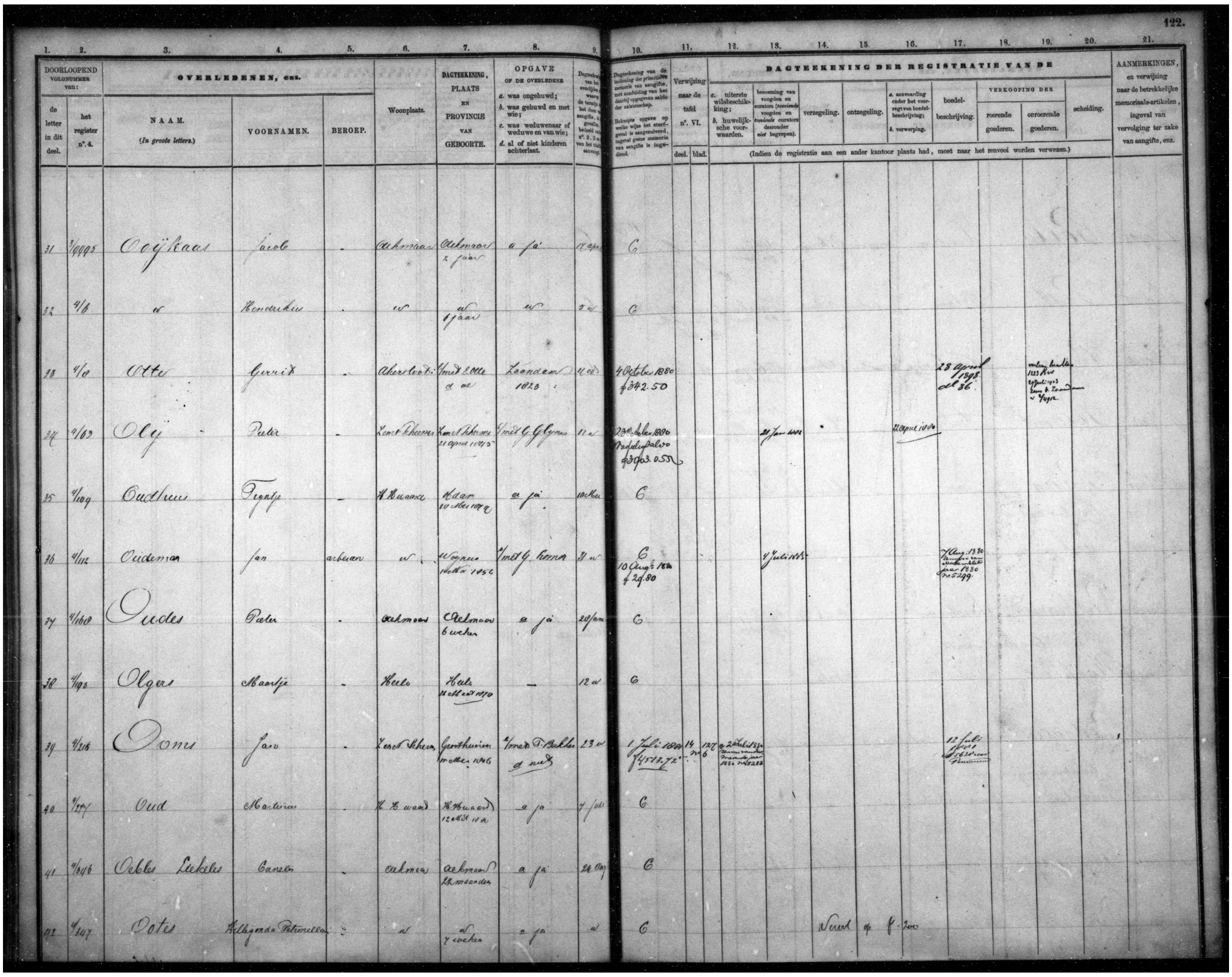
$$\frac{\int_{\tilde{\psi}}^{\infty} \pi(\psi \mid T_{new})dF(\psi)}{\int_{\bar{\psi}_{new}}^{\infty} \pi(\psi \mid T_{new})dF(\psi)} > \frac{\int_{\tilde{\psi}}^{\infty} \pi(\psi \mid T_{old})dF(\psi)}{\int_{\bar{\psi}_{old}}^{\infty} \pi(\psi \mid T_{old})dF(\psi)}$$

First, if t_{new} is adopted despite having higher fixed costs ($\kappa_{new} > \kappa_{old}$), it must offer lower marginal cost ($\alpha_{new} < \alpha_{old}$). By assumption both t_{new} and t_{old} are adopted in equilibrium and $\alpha_{new} > \alpha_{old}$. Also, recall that the benefit of marginal cost reduction is increasing in productivity (see equation (6)). Therefore, there exists a productivity threshold $\tilde{\psi}$ such that entrepreneurs with productivity $\psi \in [\bar{\psi}, \tilde{\psi}]$ adopt t_{old} and those with productivity $\psi > \tilde{\psi}$ adopt t_{new}.

D Data appendix

D.1 Examples of source files

FIGURE D.1: Example of a source image of the Dutch inheritance tax files.



Notes: The template form was consistent nationally and over time between 1879 and 1927.

FIGURE D.2: Example of a source image for the income and wealth distribution by municipality

(A) Income distribution (1946)

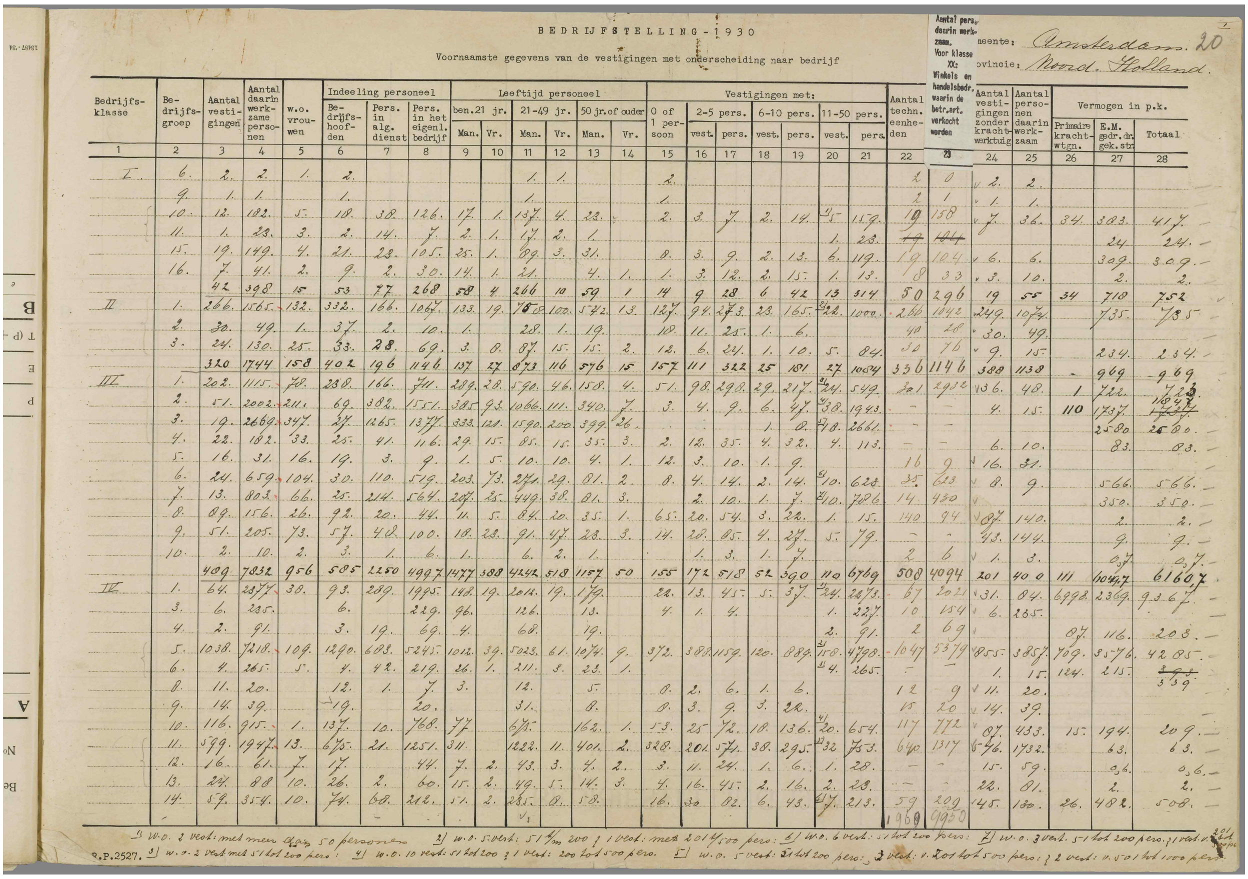
Inkomensklasse (x f. 1 000)	Aagtekerke Z.-43	
	Aantal	Inkomen
< 1	68	36 377
1 - < 2	100	141 537
2 - < 3	33	72 459
3 - < 4	1) 17	1) 57 864
4 - < 5	18	138 655
5 - < 6	2)	2)
6 - < 7	2)	2)
7 - < 8	2)	2)
8 - < 9	2)	2)
9 - < 10		
10 - < 15	2)	2)
15 - < 20	2)	2)
20 - < 50	2)	2)
50 - < 100		
100 en meer		
Totaal	236.	446 892
Totaal belasting	51 945	
Gem. inkomen:		
per inwoner	679	
per belastingpl.	1 894	

(B) Wealth distribution (1947)

Vermogensklasse (x f. 1 000)	Aagtekerke Z.-43	
	Aantal	Vermogen x f.1000
- < 10	1)	1)
10 - < 15	1)	1)
15 - < 20	2) 21	2) 248,5
20 - < 30	14	356,5
30 - < 50	10	390,5
50 - < 100	2) 18	2) 2 512,0
100 - < 200	1)	1)
200 - < 300	1)	1)
300 - < 500	1)	1)
500 - < 1 000		
1 000 en meer..		
Totaal	63	3 507,5
Totaal belasting	f. 12 285	
Gem.vermogen:		
per inwoner	" 4 772	
per belastingpl.	" 55 675	

Notes: The first column indicates the income or wealth bracket, the second column indicates the number of individuals in that bracket, and the third column the total bracket income or wealth. The notes 1) and 2) indicate which brackets have been grouped together for privacy reasons. *Source*: (Statistics Netherlands, 1952, 1953).

FIGURE D.3: Example of a source image of the Census of Companies by municipality in 1930



Notes: The example is for Amsterdam. The data contains the broad and detailed industry classification (columns 1 and 2), the number of establishments and workers by size (columns 15-21), and information on power adoption (columns 24-28). *Source*: (Statistics Netherlands, 2010).

D.2 Census of Manufactures industry crosswalks

D.2.1 1860-1900 crosswalks

Industry	Census of Manufactures industries
agricultural implements	agricultural implements; agricultural implements - fanning mills; agricultural implements - grain cradles and scythe snaths; agricultural implements - grain drills; agricultural implements - handles, plough and other; agricultural implements - hoes; agricultural implements - miscellaneous; agricultural implements - mowing and reaping machines; agricultural implements - ploughs, harrows, and cultivators; agricultural implements - rakes; agricultural implements - straw cutters; agricultural implements - threshers, horse-powers, and separators; agricultural implements, ns; mowing-machine knives; scythe rifles; scythes; shovels and spades; shovels, spades, forks, and hoes
agriculture	bee-hives; clover hulling; clover seed cleaning; cotton ginning; fences, patent; flowers; grain threshing; hay and straw, baling; hay pressing; prepared moss; rice cleaning; rice, cleaning and polishing; seeds, garden and flower
artificial limbs and surgical appliances	artificial limbs; shoulder braces; splints; surgical appliances
ashes, pot and pearl	ashes, pot and pearl
awnings and tents	awnings and tents; awnings, tents, and sails
bagging, flax, hemp, and jute	bagging; bagging, flax, hemp, and jute; hemp hose
bags, other than paper	bags; bags, other than paper
bags, paper	bags paper; paper bags
baking and yeast powders	baking and yeast cakes and powders; baking and yeast powders; baking-powders; saleratus
belting and hose	belting and hose leather; leather belting and hose; racking-hose
billiard tables and materials	billiard and bagatelle tables; billiard and bagatelle tables and materials; billiard cues; billiard tables and materials
blacking and other polishes	blacking; blacking and water-proof composition; cleansing and polishing preparations; furniture polish; polishing preparations; stove polish
blacksmithing	blacksmithing; blacksmithing and wheelwrighting; horse-shoes
bleaching, dyeing, and cleaning	bleaching and dyeing; bleaching straw goods; dyeing and bleaching; dyeing and cleaning; dyeing and finishing textiles; straw bonnet bleaching
bolts, nuts, washers, and rivets	bolts, nuts, washers, and rivets; iron and steel, bolts,nuts,washers, and rivets; iron, bolts, nuts, washers, and rivets

bookbinding	bookbinding; bookbinding and blank books; bookbinding and blank-book making
boots and shoes	boot and shoe cut stock; boot and shoe findings; boot and shoe patterns; boot and shoe uppers; boots and shoes; boots and shoes factory product; boots and shoes, custom work and repairing; boots and shoes, including custom work and repairing; shoe and boot tips; shoe findings; shoe strings
boxes, fancy and paper	boxes fancy and paper; boxes, fancy; boxes, paper
brassware and bells	bells; brass; brass and bell founding; brass and copper tubing; brass book clasps and badges; brass castings; brass castings and brass finishing; brass founding and brass ware; brass founding and finishing; brass ornaments; brass wire and wire cloth; brass, rolled; brassware
bread and bakery products	bread and crackers; bread and other bakery products; bread, crackers, and other bakery products
brick, stone, and tile	brick; brick and tile; fire-brick; masonry brick and stone; plastering and stuccowork; sand, washed
bridge building	bridge-building; bridges
bronze	bronze castings; bronze powders
brooms and brushes	broom handles; brooms; brooms and brushes; brooms and wisp-brushes; brush blocks; brush handles and stocks; brushes; mops and dusters
butter, cheese, etc	butter reworking; cheese; cheese and butter urban dairy product; cheese and butter, factory; cheese butter and condensed milk factory product
canning and preserving	fish, cured and packed; fruits and vegetables, canned and preserved; fruits and vegetables, canning and preserving; oysters canning and preserving; pickles, preserves, and sauces; preserves and sauces; provisions
carpentering	carpentering; carpentering and building
carpets	carpets; carpets and rugs other than rag; carpets, other than rag; carpets, rag
carriage and wagon materials	carriage and wagon materials; hubs, spokes, bows, shafts, wheels, and felloes; spokes, hubs, felloes, shafts, and bows; wheelwrighting
carriages and wagons	carriages; carriages and sleds, childrens; carriages and wagons; carriages and wagons, including custom work and repairing; carriages childrens; carriagesmithing; wagons and carts
cases	clock cases and materials; clock-cases; hydrant cases; jewelry and instrument cases; jewelry boxes and cases; sewing machine cases; show cases; stereoscopic cases; watchcases

chemical pigments	blueing; bluing; bone-, ivory-, and lamp-black; bone-black; ivory-black; lampblack; washing blue; white lead; whiting
chemicals, other	acid, pyroligneous; acid, sulphuric; acids, (not specified); barilla; benzoline; calcium lights; celluloid and celluloid goods; chemicals bichromate of potash; chemicals bisulphate of lime; fire clay; fire extinguishers chemical; isinglass; lye, condensed; moulding sand; mucilage and paste; oil - water; potters clay and materials; putty; saltpeter; saltpetre and nitrate of soda; sulphur; taxidermy; water lime; wood preserving
chocolate	chocolate; chocolate and cocoa products
chromos and lithographs	photolithographing and engraving; photolithographing and photoengraving
clocks and watches	clock materials; clocks; watch and clock materials; watch and clock repairing; watch clock and jewelry repairing; watch materials; watches; watches, watch repairing, and materials
clothing, general	belt clasps and slides; belts, childrens; buttons; clothing mens custom work and repairing; clothing, childrens; clothing, mens; clothing, mens, factory product; clothing, mens, factory product, buttonholes; clothing, ns; collars and cuffs, paper; furnishing goods mens; shirts; suspenders
clothing, women's	car fixtures and trimmings; carriage-trimmings; clothing - ladies; clothing, womens; clothing, womens, dressmaking; clothing, womens, factory product; coach lace; coffin trimmings; corsets; dress patterns; fancy articles; fancy articles not elsewhere specified; fruit-jar trimmings; hatters trimmings; hoop-skirts and corsets; lamp trimmings; millinery; millinery and dress making; millinery and lace goods; millinery goods; millinery, custom work; skirt supporters
coffee and spices, roasted and ground	coffee and spice, roasting and grinding; coffee and spices, ground; coffee and spices, roasted and ground; coffee roasting; coffee, essence of
coffins	coffin screws; coffins; coffins and burial cases, trimming and finishing; coffins burial cases and undertakers goods
combs	comb plates; combs; combs, shell and other
confectionery	confectionery
construction, other	building stone, artificial; cement pipe; cisterns; stair building; well curbs
cooperage	cooperage; staves, heading, hoops, and shooks
copper	copper - sheet and bolt; copper smelting; copper work; copper, milled and smelted; copper, rolled; coppersmithing; speaking tubes
cordage and twine	cordage; cordage and twine; cotton braid, thread, lines, twine, and yarn; cotton cordage; cotton thread, twine, and yarn

cork	cork cutting; corks
cotton compressing	cotton batting and wadding; cotton compressing; cotton pressing
cotton goods	cotton bags; cotton coverlets; cotton flannel carding; cotton goods; cotton goods, (not specified); cotton lamp wick; cotton mosquito netting; cotton small wares; cotton table-cloths; cotton-ties
cutlery, edge tools, and axes	cutlery; cutlery and edge tools; cutlery and edge-tools, (not specified); edge tools and axes
decorative work, other	artificial feathers and flowers; bath tubs; bead work; china and glass decorating; china decorating; embroidery; feathers, cleaned, dressed, and dyed; kaolin and ground earths; kaolin and other earth grinding; ornaments - terra cotta; pearl goods; pencils and pens, gold; pens, gold; pipes - clay; pipes - meerschaums; porcelain ware; spelter; stuffed birds; teeth, porcelain; terra-cotta ware; veneers
dentistry	dentistry; dentistry, mechanical; dentists materials
drugs, chemicals, and medicines	chemicals; drug grinding; druggists preparations not including prescriptions; drugs and chemicals; drugs, ground; magnesia; manganese; medicines, extracts, and drugs; nitro-glycerine; patent medicines and compounds; zinc, oxide of
dyestuffs and extracts	bark - ground; bark - sumac, and sumac prepared; dye stuffs and extracts; dye woods and dye stuffs; gum and gum cleaning; hemlock-bark, extract; liquor coloring
electrical, telegraph, and telephone apparatus	electrical apparatus and supplies; telegraph and telephone apparatus
emery	corundum; emery; emery wheels; emery, reduced and ground
enameled goods	enameled goods; enameling; enameling and enameled goods; enamelling
engines and railroad cars	car brakes; car wheels; cars and general shop construction and repairs by steam-railroad companies; cars and general shop construction and repairs by street railroad companies; cars steam railroad not including operations of railroad companies; cars street-railroad not including operations of railroad companies; cars, omnibuses, and repairing; cars, railroad, street, and repairs; fire engines; locomotive engines and repairing; machinery, fire-engines
engraving	carving; engravers materials; engraving; engraving and die-sinking; engraving and stencil-cutting; engraving steel including plate printing; engraving, calico; engraving, steel; engraving, wood; gilding; watch engraving
envelopes	envelopes; envelopes and cards, embossed
explosives and fireworks	explosives; explosives and fireworks; fireworks; high explosives

fertilizers	fertilizers
files	files
fisheries	fisheries
fishing supplies	fish hooks; fishing lines, nets, and tackle; hunting and fishing tackle; nets; nets and seines; nets, fish, and seines
flags and banners	flags and banners; regalia and society banners and emblems; regalias, banners, and flags
flax, dressed	flax dressing; flax, dressed
flour and grist mills	flour and meal; flouring and grist mill products
food products, other	barley, pearl; bone boiling; cocoa; cordials and sirups; dippers, cocoa-nut; fish canning and preserving; flavoring extracts; food preparations; food preparations, animal; food preparations, macaroni and vermicelli; food preparations, vegetable; ginseng; hemp dressing; hominy; macaroni and vermicelli; milk, condensed; mustard; mustard, ground; oleomargarine; rice flour; sumac, ground
fuel, charcoal and coke	charcoal; charcoal, pulverized; coke
fuel, gas	gas; gas illuminating and heating; gas, illuminating
fuel, kerosene and camphene	camphene and burning fluid; coal-oil, rectified; oil - coal; oil - kerosene
fuel, other	fuel, artificial; granular fuel; oil, illuminating, not including petroleum refining
furniture	beds, spring; furniture; furniture factory product; furniture, (not specified); furniture, cabinet, school, and other; furniture, cabinetmaking, repairing and upholstering; furniture, chairs; furniture, iron bedsteads; furniture, refrigerators; house-furnishing goods, not elsewhere classified; housefurnishing goods; mattresses and beds; mattresses and spring beds; medicine chests; money drawers; printers chases, furniture, and rollers; refrigerators; refrigerators and water-coolers
furs	fur goods; furs; furs, dressed
glass	aquariums; artificial eyes; bottle moulds; bottling; glass; glass cutting staining and ornamenting; glass sand; glass ware; glass, cut; glass, cut, stained, and ornamented; glass, plate; glass, stained; glass, window; looking-glasses; mineral water apparatus; mirrors; optical goods; soda-water apparatus; spectacles and eye-glasses
gloves and mittens	gloves and mittens
glue	glue
gold and silver leaf and foil	gold and silver leaf and foil; gold, leaf and foil

gold and silver refining	gold and silver assaying and refining; gold and silver reducing and refining not from the ore; gold and silver, reduced and refined
grease, hides, and tallow	grease; grease and tallow; hides and tallow; lard, refined
gun- and lock-smithing	ammunition; bank locks; fire bomb-lances; fire-arms; gun locks and materials; gunsmithing; keys, metallic; lock and gun smithing; locksmithing and bellhanging; percussion-caps; powder flasks and percussion caps
gunpowder	gunpowder
hair-work	hair jewelry; hairwork; wigs and hair work
hardware	hardware; hardware saddlery
hats and caps	cap fronts; fur hats; hat and cap materials; hat materials; hat-bodies; hat-tips; hats and caps; hats and caps not including fur hats and wool hats; hats and caps, not including wool hats; wool hats
hones and whetstones	hones and whetstones; whetstones
hooks and eyes	hooks and eyes
hosiery and knit goods	hand knit goods; hosiery; hosiery and knit goods
ice	ice; ice, artificial; ice, manufactured
ink	ink; ink, printing; ink, writing
instruments, professional and scientific	globes, terrestial and celestial; instruments; instruments professional and scientific
iron and steel products, other	anchors and chains; axles; candle moulds; carpet-sweepers; cheese presses and vats; chimney flues; eave troughs; grates and fenders; handspikes; hydrants; iron anchors and cable-chains; iron and steel, doors and shutters; iron doors and shutters; iron, castings, stoves, heaters, and hollow ware; ironwork, architectural and ornamental; metallic caps and lables; plugs and wedges; plumbers materials; sad-irons; sash, metal; sieve hoops; stair rods; tinned iron ware; torpedoes; truss hoops; vats; wheelbarrows; whitesmithing
iron and steel, forged and wrought	fire-escapes; hinges, wrought and cast; iron - forged, rolled, and wrought; iron and steel forgings; iron and steel pipe wrought; iron forgings; iron pipe, wrought; iron, forged and rolled; iron, railing, wrought; steel, forged
iron and steel, general	iron - cast; iron and steel; iron, castings, (not specified); steel, (not specified); steel, and manufactures of; steel, cast
iron and steel, other	galvanizing; iron, blooms; steel, bessemer
iron and steel, pig	iron, pig; iron, pigs
ivory and bone work	ivory and bone work; ivory-work; turning, ivory and bone
japanned ware	japanned ware; japanning

jewelry	jewelry; jewelry, (not specified)
kindling wood	kindling wood
lapidary work	lapidaries work; lapidary work
lasts	lasts; lasts and boot trees
lead	lead bar pipe and sheet; lead, bar and sheet; lead, bar, pipe, sheet, and shot; lead, manufactures of; lead, pipe; lead, shot; plumbago, black and silver lead
leather	leather; leather board; leather morocco; leather patent and enameled; leather patent and enamelled leather; leather skin dressing; leather tanned, curried, and finished; leather, curried; leather, dressed skins; leather, morocco, tanned and curried; leather, tanned; leather, tanned and curried
leather products, other	leather goods; razor-strops; watch guards
lightning rods	lightning-rods
lime and cement	cement; lime; lime and cement
linen and linen goods	belting and hose, linen; flax and linen goods; linen goods; thread, linen
liquors and beverages, other	alcohol; cider; cider refined; liquors - bottled; liquors - cordials; malt kilns
liquors, distilled	liquors, distilled
liquors, malt	liquors malt; small beer
liquors, rectified	liquors - rectified
liquors, vinous	liquors - wine; liquors vinous
lithographing	chromos and lithographs; lithographing; lithographing and engraving; lithography
looking-glass and picture frames	looking-glass and picture frames
lumber	lumber and other mill products from logs or bolts; lumber and timber products; lumber, ns; lumber, planed; lumber, planing mill products , including sash , doors, and blinds; lumber, sawed; timber cutting and timber hewed; timber products, not manufactured at mill

machinery, iron and steel	anvils and vices; automaton pressmen; bellows; bookbinders machinery; coffee, roasters; cotton gins; crucibles; electro-magnetic machines; foundery and machine-shop products; foundry and machine shop products; furnaces, ranges, registers, and ventilators; gas and oil stoves; gas stoves; gas works, portable; gas-retorts; hoisting apparatus and machines; machinery - hay and cotton presses; machinery - paper; machinery - rice machines; machinery - shingle machines; machinery - silk; machinery - stamp machines; machinery - steam-engines, and c; machinery - turbine water-wheels; machinery - wood working; machinery, railroad repairing; machinery, steam engines and boilers; metal spinning; newspaper directing machines; oil-tanks; paint mills; pipe tongs; portable forges; printing and lithographic presses; registers cash; registers, car-fare; seal and copying presses; steering apparatus; sugar evaporators; watch-makers lathes; windmills
machinery, other	foundery supplies; foundry supplies; machinery, (not specified); shoe peg machines; vanes, weather; windlasses
machinery, wooden	machinery - cotton and woollen; machinery - ribbon looms; machinery, cotton and woolen; washing machines and clothes dryers; washing machines and clothes wringers
malt	malt
marble and stone work	mantels slate marble and marbleized; marble and stone work; marble and stone work, (not specified); marble and stone work, monuments and tombstones; monuments and tombstones
matches	matches
mats and matting	mats and matting; mats and rugs
military goods	military goods
milled quartz	quartz, milled
millstones	millstones; millstones and mill furnishing
millwrighting	millwrighting
mineral and soda waters	mineral and soda waters; mineral water
mining, coal	coal - anthracite; coal - bituminous; coal, ns
mining, gold and silver	gold mining; silver mining
mining, iron	iron ore
mining, lead	lead mining and smelting; lead, pig
mining, other	asphaltum work; chrome mining; clay mining; copper mining; nickel ore; zinc ore

musical instruments	musical instrument materials; musical instruments - melodeons; musical instruments - miscellaneous; musical instruments - piano-fortes; musical instruments and materials not specified; musical instruments organs; musical instruments, nec; musical instruments, organs and materials; musical instruments, pianos and materials; piano-forte stools
nails and spikes	horse-shoe nails; iron and steel nails and spikes cut and wrought including wire nails; iron, nails and spikes, cut and wrought; nails, cut, wrought, and spikes
non-metal minerals, other	foundry facings; glaziers diamonds; graphite; graphite and graphite refining; grindstones; oil-stones; paving and paving materials; paving materials; scythe stones; soap-stone
oilcloth	clothing - oil; oil and enamelled cloth; oil floor cloth; oil-cloth, silk; oilcloth, enameled; oilcloth, floor
oils	oil - cocoa-nut; oil - cotton-seed; oil - fish, whale and other; oil - lard; oil - neatsfoot; oil - rosin; oil cotton-seed and cake; oil, animal; oil, castor; oil, essential; oil, fish; oil, linseed; oil, not elsewhere specified; oil, resin; oil, vegetable, (not specified); oil, vegetable, castor; oil, vegetable, cotton-seed; oil, vegetable, essential; oil, vegetable, linseed; oils - essential; pitch, brewers and burgundy
oils, lubricating	axle grease; oil, lubricating; oils - chemical
other metal products	babbitt metal and solder; brass and copper, rolled; brass and german silver, rolled; candlesticks; copper and brass ware; electroplating; metal, repaired and white; stamped ware; tin foil
painting and paperhanging	painting; painting and paperhanging; painting house sign etc; paperhanging; paperhangings
paints	paints; paints, (not specified); paints, lead and zinc; zinc paint
paper	paper; paper and wood pulp; paper goods not elsewhere specified; paper, (not specified); paper, printing; paper, writing
paper, other	card boards; card cutting; card cutting and designing; cardboard; cards - enameled; cards - hand; cards - playing; cards, other than playing; ornaments - paper; paper clay; paper patterns; paper ruling; paper shades; paper staining; paper, wrapping; postal cards; valentines
patterns and models	models and patterns; patterns and models
perfumery and cosmetics	perfumery and cosmetics; perfumery and fancy soaps
photography	cameras; photographic apparatus; photographic materials; photographing; photographing materials; photographs; photography
pipes	pipe, wooden; pipes, tobacco

plumbing, heating, and lighting	drain and sewer pipe; drain tile; drain-pipe; electric light and power; electric lights; gas and lamp fixtures; gas fixtures, lamps, and chandeliers; gas machines and meters; gasometers; gasometers and tanks; heating apparatus; lamp fixtures; lamps; lamps and lanterns; lamps and reflectors; metal cocks and faucets; meters, gas; meters, water; plumbers supplies; plumbing and gas and steam fitting; plumbing and gasfitting; steam and gas fittings and valves; steam and water gauges; steam fittings and heating apparatus; steam heaters and heating apparatus
pocket-books	pocket-books, porte-monnaies, and wallets; pocketbooks
printing and publishing	printing and publishing; printing and publishing, (not specified); printing and publishing, book and job; printing and publishing, music; printing and publishing, newspaper; printing and publishing, newspapers and periodicals; printing materials; printing, job
printing and publishing, other	block letters; charts, hydrographic; map mounting and coloring; maps; maps and atlases; music printing; printers fixtures; show cards; signs; stencils and brands
pumps	pumps; pumps and hydraulic rams; pumps not including steam pumps
quarrying	barytes; grindstones and grindstone quarrying; ochre; slate quarrying
roofing and plastering	coal-tar; ornaments - plaster; plaster, and manufactures of; plaster, ground; plastering; roofing; roofing and roofing materials; roofing materials; shingles and lath; shingles, split; stucco and stucco work
rubber and elastic goods	belting and hose, rubber; boots and shoes rubber; gutta-percha goods; india-rubber and elastic goods; india-rubber goods; rubber and elastic goods; rubber, vulcanized; safety-fuse
saddlery and harness	saddlery and harness; saddlery and harness materials
safes, doors, and vaults	safes - cheese; safes - fire-proof; safes - provision; safes and vaults; safes, doors, and vaults, (fire-proof)
salt	salt; salt ground
sand and emery paper and cloth	sand and emery paper and cloth; sand-paper
sash, doors, and blinds	curtain fixtures; sash, doors, and blinds; venetian blinds; window blinds and shades; window shades; wooden door knobs
saws	saws
scales and balances	scales and balances
screws	jack-screws; screws; screws machine; screws wood

sewing machines	needle-threaders; needles; needles and pins; pins; sewing birds; sewing machine needles; sewing machine repairing; sewing machine shuttles; sewing machines and attachments; sewing-machine fixtures; sewing-machines
ship and boat building	blocks and spars; blocks, pumps, and spars; boats; iron steamships; iron, ship building and marine engines; mast hoops and hanks; masts and spars; oakum; oars; rigging; sails; ship and boat building; ship and boat building wooden; ship building, repairing, and ship materials; shipbuilding; shipbuilding iron and steel
shoddy	shoddy
silk and silk goods	silk and fancy goods, fringes, and trimmings; silk and silk goods; silk goods, (not specified); silk, sewing and twist
silverware	plated and britannia ware; plated ware; silver, manufactures of; silver-plated and britannia ware; silversmithing; silverware
slaughter and meat packing	butchering; meat, cured and packed, (not specified); meat, packed, beef; meat, packed, pork; sausage; slaughtering and meat packing; slaughtering and meat packing, wholesale; slaughtering wholesale not including meat packing
smelting and refining, other	copper smelting and refining; lead smelting and refining; nickel and cobalt; quicksilver; quicksilver, smelted; smelting and refining; smelting and refining, not from the ore
soap and candles	candles - adamantine; candles - wax; candles, adamantine and wax; soap and candles; wax work
springs	springs steel car and carriage; springs, car, carriage, locomotive, and other; steel, springs
stationery and school supplies	artists materials; chalk and crayons; chalk, prepared; pencils, indelible; pencils, lead; pens fountain and stylographic; pens, steel; school apparatus; stationery; stationery goods; stationery goods, not elsewhere classified
stereotyping and electrotyping	stereotyping and electrotyping
stone- and earthen-ware	clay and pottery products; pottery and stone ware; pottery terra-cotta and fire-clay products; stone and earthen ware
straw goods	straw goods
sugar, glucose, and starch	arrow-root; glucose; molasses, refined; sirups, other than sorghum; sorghum sirup; starch; sugar and molasses; sugar and molasses beet; sugar and molasses refining; sugar and molasses, refined; sugar refining
tar and turpentine	tar; tar and turpentine; turpentine - crude; turpentine - distilled; turpentine and rosin

textile products, other	calico printing; car linings; carpet cleaning; cloth finishing; cloth sponging and refinishing; clothing, horse; costumes; filter bags; fly nets; hair-cloth; hammocks; horse-covers; labels and tags; laundry work; life-preservers; mixed textiles; printing cotton and woolen goods; quilts; satinet printing; tags; tapes and binding; trusses, bandages, and supporters; weaving, (not specified); webbing; wool cleaning and pulling
tin, copper, and sheet-iron ware	tin and terne plate; tin, copper, and sheet-iron ware; tinsmithing coppersmithing and sheet-iron working; tinware, copperware, and sheet-iron ware
tobacco	cigars; tobacco and cigars; tobacco and snuff; tobacco chewing smoking and snuff; tobacco cigars and cigarettes; tobacco stemming; tobacco, chewing and smoking, and snuff; tobacco, cigars; tobacco, stemming and rehandling
tools	blacksmiths tools; bookbinders tools; brick machinery and tools; carpenters tools; confectioners tools; coopers tools; curriers tools; hatters tools; jewelers dies, tools, and machinery; machinists tools; shoemakers tools; stencil tools; stone-cutters tools; tinners tools and machines; tools; tools not elsewhere specified
toys, games, and sporting goods	base-ball goods; croquet sets; sporting goods; toy books and games; toys; toys and games; toys, tin
trunks, carpet bags, and valises	trunk and carpet bag frames; trunks and valises; trunks, carpet bags, and valises; trunks, seamens chests; trunks, valises and satchels
type founding	metal type; type and type and stereotype founding; type founding
umbrellas, whips, and canes	umbrella furniture; umbrellas and canes; whips; whips and canes; whips, whip-lashes, sockets, and canes
upholstery	curled hair; curtains; husks, prepared; sponges; upholstering; upholstering materials; upholstery; upholstery materials
varnish	varnish
vault lights	vault lights; vault lights and ventilators
vinegar	vinegar; vinegar and cider
willow ware, baskets, and rattan	baskets; baskets, and rattan and willow ware; baskets, rattan and willow ware; whalebone and ratan; whalebone and rattan; whalebone and rattan, prepared; willow furniture and willow ware; willow ware and rustic ornaments
wire	wire; wire cloth; wire rope; wire work - sieves and bird cages; wire, insulated; wired steel; wirework; wirework including wire rope and cable

wood products, other	carpets, wood; churns; cigar molds; drain pipe, wooden; dumb waiters; engravers blocks and wood; fans; hand stamps; handles; handles, wooden; hat and bonnet blocks; pulp goods; pulp,wood; rules ivory and wood; shoe-pegs; sugar moulds; type, wooden; veneering; water-closets; wood cutting; wood pulp; wood work, miscellaneous; wood, brackets, moldings and scrolls; wooden clothes frames; wooden screws
wood, turned and carved	turning, scroll sawing, and moulding; wood, turned and carved
wooden boxes	box shooks; boxes - packing; boxes - sugar; boxes - tobacco; boxes, cheese; boxes, cigar; boxes, ns; boxes, wooden packing
wooden ware	wooden ware; woodenware, not elsewhere specified
wool-carding and cloth-dressing	wool-carding and cloth-dressing
woolen goods	wool pulling; wool scouring; woolen goods; woollen goods; woollen yarn
worsted goods	worsted goods
yarn and cloth, other	felt goods; felting; jute and jute goods
zinc	zinc; zinc smelting and refining; zinc, (statuary and building ornaments); zinc, smelted and rolled

D.2.2 1890-1929 crosswalks

Industry	Census of Manufactures industries
agricultural implements	agricultural implements
aircraft and parts	aircraft and parts; airplanes, seaplanes, and airships, and parts
artificial flowers and feathers and plumes	artificial and preserved flowers and plants; artificial feathers and flowers; artificial flowers; artificial flowers and feathers and plumes; feathers and plumes; feathers, plumes, and manufactures thereof
artists materials	artists materials
automobiles including bodies and parts	automobile bodies and parts; automobiles; automobiles including bodies and parts; motor vehicles, not including motorcycles; motor-vehicle bodies and motor-vehicle parts
awnings tents and sails	awnings tents and sails; awnings, tents, sails, and canvas covers
axle grease	axle grease; lubricating greases; lubricating oils and greases, not made in petroleum refineries

bags other than paper	bagging, flax, hemp, and jute-; bags, other than paper; bags, other than paper, not including bags made in textile mills; bags, other than paper, not made in textile mills
bags paper	bags paper; bags, paper, exclusive of those made in paper mills; bags, paper, not including bags made in paper mills
baking and yeast powders	baking and yeast powders; baking powders and yeast; baking powders, yeast, and other leavening compounds; baking-powders
baskets and rattan and willowware	baskets and rattan and willow ware, not including furniture; baskets, and rattan and willow ware
belting and hose leather	belting and hose leather; belting, leather
belting and hose woven and rubber	belting and hose woven and rubber; belting and hose, linen; belting and hose, other than rubber; belting and hose, rubber; belting and hose, woven, other than rubber; belting, other than leather and rubber, not made in textile mills
beverages	beverages; liquors malt; liquors, malt, including cereal beverages; mineral and soda waters
bicycles motorcycles and parts	bicycles and tricycles; bicycles motorcycles and parts; motorcycles, bicycles, and parts
billiard tables and materials	billiard and pool tables, bowling alleys, and accessories; billiard tables and accessories; billiard tables and materials; billiard tables, bowling alleys, and accessories
blacking and cleansing and polishing preparations	blacking; blacking and cleansing and polishing preparations; blacking, stains and dressings; cleaning and polishing preparations; cleansing and polishing preparations; cleansing preparations
bluing	bluing
bone ivory and lamp black	bone and carbon black; bone black, carbon black, and lampblack; bone ivory and lampblack; bone, carbon, and lamp black
boots and shoes including cut stock and findings	boot and shoe cut stock; boot and shoe cut stock and findings; boot and shoe cut stock, not made in boot and shoe factories; boot and shoe findings; boot and shoe findings, not made in boot and shoe factories; boot and shoe uppers; boots and shoes; boots and shoes factory product; boots and shoes including cut stock and findings; boots and shoes, custom work and repairing; boots and shoes, not including rubber boots and shoes; boots and shoes, other than rubber
boots and shoes rubber	boots and shoes rubber
boxes cigar	boxes, cigar; boxes, cigar, wooden
boxes fancy and paper	boxes fancy and paper; boxes, paper and other, not elsewhere specified; boxes, paper, not elsewhere classified; boxes, paper, shipping containers; boxes, set-up paper boxes; boxes, set-up paper boxes and cartons

bread and other bakery products	bread and other bakery products
brick and tile pottery terracotta and fire clay products	brick and tile; brick and tile, terra-cotta , and fire clay products; clay and pottery products; clay products (other than pottery) and non-clay refractories; sand-lime brick
brooms and brushes	brooms; brooms and brushes; brooms, from broom corn; brushes; brushes, other than rubber
butter cheese and condensed milk	butter; butter cheese and condensed milk; butter reworking; cheese; cheese and butter urban dairy product; cheese butter and condensed milk factory product; condensed and evaporated milk; condensed milk
buttons	buttons
canning and preserving	canning and preserving; canning and preserving fish, crabs, shrimps, oysters, and clams; canning and preserving fruits and vegetables pickles, jellies, preserves, and sauces; canning and preserving, fish; canning and preserving, fruits; canning and preserving, fruits and vegetables; canning and preserving, oysters; canning and preserving, vegetables; canning and preserving, vegetables and dried fruits; fish, canning and preserving; fruits and vegetables, canning and preserving; oysters canning and preserving; pickles, preserves, and sauces
card cutting and designing	card cutting and designing
carpets and rugs other than rag	carpets and rugs, other than rag; carpets and rugs, wool, other than rag; carpets, wood
carpets rag	carpets and rugs, rag; carpets, rag
carriages and sleds childrens	carriages and sleds, childrens
carriages and wagons and materials	carriage and wagon materials; carriages and wagons; carriages and wagons and materials; carriages and wagons, including custom work and repairing; carriages and wagons, including repairs; carriages and wagons, repair work only; carriages, wagon, sleigh, and sled materials; carriages, wagons, sleighs, and sleds
cars and general shop construction by railroad companies	cars and general construction and repairs, electric-railroad repair shops; cars and general construction and repairs, steam railroad repair shops; cars and general shop construction and repairs by electric-railroad companies; cars and general shop construction and repairs by eletric-railroad companies; cars and general shop construction and repairs by steam railroad companies; cars and general shop construction and repairs by street-railroad companies
cash registers and calculating machines	cash registers and calculating machines; cash registers, and adding, calculating, and card-tabulating machines; registers cash; registers, car-fare

chemicals	chemicals; chemicals, not elsewhere classified; coal-tar products; rayon and allied products; sulphuric, nitric, and mixed acids; wood distillation; wood distillation and charcoal manufacture; wood distillation not including turpentine and rosin
china decorating	china decorating, not including that done in potteries; china firing and decorating, not done in potteries; china, decorating
chocolate and cocoa products	chocolate and cocoa products; chocolate and cocoa products, not including confectionery
clocks and watches including cases and materials	clocks; clocks and watches including cases and materials; clocks, clock movements, time-recording devices, and time stamps; watch and clock materials; watch and clock materials and parts, except watchcases; watch and clock materials, except watchcases; watch materials, except watchcases; watch, clock and jewelry repairing; watchcases; watches
clothing mens including shirts	clothing (except work clothing), mens, youths, and boys, not elsewhere classified; clothing mens factory product buttonholes; clothing mens including shirts; clothing, mens; clothing, mens, buttonholes; clothing, mens, factory product; clothing,mens, custom work and repairing; shirts
clothing womens	clothing, womens; clothing, womens, dressmaking; clothing, womens, factory product; clothing, womens, not elsewhere classified; clothing, work (including sheep-lined and blanket-lined work coats but not including shirts), mens
cloth sponging and refinishing	cloth, sponging and refinishing
coffee and spice roasting and grinding	coffee and spice roasting and grinding; peanuts, grading, roasting, cleaning, and shelling; peanuts, walnuts, and other nuts, processed or shelled
coffins burial cases and undertakers goods	caskets, coffins, burial cases, and other morticians goods; coffins, burial cases, and undertakers goods
coke	coke; coke, not including gas-house coke
confectionary and ice cream	ice cream
confectionery and ice cream	chewing gum; confectionery; confectionery and ice cream
copper tin and sheet iron products	aluminum manufactures; copper tin and sheet-iron products; copper, tin, and sheet-iron work; copper, tin, and sheet-iron work, including galvanized-iron work, not elsewhere classified; enameled goods; enameling; enameling and enameled goods; enameling and japanning; stamped and enameled ware, not elsewhere specified; stamped ware; stamped ware, enameled ware, and metal stamping, enameling, japanning, and lacquering; stamped ware, not elsewhere specified; tin and terne plate; tin cans and other tinware not elsewhere classified; tin plate and terneplate; tinsmithing, coppersmithing, and sheet-iron working; tinware, not elsewhere specified

cordage and twine	linen goods
cordage and twine and jute and linen goods	cordage and twine; cordage and twine and jute and linen goods; jute and jute goods; jute goods
cork cutting	cork cutting; cork products
corsets	corsets; corsets and allied garments
cotton goods including cotton smallwares	cotton goods; cotton goods including cotton small wares; cotton lace; cotton small wares
crucibles	crucibles
cutlery and tools not specified	cutlery (not including silver and plated cutlery) and edge tools; cutlery and edge tools; cutlery and tools not elsewhere specified; tools, not elsewhere specified
dentists materials	dental goods; dental goods and equipment; dentists materials
drug grinding	drug grinding
dyeing and finishing textiles	dyeing and finishing textiles; dyeing and finishing textiles, exclusive of that done in textile mills
dyestuffs and extracts	dye stuffs and extracts; dyestuffs and extracts—natural; tanning materials, natural dyestuffs, mordants and assistants, and sizes
electrical machinery apparatus and supplies	electrical apparatus and supplies; electrical machinery, apparatus, and supplies
electroplating	electroplating
emery and other abrasive wheels	emery and other abrasive wheels; emery wheels; emery wheels and other abrasive and polishing appliances
enameling and japanning	japanning
engravers materials	engravers materials
engraving and die sinking	engraving (other than steel, copperplate, or wood), chasing, etching, and diesinking; engraving and die-sinking
engraving wood	engraving, wood
explosives	explosives; gunpowder; high explosives
fancy articles not specified	combs; combs and hairpins, except those made from metal or rubber; combs and hairpins, not made from metal or rubber; fancy and miscellaneous articles, not elsewhere classified; fancy articles not elsewhere specified; fancy articles, not elsewhere-specified; ivory and bone work; ivory, shell, and bone work, not including buttons, combs, or hairpins; ivory, shell, and bone work, not including combs and hairpins; signs and advertising novelties
fertilizers	fertilizers
files	files
firearms and ammunition	ammunition; ammunition and related products; fire-arms; firearms and ammunition
fire extinguishers chemical	fire extinguishers, chemical

fireworks	fireworks
flags banners regalia society badges and emblems	flags and banners; flags banners regalia society badges and emblems; flags banners regalia society banners and emblems; regalia and society banners and emblems; regalia, and society badges and emblems; regalia, badges, and emblems
flavoring extracts and flavoring sirups	cordials and flavoring sirups; cordials and sirups; flavoring extracts; flavoring extracts and flavoring sirups
flour mill and grist mill products	flour and other grain-mill products; flour-mill and gristmill products; flouring and gristmill products
food preparations	cereal preparations; feeds, prepared, for animals and fowls; food preparations; food preparations, not elsewhere classified; macaroni, spaghetti, vermicelli, and noodles
foundry and machine shop products	automobile repairing; bells; bridges; cast-iron pipe; engines, steam, gas, and water; engines, turbines, tractors, and water wheels; foundry and machine shop products; foundry and machine-shop products, not elsewhere classified; gas and oil stoves; gas machines; gas machines and gas and water meters; gas machines and meters; gas machines, gas meters, and water and other liquid meters; gas stoves; hardware; hardware saddlery; hardware, nec; iron and steel, cast-iron pipe; iron and steel, tempering and welding; iron and steel, welding; ironwork architectural and ornamental; lightning-rods; machine tools; machine-tool accessories and small metal working tools, not elsewhere classified; plumbers supplies; plumbers supplies, not elsewhere specified; plumbers supplies, not including pipe or vitreous-china sanitary ware; pumps (hand and power) and pumping equipment; pumps not including steam pumps; pumps, not including power pumps; pumps, steam; pumps, steam and other power; steam fittings and heating apparatus; steam fittings and steam and hot water heating apparatus; steel barrels, drums, and tanks; steel barrels, drums, and tanks, portable; steel barrels, kegs, and drums; stoves and furnaces including gas and oil stoves; stoves and hot-air furnaces; stoves and ranges (other than electric) and warm-air furnaces; stoves, gas and oil; structural and ornamental iron and steel work, not made in plants operated in connection with rolling mills; structural ironwork, not made in steel works or rolling mills; textile machinery and parts
foundry supplies	foundry supplies
fur goods	fur goods

furnishing goods mens	collars and cuffs, mens; furnishing goods mens; furnishing goods, mens, not elsewhere classified; gloves and mittens, cloth or cloth and leather combined, made from purchased fabrics; gloves and mittens, cloth, not including gloves made in textile mills; suspenders, garters, and elastic woven goods; suspenders, garters, and other elastic woven goods, made from purchased webbing
furniture and refrigerators	furniture; furniture and refrigerators; furniture factory product; furniture, cabinetmaking, repairing and upholstering; furniture, chairs; furniture, except rattan and willow; furniture, including store and office fixtures; furniture, store and office fixtures; furniture, wood, other than rattan and willow; refrigerators; refrigerators and refrigerator cabinets, exclusive of mechanical refrigerating equipment; refrigerators, mechanical
furs dressed	furs, dressed
galvanizing and other coating processes	galvanizing; galvanizing and other coating processes; galvanizing and other coating, not done in plants operated in connection with rolling mills
gas and electric fixtures and lamps and reflectors	gas and electric fixtures; gas and electric fixtures and lamps and reflectors; gas and electric fixtures lamps, lanterns, and reflectors; gas and lamp fixtures; lamps; lamps and reflectors
gas illuminating and heating	gas, illuminating and heating; gas, manufactured, illuminating and heating
glass	glass
glass cutting staining and ornamenting	glass cutting staining and ornamenting; glass products (except mirrors) made from purchased glass
gloves and mittens leather	gloves and mittens; gloves and mittens leather
glucose and starch	corn sirup, corn sugar, corn oil, and starch; glucose; glucose and starch; starch
glue and gelatin	glue; glue and gelatin; glue, not elsewhere specified
gold and silver leaf and foil	gold and silver leaf and foil
gold silver and platinum reducing and refining not from the ore	gold and silver reducing and refining not from the ore; gold, silver, and platinum, reducing and refining, not from the ore
graphite and graphite refining	graphite; graphite and graphite refining; graphite, ground and refined
grease and tallow	grease and tallow; grease and tallow, not including lubricating greases
grindstones	grindstones
hairwork	hair work
handstamps and stencils and brands	hand stamps and stencils and brands; hand-stamps; stencils and brands
hat and cap materials	hat and cap materials; hat and cap materials, mens

hats and caps not including wool hats	fur hats; hats and caps not including fur hats and wool hats; hats and caps other than felt straw and wool; hats and caps, except felt and straw, mens; hats and caps, not including wool hats; hats fur-felt; hats, straw; hats, straw, mens
hones and whetstones	hones and whetstones; hones whetstones and similar products
hosiery and knit goods	hand-knit goods; hosiery and knit goods; knit goods
housefurnishing goods not specified	house-furnishing goods, not elsewhere classified
ice manufactured	ice, artificial; ice, manufactured
ink printing	ink, printing
ink writing	ink, writing
instruments professional and scientific	instruments, professional and scientific
iron and steel blast furnaces steel works and rolling mills	ferroalloys; iron and steel; iron and steel blast furnaces; iron and steel, steel works and rolling mills
iron and steel bolts nuts washers and rivets	bolts, nuts, washers, and rivets, not made in plants operated in connection with rolling mills; iron and steel bolts nuts washers and rivets not made in steel works or rolling mills; iron and steel, bolts, nuts, washers, and rivets, not made in rolling mills; iron and steel, bolts,nuts,washers, and rivets
iron and steel doors and shutters	doors, shutters, and window sash and frames, metal; iron and steel doors and shutters
iron and steel forgings	forgings, iron and steel, not made in plants operated in connection with rolling mills; iron and steel forgings; iron and steel, forgings, not made in steel works or rolling mills
iron and steel nails and spikes cut and wrought including wire nails	iron and steel nails and spikes cut and wrought including wire nails; iron and steel, nails and spikes, cut and wrought, including wire nails, not made in steel works or rolling mills; nails, spikes, etc, not made in wire mills or in plants operated in connection with rolling mills
iron and steel pipe wrought	iron and steel, pipe, wrought; iron and steel, wrought pipe; wrought pipe, welded and heavy riveted, not made in plants operated in connection with rolling mills
jewelry	jewelry
jewelry and instrument cases	jewelry and instrument cases
labels and tags	labels and tags
lapidary work	lapidary work
lasts	lasts; lasts and related products
leather goods	bellows; leather goods; leather goods, nec; pocket books; pocketbooks, purses, and cardcases; saddlery and harness; trunks and valises

leather tanned curried and finished	leather morocco; leather tanned curried and finished; leather, dressed skins; leather, patent and enameled; leather, tanned and curried
lime and cement	cement; lime; lime and cement
liqours distilled	alcohol, ethyl, and distilled liquors; liquors, distilled; liquors, distilled, grain alcohol; liquors, distilled, grain alcohol and rum
liquors vinous	liquors vinous
looking glass and picture frames	looking glass and picture frames; mirror and picture frames
lumber and timber products	boxes, wooden packing except cigar boxes; boxes, wooden, except cigar boxes; boxes, wooden, packing; lumber and other mill products from logs or bolts; lumber and timber products; lumber and timber products, not elsewhere classified; lumber, planing mill products , including sash , doors, and blinds; lumber, planing-mill products, not including planing mills connected with sawmills; planing-mill products (including general millwork), not made in planing mills connected with saw mills; timber products, not manufactured at mill; window and door screens; window and door screens and weather strip; window and door screens and weather strips
malt	malt
marble and stone work	artificial stone; artificial stone products; concrete products; marble and stone work; marble, granite, slate, and other stone products; monuments and tombstones
masonry brick and stone	masonry brick and stone
matches	matches
mattresses and spring beds	mattresses and bed springs, not elsewhere classified; mattresses and spring beds; mattresses and spring beds not elsewhere specified
millinery and lace goods	embroideries; handkerchiefs; millinery; millinery and lace goods; millinery and lace goods, not elsewhere specified; trimmings (not made in textile mills) and stamped art goods for embroidering
minerals and earths ground	kaolin and ground earths; kaolin and other earth grinding; minerals and earths, ground or otherwise treated
mirrors	mirrors; mirrors, framed and unframed; mirrors, framed and unframed, not elsewhere specified
models and patterns not including paper patterns	models and patterns; models and patterns not including paper patterns
mucilage and paste	mucilage and paste; mucilage, paste, and other adhesives, except glue and rubber cement; mucilage, paste, and other adhesives, not elsewhere specified

musical instruments pianos and organs and materials	musical instrument parts and materials piano and organ; musical instruments - organs; musical instruments and materials not specified; musical instruments and parts and materials, not elsewhere classified; musical instruments pianos and materials; musical instruments pianos and organs and materials; musical instruments, organs and materials; musical instruments, piano and organ materials; musical instruments, pianos
needles pins and hooks and eyes	hooks and eyes; needles and pins; needles, pins, and hooks and eyes; needles, pins, hooks and eyes, and snap fasteners
nonferrous metal alloys and products not including aluminum products	babbitt metal and solder; brass; brass and bronze products; brass and copper, rolled; brass castings and brass finishing; brass, bronze, and copper products; brass, ware; lead, bar pipe and sheet; nonferrous-metal alloys and products, not including aluminum products
oilcloth and linoleum	linoleum; oilcloth; oilcloth and linoleum; oilcloth and linoleum floor; oilcloth, enameled; oilcloth, floor
oil cottonseed and cake	oil and cake, cottonseed; oil cottonseed and cake; oil, cake, and meal, cottonseed
oil essential	oil essential; oils - essential
oil linseed	oil, cake, and meal, linseed; oil, linseed
oleomargarine	oleomargarine; oleomargarine and other butter substitutes; oleomargarine, not made in meat-packing establishments
optical goods	optical goods
paints and varnishes	paint and varnish; paints; paints and varnishes; varnish; varnishes
paper and wood pulp	paper; paper and wood pulp; pulp (wood and other fiber); pulp,wood
paper goods not specified	envelopes; paper goods, not elsewhere classified
patent medicines and compounds and druggists preparations	druggists preparations; druggists preparations not including prescriptions; patent and proprietary medicines; patent medicines and compounds; patent medicines and compounds and druggists preparations; patent or proprietary medicines and compounds; perfumery and cosmetics; perfumes, cosmetics, and other toilet preparations
paving materials	paving and paving materials; paving materials; paving materials asphalt, tar, crushed slag, and mixtures
pencils lead	pencils lead; pencils, lead (including mechanical)
pens fountain stylographic and gold	pens fountain stylographic and gold; pens, fountain and stylographic; pens, fountain and stylographic pen points, gold, steel, and brass; pens, gold
petroleum refining	petroleum refining
phonographs and graphophones	phonographs; phonographs and graphophones

photo engraving	photo-engraving, not done in printing establishments; photoengraving; photolithographing and engraving; photolithographing and photoengraving
photographic apparatus and materials	photographic apparatus; photographic apparatus and materials; photographic materials
pipes tobacco	pipes tobacco
plumbing and gas and steam fitting	plumbing and gas and steam fitting; plumbing and gasfitting
pottery terracotta and fire clay products	pottery; pottery terra-cotta and fire-clay products; pottery, earthen and stone ware; pottery, including porcelain ware
printing and publishing	bookbinding and blank-book making; engraving steel including plate printing; engraving, steel and copper plate, including plate printing; engraving, steel and copper plate, including preprinting; engraving, steel and copperplate, and plate printing; lithographing; lithographing and engraving; paper patterns; printing and publishing; printing and publishing, book and job; printing and publishing, book and job job printing; printing and publishing, job printing; printing and publishing, music; printing and publishing, newspaper and periodical; printing and publishing, newspapers and periodicals; printing,tip
pulp goods	pulp goods
railroad cars	cars steam-railroad not including operations of railroad companies; cars street-railroad not including operations of railroad companies; cars, electric and steam railroad, not built in railroad repair shops
rice cleaning and polishing	rice cleaning and polishing
roofing materials	roofing and roofing materials; roofing materials; roofing, built-up and roll asphalt shingles roof coatings other than paint
rubber goods not specified	rubber and elastic goods; rubber goods (other than rubber boots and shoes) and rubber tires and inner tubes; rubber goods other than tires, inner tubes, and boots and shoes; rubber goods, not elsewhere specified; rubber tires and inner tubes; rubber tires, tubes, and rubber goods, not elsewhere specified
safes and vaults	safes and vaults
salt	salt
sand and emery paper and cloth	sand and emery paper and cloth; sandpaper, emery paper, and other abrasive paper and cloth
saws	saws
scales and balances	scales and balances
screw machine products and wood screws	screw-machine products and wood screws; screws wood; screws, machine
sewing machines cases and attachments	sewing machine cases; sewing machines and attachments; sewing machines cases and attachments

shipbuilding	ship and boat building wooden; ship and boat building, steel and wooden, including repair work; shipbuilding; shipbuilding including boat building; shipbuilding iron and steel; shipbuilding, steel; shipbuilding, steel, new vessels; shipbuilding, steel, new vessels and repair work; shipbuilding, steel, new vessels and small boats; shipbuilding, wooden, including boat building
silk and silk goods including throwsters	silk and rayon manufactures; silk and silk goods; silk and silk goods including throwsters; silk goods; silk goods, including throwsters
silverware and platedware	plated and britannia ware; plated ware; silver ware; silversmithing; silversmithing and silverware; silverware and plated ware
slaughtering and meat packing	meat packing, wholesale; sausage; sausage, meat puddings, headcheese, etc, and sausage casings, not made in meat-packing establishments; sausage, not made in slaughtering and meat-packing establishments; slaughtering and meat packing; slaughtering and meat packing wholesale; slaughtering wholesale not including meat packing
smelting and refining copper	copper smelting and refining; smelting and refining copper
smelting and refining lead	lead smelting and refining; smelting and refining, lead
smelting and refining not from the ore	smelting and refining; smelting and refining not from the ore; smelting and refining, metals other than gold, silver, or platinum, not from the ore
smelting and refining zinc	smelting and refining, zinc; zinc smelting and refining
soap and candles	candles; soap; soap and candles
soda water apparatus	soda-water apparatus
sporting and athletic goods	sporting and athletic goods; sporting and athletic goods, not including firearms or ammunition; sporting goods
springs steel car and carriage	springs steel car and carriage; springs, steel, car and carriage, not made in steel works or rolling mills; springs, steel, except wire, not made in plants operated in connection with rolling mills
stationery goods not specified	stationery goods not elsewhere specified
steam packing	steam and other packing, pipe and boiler covering, and gaskets, not elsewhere classified; steam packing
stereotyping and electrotyping	stereotyping and electrotyping; stereotyping and electrotyping, not done in printing establishments
sugar and molasses beet	beet sugar; sugar and molasses beet; sugar, beet
sugar and molasses not including beet	sugar and molasses; sugar and molasses refining; sugar refining, cane; sugar, cane; sugar, cane, not including products of refineries; sugar, refining, not including beet sugar

surgical appliances and artificial limbs	artificial limbs; surgical and orthopedic appliances, including artificial limbs; surgical appliances; surgical appliances and artificial limbs
tobacco manufactures	cigars and cigarettes; tobacco cigars and cigarettes; tobacco manufactures; tobacco stemming and rehandling; tobacco, chewing and smoking, and snuff; tobacco, chewing, smoking and snuff; tobacco, cigars; tobacco, smoking; tobacco, smoking, and snuff
tools not including edge tools machine tools files or saws	tools, not including edge tools, machine tools, files, or saws
toys and games	toys (not including childrens wheel goods or sleds), games, and playground equipment; toys and games
trunks suitcases and bags	trunks, suitcases, and bags
turpentine and rosin	tar and turpentine; turpentine and rosin
type founding and printing materials	printing materials; printing materials, not including type or ink; type founding; type founding and printing materials
typewriters and supplies	typewriters and parts; typewriters and supplies
umbrellas and canes	umbrellas and canes; umbrellas, parasols, and canes
upholstering materials	hair-cloth; upholstering materials; upholstering materials, excelsior; upholstering materials, not elsewhere specified; upholstery materials
vinegar and cider	vinegar; vinegar and cider
wallpaper	paper hangings; wall paper; wallpaper, not made in paper mills
washing machines and clothes wringers	washing machines and clothes wringers; washing machines, wringers, driers, and ironing machines, for household use
waste	cotton waste; waste; waste, cotton
whips	whips
windmills	windmills; windmills and windmill towers
window shades and fixtures	window shades; window shades and fixtures
wire	wire; wire, drawn from purchased bars or rods
wirework not specified	wirework; wirework, including wire rope and cable; wirework, not elsewhere classified
wood preserving	wood preserving
wood turned and shaped and other wooden goods not specified	cooperage; cooperage and wooden goods not elsewhere specified; wood, turned and carved; wood, turned and shaped and other wooden goods, not elsewhere classified; wooden goods, not elsewhere specified
woolen worsted and felt goods and wool hats	felt goods; felt goods, wool, hair, or jute; hats, wool-felt; wool hats; wool pulling; wool scouring; wool shoddy; woolen and worsted goods; woolen goods; woolen worsted and felt goods and wool hats; worsted goods

D.3 Income distribution by Dutch municipality

1883

The main source of the data reports the income distribution of 79 municipalities. I added data on the income distribution for 8 large municipalities with an income tax. The data for each additional cities derives from the same source as the other 79 municipalities. Table D.3 documents the relevant year that the income distribution was measured and the source of the data.

TABLE D.3: Sources of income distribution data for 8 additional cities

City	Year	Archive	Source
Breda	1881	Stadsarchief Breda	Municipal year report ("Gemeenteverslag") 1880
Delft	1893	Stadsarchief Delft	Municipal year report ("Gemeenteverslag") 1893
Eindhoven	1885	RHC Eindhoven	Original assessment lists, archive number 10246.925
Enschede	1880	Stadsarchief Enschede	Original assessment lists, archive number 1.1226
Hilversum	1880	Archive Prof. Van Zanden	Original assessment lists
Nijmegen	1880	Regionaal Archief Nijmegen	Overview by income class, archive number 2.14167
Utrecht	1888	Utrechts Archief	Municipal year report ("Gemeenteverslag") 1900
Vlissingen	1883	Zeeuws Archief	Original assessment lists, available here.

D.4 Matching the inheritance tax records to the civil registry

I first download all deaths recorded between 1879 and 1927 in the civil registry databases from four regional archives, each covering the near-universe of deaths in their province: Brabants Historich Informatie Centrum (Noord-Brabant), Collectie Overijssel (Overijssel), Gelders Archief (Gelderland), Noord-Hollands Archief (Noord-Holland). These datasets contain high quality hand-collected information on each deaths. While the type of information that was digitized varies somewhat by archive, each archive has digitized the name(s) of the decedent and their parents, the date of death, the sex, and the place of death. In all cases except Noord-Brabant, the age at death was also collected. Amsterdam is the only place in the regions covered for which digitized records of the civil death registry are not available. To maximize the amount of information available for each person that appears in the death records, I also link the civil death records to the civil marriage and birth records.

The inheritance tax records were ordered by place and date of death. Furthermore, all decedents on the same inheritance tax table share the same first letter of the surname.

For instance, Figure D.1 shows a page for individuals with last names starting with the letter ”O”. I use this to narrow down the possible matches in the civil registry data for each person in the inheritance tax data. In record linking terminology, I use the relevant image set and the first letter of the surname as *blocking variables* for the linking between the inheritance tax records and the civil registry data. This generates for each individual in the inheritance tax records, a set of possible matches from the civil registry.

From the set of available matches, I choose the most appropriate match (if any) by using a heuristic multi-stage matching algorithm. The algorithm takes into account information on the name, the date of death, and the date of birth.

E Details on steam engine and electric motor costs

In this section, I explain in detail the sources, assumptions and computations underlying the average and marginal cost curves of steam engines and electric motors shown in Figures 4 and A.2. The underlying data for steam engines, taken directly from (Emery, 1883), are displayed in Table E.1. The data for electric motors, from (Bolton, 1926), are displayed in Table E.2. I take these to be a full description of the costs.

TABLE E.1: Cost parameters (in \$, 1874) of steam engines of different capacities

	Purchase costs		Yearly operating costs (\$)				
HP	Price (\$)	Life (yrs)	Engineer	Firemen	Oil, etc.	Repairs	Coal
5	645	30	540.75		61.80	40.17	226.64
10	988	30	540.75		77.25	49.44	412.44
15	1487	30	618.00		83.43	52.53	568.33
20	1981	30	618.00		92.70	67.98	647.14
25	2441	30	695.25		101.90	83.43	752.41
50	5331	30	618.00	432.60	111.24	135.96	1202.82
100	9207	30	695.25	463.50	123.60	237.93	1898.28
150	13046	30	772.50	463.50	145.23	309.00	2718.00
200	16785	30	772.50	463.50	169.95	383.16	3603.86
250	20426	30	849.75	463.50	200.85	454.23	4504.68
300	23899	30	927.00	463.50	247.20	525.30	5406.08
400	29958	30	927.00	695.25	293.55	679.80	7207.72
500	36220	30	927.00	927.00	355.35	886.83	9009.94

Source: (Emery, 1883, p. 430).

Both the coal and electricity input costs are based on the assumption that the engine/motor is run at capacity 309 days per year, 10 days per hour. For steam engines, coal input data comes directly from (Emery, 1883). For electric motors, I computed the cost using electricity prices. For example, running a 1 horsepower electric motor at full capacity for 309×10 hours requires 3090 horsepower-hour, which corresponds to $0.7457 \times 3090 \approx 2304$ kWh. The price of electricity per kWh in the UK in 1925 was £0.00687.

From the data in Tables E.1 and E.2, I compute the annualized cost of purchase and renewal using the sinking fund formula:

$$\text{Annualized purchase cost} = \text{Price} \times \frac{r}{(1+r)^{\text{Life}} - 1}. \tag{41}$$

I set the interest rate r equal to 0.05. Then, for example, the annualized cost of renewal of a 5 horsepower steam engines every 30 years becomes \$9.71. In other words, with an

TABLE E.2: Cost (in £, 1925) of electric motors (squirrel-cage induction motors) of different capacities

		Purchase costs		Electricity input	
HP	Efficiency	Price (£)	Life (yrs)	kWh	£
1	0.770	12.90	15	2304	15.83
2	0.787	14.50	16	4608	31.66
3	0.800	16.20	17	6913	47.49
5	0.820	22.20	18	11521	79.15
7.5	0.833	26.80	18	17282	118.72
10	0.840	31.50	19	23042	158.30
15	0.853	39.25	19	34563	237.45
20	0.860	46.20	20	46084	316.60
25	0.870	52.80	20	57605	395.75
30	0.875	58.80	20	69126	474.90
40	0.885	69.90	20	92169	633.20
50	0.890	81.25	20	115211	791.50
60	0.900	92.00	20	138253	949.80
80	0.910	110.50	20	184337	1266.40
100	0.915	132.20	20	230421	1582.99

Notes: The price of electricity per kWh in 1925 was £0.00687 (Hannah, 1979). *Source of all other data*: (Bolton, 1926, p. 344).

interest rate of 5 percent, a deposit of $9.71 each year would yield $645 every 30 years. From there, the total annual costs per horsepower per year are calculated as the sum of the annualized purchase costs and the yearly operating costs. Figure 4 illustrates the data on cost per horsepower per year tabulated in Table E.3.

TABLE E.3: Total and per horsepower annualized cost of purchase, renewal, maintenance and operation (including and excluding of fuel) of a steam engine and electric motor of different sizes at capacity for 309 days, 10 days per hour.

	Steam engines (in 1874 $)				Electric motors (in 1925 £)			
	Excl. fuel		Incl. fuel		Excl. fuel		Incl. fuel	
HP	Total	Per HP	Total	Per HP	Total	Per HP	Total	Per HP
1					0.60	0.78	16	21
2					0.61	0.39	32	21
3					0.63	0.26	48	20
5	652	130	879	176	0.79	0.19	80	19
7.5					0.95	0.15	120	19
10	682	68	1095	109	1.03	0.12	159	19
15	776	52	1345	90	1.29	0.10	239	19
20	808	40	1456	73	1.40	0.08	318	18
25	917	37	1670	67	1.60	0.07	397	18
30					1.78	0.07	477	18
40					2.11	0.06	635	18
50	1378	28	2581	52	2.46	0.06	794	18
60					2.78	0.05	953	18
80					3.34	0.05	1270	17
100	1659	17	3557	36	4.00	0.04	1587	17
150	1887	13	4605	31				
200	2042	10	5646	28				
250	2276	9	6780	27				
300	2523	8	7929	26				
400	3047	8	10254	26				
500	3641	7	12651	25				

Notes: To compute the cost per horsepower per year for electric motors, an efficiency loss relative to capacity that varies across sizes is taken into account (see Table E.2).

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