Power for progress: The impact of electricity on individual labor market outcomes

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Abstract

How does new technology impact labor market outcomes? We address this question by examining the adoption of electricity in Sweden during the early 20th century using detailed individual-level data that covers the entire labor market. Leveraging exogenous variation in electricity access driven by proximity to hydro-power plants, we estimate the impact of electrification on individual labor market outcomes. Our findings show that individuals in electricity-adopting parishes earned significantly higher incomes than comparable individuals in control areas. The income gains were particularly pronounced among lower-income workers and those with only primary education, leading to a reduction in income inequality. These effects held across labor markets with both strong and weak union presence, suggesting that electricity functioned as a labor-supporting technology. Our results highlight how specific technologies shape individual outcomes and income distributions.

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1 Introduction

Since at least the writing of Ricardo (1821) there has been a concern that new technology will be detrimental to the laboring class. New technology impacts the labor market by changing the content of work, thereby destroying some jobs while creating new ones. The Skill-Biased Technical Change (SBTC) hypothesis suggests that the less educated suffer the most, as new technology tends to replace positions requiring lower skills more quickly. A common concern is therefore that technology-driven increases in skill requirements will lead to exacerbated wage inequality if education levels lag behind (Katz and Murphy, 1992; Autor et al., 1998), and already in the 1970s Tinbergen (1975) famously suggested that the long-run wage evolution should resemble a "race between technological development and access to education".[1] Recently, scholars have extended the analysis to suggest that broader societal institutions, such as strong labor unions, are necessary to ensure that low-income groups benefit from technological progress. Studying the impact of exposure to Computer Numerical Control (CNC) for factory automation, Boustan et al. (2022) find that the new technology resulted in rising total employment, highlighting that employment gains were strongest for unionized jobs.

Based on previous findings, concerns abound that the current wave of automation will be detrimental to workers' interests, especially since it coincides with declining union membership and weakening societal safety nets. The current situation is sometimes contrasted with the early 20$^{\text{th}}$ century, when strong labor organizations and expanding educational systems ensured that workers shared in the rising prosperity (see for example Frey (2019), or Acemoglu and Johnson (2023)).

In this paper, we revisit Sweden in the early decades of the 20$^{\text{th}}$ century to analyze the impact of new technology on individual outcomes in the labor market. Our focus is on electricity, the most significant technological innovation of the period. Electricity played a key role in reforming production methods through mechanization, but it also had the potential to eliminate many jobs previously done by hand, as it allowed traditional workflows to be reorganized away from conventional energy sources like water power. In industry, the unit drive placing one motor per machine revolutionized the organization of the factory floor and made for a safer and cleaner work environment. At the same time, running boys, helpers, and boilers crucial to the old factory organization were rationalized away from the labor market. In agriculture, the introduction of electric-powered equipment allowed farmers to accomplish more work in less time with fewer people.

Given the revolutionary character of this technological shift, the impact of electricity on local labor markets was likely substantial and could have posed a risk of technological unemployment. Yet, observers note a relative absence of

[1]The effects on the incomes and skills distributions have been debated. Autor et al. (2015) compare the impact of trade and technology and find that labor markets vulnerable to computerization undergo occupational polarisation but, unlike labor markets susceptible to import competition, do not exhibit a net decline in employment.

resistance to technological change during this period, in stark contrast to the famous Luddite movement and the numerous violent uprisings against machinery in the 19^{th} century (Frey, 2019). One possible explanation is that labor unions, which had begun forming and gaining influence at the turn of the century, managed to guide technological change in ways that benefitted workers (Acemoglu and Johnson, 2023)[2]. An alternative interpretation suggests that, unlike the labor-replacing technologies of the First Industrial Revolution, the technologies of the Second Industrial Revolution predominantly created jobs, leading to increased employment opportunities and reduced unemployment as direct outcomes of technological advancement (Alexopoulos and Cohen, 2016).

We contribute to the debate on the impact of revolutionary technologies on the labor market by examining the impact of electrification on employment and incomes from digitized censuses. Exploiting the fact that access to electricity was rolled out in a quasi-exogenous fashion connecting Sweden's two largest hydroelectric power stations at the time (Olidan and Älvkarleby), we can pinpoint places that gained access to stable and reliable electricity, providing them with an advantage over other, comparable areas. The location of the power plants was selected due to their superior natural capacity for hydroelectricity generation. The linking grid, called Western Line (Centralblocket), served as the initial pillar of "the electric mainline system" and was completed in 1921. It connected Olidan and Älvkarleby in a straight-line manner independent of previous local conditions.

Evidence shows that penetration of electricity was early in Sweden. By the early 20^{th} century, electric motors had become affordable, costing around 420 SEK— less than the annual wage of an unskilled worker. Historical sources list how farms and businesses closer to power plants electrified early (ASEA, 1912; Morell, 2001). ASEA (1912) details how electric motors could handle common tasks on e.g. farms and were portable, making them versatile for various uses. Figure 1 illustrates the early spread of electricity among rural parishes in Sweden. Between 1915 and the early 1920s, the share of electrified rural households grew rapidly. By 1930, over one-third of these households had access to electricity, and after the war, electrification continued to expand, eventually reaching nearly the entire population. By the 1960s, electrification was almost complete, and most households relied on electric power for everyday needs such as washing machines, refrigerators, cookers, vacuum cleaners, and irons.[3] By examining outcomes in the 1930s comparing areas strategically situated along this line, with similar unconnected areas, we may estimate the effect of electricity before it encompassed the entire population.

[2] Molinder et al. (2021) show, for example, that electrification increased the prevalence of strikes, and that these strikes were often "offensive" in nature, with workers—empowered by the new technology—demanding higher wages. While Molinder et al. (2021) focus on the period until 1920 and analyze how electrification affected the prevalence of technology-driven labor market conflicts, this paper examines individual income effects in 1930, introducing heterogeneous effects by interacting with educational and institutional variables not previously included.

[3] Because of its lack of domestic coal and oil, Sweden became the first country in the world to electrify nearly all households.

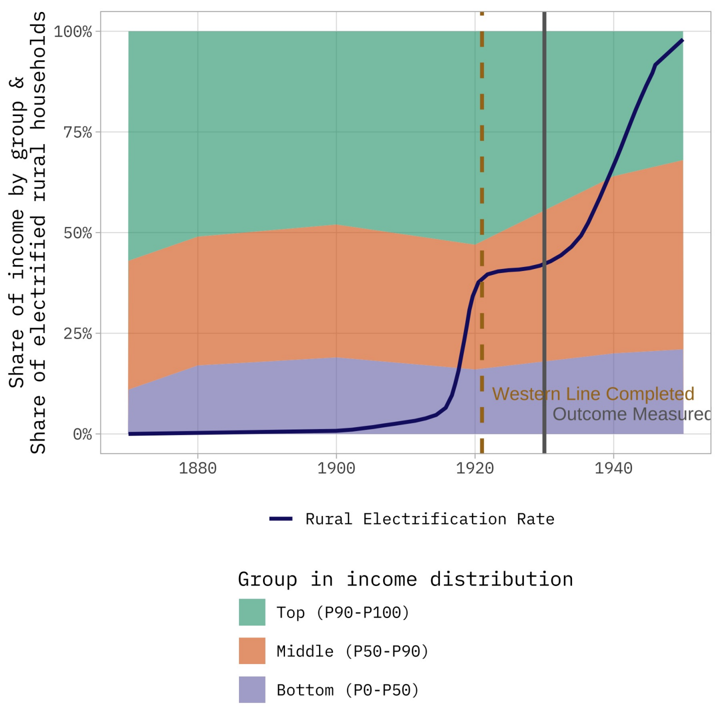

Figure 1: Evolution of income shares in Sweden and rural electrification rate.
Notes: The figure shows the evolution of income shares across three income groups — The Top (P90-P100), Middle (P50-P90), and Bottom (P0-P50) — and the rural electrification rate in Sweden from 1870 to 1950. The dark blue line represents the share of rural households with access to electricity, sourced from Vattenfall (1948). The shaded areas represent the share of total income held by each group, as calculated by Bengtsson et al. (2021a). The vertical dashed line marks the completion of the Western Line, while the solid vertical line highlights the year 1930 when outcomes from the census are measured.

During electrification, Sweden also experienced significant institutional and social changes. Between 1890 and 1930, GDP per capita in constant SEK nearly tripled (Schön and Krantz, 2012), yet inequality declined as the bottom and middle segments of the income distribution gained a larger share of total income—at the expense of the top 10 percent, as shown in Figure 1.

Our findings reveal that individuals born in Western Line parishes earned over 30 percent higher incomes by 1930. When we examine the impacts across the income distribution we find that gains were concentrated at the lower end, resulting in reduced inequality in the Western Line parishes. Putting these results in the historical context of the period, we suggest that electrification resulted in an average income growth of about 29 percent between 1910 and 1940, which amounts to about 12 percent of the overall market income growth of 230 percent over the same period (Roine and Waldenström, 2010). Since the positive impact of electricity on income was concentrated at the bottom end of the income distribution, it accounts for an even larger share of income growth for these groups.

Of course, the expansion of electricity was only one of many changes during this period, including the First World War, the 1920s crisis, and the Great Depression. These events coincided with rapid technological change, a continued shift away from agriculture, rising union density, and the further growth of Sweden's internationally competitive engineering industry. In line with this, previous research suggests that Swedish workers emerged relatively unscathed from these disruptions, as real wages continued to rise throughout the period. Although all of these factors undoubtedly contributed to increasing wages and reducing inequality, a back-of-the-envelope calculation indicates that the spread of electricity alone can account for most of the decrease in the Gini coefficient between 1900 and 1940. Our findings therefore suggest that Sweden's labor market institutions were bolstered by the early penetration of labor-enhancing technology.

In terms of occupational change, we observe that individuals born in Western Line parishes were more likely to be employed in occupations enhanced by electrification, such as electricity workers and linemen, as well as in low- and medium-skilled occupations in manufacturing. The jobs that were replaced were mainly unskilled occupations in agriculture, where we see an increase in the share of independent farmers, but we do not see a general shift away from agriculture.

Further decomposing the income effect, we show that less than one-third of the effect was explained by occupational change, whereas most (about two-thirds) took place within broad occupational categories. This suggests that electricity benefited workers broadly, independent of their relative occupational specialization. Exploring heterogeneous effects, we investigate the interaction between education and electricity and find that the most substantial effects emerged among those with primary education only. However, we do not observe any interaction effect between local union strength and the income distribution; the inclusive profile of this new technology appears in areas with both strong and weak unions.

1.1 Relation to earlier literature

We contribute to the literature in several ways. First, by examining a comparative case from an earlier wave of technology adoption, we add to the debate on the role of technology's inherent characteristics for inequality outcomes. This discussion has recently gained renewed attention in light of findings that suggest new generative AI tools disproportionately benefit lower-skilled workers. The current wave of technological change may thus produce equalizing outcomes that diverge from the skill-biased, wage-polarizing effects of computerization just a few decades ago (e.g., Noy and Zhang, 2023; Brynjolfsson et al., 2023). By investigating the role of institutions—particularly education and local union presence—in moderating technology's impact, we join a growing literature on the importance of labor market institutions in harnessing the benefits of new technologies (Acemoglu and Johnson, 2023; Boustan et al., 2022). Sweden serves as an ideal testing ground for this hypothesis, as previous work has documented electrification's effect on "offensive" strikes (Molinder et al., 2021) and argued that strong labor market institutions helped mitigate potential inequality-inducing forces of the technology (Prado and Theodoridis, 2017; Bengtsson, 2019). Given that lagging education often contributes to rising income inequality in the face of technological change (Katz and Murphy, 1992; Autor et al., 1998), it is especially valuable to analyze income outcomes for workers with varying education levels. To our knowledge, this is the first study to test how new technology affects incomes and inequality by comparing the roles of institutions (unions and education) with the technology's intrinsic characteristics.

Second, our paper expands the literature on labor market outcomes by placing explicit focus on the income distribution. While a large body of research documents the growth-promoting effects of electrification, with some studies suggesting that wealthier households benefit the most (Khandker et al., 2014) and others finding a hollowing out of the skill distribution (Gray, 2013), our evidence points to the most substantial effects at the lower end of the income and skill distributions. Existing research on historical electrification has largely centered on industry- or municipal-level outcomes. Individual-level evidence typically concerns other labor market measures: for instance, Vidart (2024) on female labor market outcomes, Gaggl et al. (2021) on changes in employment structure, Fiszbein et al. (2020) on manufacturing productivity, or Leknes and Modalsli (2020) who link municipal-level data with individual census records to study occupational mobility. In terms of occupational upgrading, our results support the upward mobility of the lowest skilled that has previously been demonstrated from Norway (Leknes and Modalsli, 2020). By concentrating on income effects among workers in electricity-related jobs versus other occupations, we can distinguish direct income gains from indirect spillover effects.

Third, we contribute to the expanding debate on how electricity shapes labor markets, including its roles in structural change, occupational mobility, and long-term agglomeration. Ample evidence highlights electricity as a catalyst for economic development, with studies documenting, for example, increases in manufacturing output in India (Rud, 2012) and improvements in housing values and the Human Development Index in Brazil (Lipscomb et al., 2013). Kline and Moretti (2014) found long-lasting impacts in terms of local economic development in the USA and Brey (2021) found lasting effects in Switzerland. Further research has illuminated the mechanisms linking electrification with development, including female participation in the labor force (Dinkelman, 2011), better educational outcomes (Khandker et al., 2009), children substituting wood collection time for studying (Khandker et al., 2014), and improved health through reduced indoor air pollution.[4] Regarding structural change, Gaggl et al. (2021)

[4] For a methodological survey of the extensive literature on household and rural electrification programs, see Lee et al. (2020).

show that electrification spurred manufacturing growth not only in urban centers but also in predominantly rural areas as of 1910. These findings conflict with those of Lewis and Severnini (2020), who find that electrification slowed structural change by temporarily expanding the agricultural sector, thereby benefiting rural areas between 1930 and 1960. Our results suggest that electricity did not drive structural change away from agriculture broadly, but that electricity impacted work processes in a way that can best be described as occupational upgrading. The results on structural change are in line with the late US experience (1930-1960), when electrification reached farms in rural areas and slowed down the rate of structural transformation (Lewis and Severnini, 2020).[5]

Much of the historical literature has focused on the United States, yielding mixed results. A recent study on electrifying manufacturing firms presents evidence of skill-biased technical change, indicating that electricity boosted wages most for top earners (Damron, 2025), while others report a hollowing out of the skill distribution (Gray, 2013) or even deskilling (Fiszbein et al., 2020) in the manufacturing sector. While these studies center on U.S. manufacturing, our focus is on the entire labor market. We find that electrification primarily benefited lower-wage, lower-skilled workers, thus raising overall incomes and reducing inequality. Instead of polarizing the labor market, electrification in Sweden particularly elevated wages among workers with only primary education, and these gains occurred across occupational groups and in both unionized and non-unionized areas.

2 Measuring individual-level outcomes

The analysis in the paper relies on the digitized decennial full-count historical Swedish censuses. In the baseline specification, we focus on individual-level outcomes measured in 1930 associated with being born in a parish located along the Western Line prior to electrification. We utilize the 1890 and 1900 censuses to measure characteristics of childhood parishes and to balance on pre-trends. The 1930 census is unique in the Swedish context because, in addition to demographic and other characteristics such as sex, age, marital status, occupation, and parish of birth available in earlier censuses from 1880 to 1910, it also includes information on income, wealth, and education. While the 1890, 1900, and 1910 digitization is complete, for 1930 we make use of data from the roughly 30 percent of parishes that have so far been digitized by the Swedish National Archive (*Riksarkivet*). Unfortunately, later censuses are not available in digital form.

To ensure that our sample is not biased in terms of social structure, we run a regression on probability of being included in the sample based on all available HISCLASS parish characteristics in 1900. We do not see any systematic differences between the samples as evidenced in Table 9 in Appendix A.1.[6]

[5] The discrepancy between Lewis and Severnini (2020) and Gaggl et al. (2021) can be reconciled by noting that agriculture was not electrified until after 1930, when it experienced a productivity surge (Kitchens and Fishback, 2015). Therefore, the initial wave of electrification mostly favored manufacturing, whereas agriculture also reaped benefits in the post-1930 era.

[6] See Appendix for further explanations A.1.

Income data are drawn from tax registers and measure gross income from all sources for individuals earning above the tax threshold, which was 600 crowns in 1930. This limit can be compared to the typical wages in 1930 for some low-income groups, such as male agricultural laborers who earned just over 1,000 crowns, and female servants in agriculture who earned slightly less than 900 crowns. Male workers in a typical low-wage industry such as textile and clothing earned more than 2,000 crowns while for women the figure was just above 1,500 crowns. Even minors in this sector earned enough to pay taxes, around 800 crowns.[7] Consequently, in our data, more than 80 percent of men and 30 percent of women aged 20 to 60 reported income.

Occupations in 1890, 1900, and 1930 have been coded into the HISCO and HISCLASS schemes. The Historical International Standard Classification of Occupations (HISCO) was created to compare historical occupational data across different regions and periods. Codes can comprise one to five digits, from broad (e.g. sales workers) to specific (e.g. watch and clock makers). We elect to use two-digit HISCO codes to control for occupation in our analysis, which is a rich control, without creating too much sparsity in our controls. In our dataset, we observe 74 of the 83 possible HISCO two-digit minor groups. The HISCLASS (historical international social class) scheme, introduced in van Leeuwen and Maas (2011), builds on HISCO, where historical occupations are coded into six-digit codes indicating one of 1,600 possible unit groups (van Leeuwen et al., 2002). HISCLASS codes each HISCO occupation into one of twelve social classes ranging from "1. Higher managers" to "12. Unskilled farm workers".[8]

To assess the impact of electricity on occupational change, we manually code occupational titles from the 1930 census into categories distinguishing between jobs directly and indirectly impacted by electricity, and those that were less affected. Occupations deemed directly related are those prefixed with "*El-*" (Electricity-) or similar, indicating a role intimately connected with the emergent technology. Examples include *Elektriker* (Electrician), *Elinstallatör* (Electrical Installer), and *Linjearbetare* (Lineman). Following the same logic, indirectly related jobs are those in which electricity had the potential to significantly enhance productivity and to reshape the work processes. This category encompasses a variety of roles in manufacturing that involve operating and managing machinery, such as *Sågverksarbetare* (Sawmill Worker), *Textilarbetare* (Textile Worker), and *Maskinist* (Machinist). This is not to say that other jobs were

[7] Information on wages comes from the official wage statistics collected by Statistics Sweden and digitized by the Historical Labor Database (HILD) project.

[8] The scheme is based on three levels of differentiation: between manual and non-manual work, between levels of skill, and whether the occupation involves a supervisory role. Although the HISCLASS scale, which runs from one to twelve, is nominal, it can be read as a ranking where "Higher managers" have the highest social status and "Unskilled workers" have the lowest. An exception to this rule is "8. Farmers and fishermen," which constitute their own social class. The occupations included in this group involve people who have a wide range of skills and exercise a wide range of degrees of supervision. The scheme also divides low-skilled and unskilled workers between the primary sector and the rest of the economy. This means that a move in the ranking from group nine, "Low-skilled workers," to group ten, "Low-skilled farm workers," does not mean a drop in social status, but rather a change of sector.

not affected by electricity, either directly, or through general equilibrium effects altering their demand. This categorization, however, pinpoints the type of jobs that were most likely to be significantly impacted by the advent of the new technology.

The level of education is recorded in the 1930 census as the highest level of education attained by an individual. Based on this information, we construct an indicator that categorizes education levels into four groups: "less than primary education", "primary education", "secondary education", and "tertiary education".

3 Electricity and Local Technological Change

3.1 The Expansion of the Power Grid

Electricity has been described as the most important general purpose technologies (GPTs) of our century (David, 1990; Jovanovic and Rousseau, 2005). It plays a central role in the rapid productivity advances of the interwar period, when discoveries from the 1920s increased productivity growth to such an extent that Alexander Field (2003) labeled the 1930s "the most technologically progressive decade of the 20$^{\text{th}}$ century".

The invention of three-phase alternating current made it possible to transfer electricity through high-voltage cables, enabling, for the first time, the production and consumption of energy in different locations. In 1890, the Swedish engineer Jonas Wenström patented the components of a three-phase electrical power system. He was not alone in his technical insights—Michael Dolivo-Dobrowolsky had filed a patent for three-phase alternating current one year earlier—but Wenström's patent was the first to involve a complete system with an electricity generator, transformer, and motor. Sweden was one of the first countries to experiment with the new technology and the Swedish state was the first in the world to get engaged in the commercial running of power plants when The Royal Waterfall Board (*Kungliga Vattenfallsstyrelsen*) was established in 1907 with the goal of utilizing water power for electricity generation (Stymne, 2002).[9] The rapid adoption of electricity is evidenced in Figure 2 where Schön (2000) shows that in the three decades between 1900 and 1930, electricity as a share of energy use increased among the most energy intensive industries (iron and steel, pulp and paper and chemical industries) from an average of 8 percent to 80 percent. But even for less energy-intensive industries, such as the food industry, electricity's share of total energy use was over 50 percent by 1930.

Due to disparities in the natural resources available, Olidan and Älvkarleby were the natural candidate sites for large water power plants. The connecting grid was called the Western Line and became a first cornerstone in a strategic

[9] The incentives to electrify were strong. Lacking domestic coal, Swedish industrialization had previously been dependent either on imported coal or on early turbines generating water power from nearby waterfalls.In 1893, the first commercial three-phase transmission in the world was created in Sweden to link a mine and a waterfall that were located 14 kilometers apart.

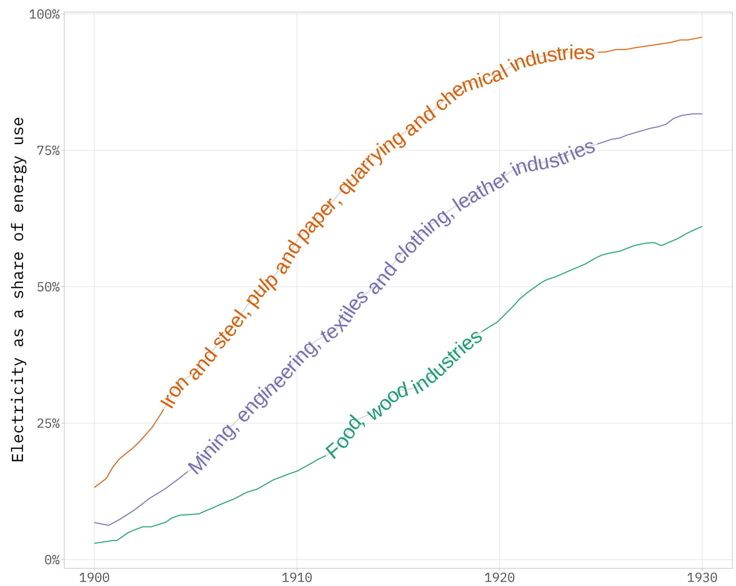

Figure 2: Electricity as a share of energy use in Sweden among industry
Notes: The figure illustrates the growing role of electricity in Sweden's energy-intensive industries from 1900 to 1930. The numbers drawn from Schön (2000) show that electricity's share of total energy use increased significantly during this period.

electricity network called "the electric mainline system". When it was finalized in 1921 it connected Olidan with a capacity of 165 MW to Älvkarleby's 50 MW through a large steam-powered power station in Västerås. By joining three of Sweden's four largest power sources into a pioneering state-sponsored grid, the Western line with its outstanding generating and balancing capacity came to challenge smaller private power providers (Bladh, 2020, p. 95). The roll-out of the grid between 1900 and 1926 and its concentration along the Western Line between Olidan and Älvkarleby is depicted in Figure 11 in the Appendix A.2.

3.2 Western Line and control parishes

The Western Line meant that localities situated between Olidan and Älvkarleby gained an early advantage in the provision of electricity. Figure 3 shows the location of the electricity-adopting, "Western Line", parishes on a map (in orange). The left panel of the map shows the theoretically eligible areas based on our selection criteria (Western Line parishes should be along a straight line between Olidan and Älvkarleby and control groups should be in 300 kilometers-wide band around Western Line (in beige). The right panel takes into account that the 1930 census is not yet completely digitized (see Section 2) and that consequently we only have access to data from sub-sample of the eligible re-

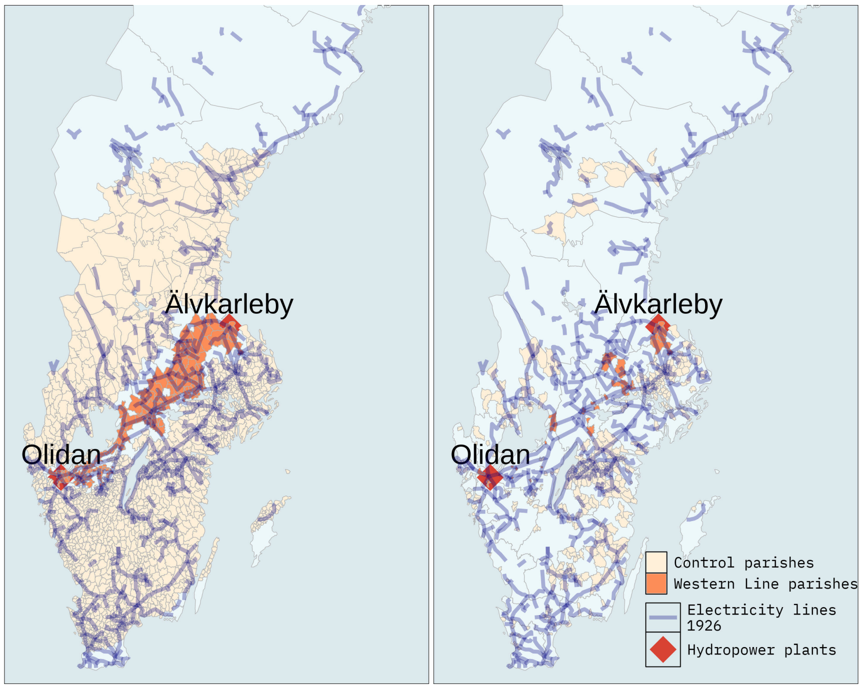

Figure 3: Western Line parishes and Control parishes

Notes: The maps show the parishes that lie along the Western Line (orange) between the two hydropower plants Olidan and Älvkarleby (marked with red diamonds) and the Control parishes (beige) that lie within a 300km band of the straight line between the power stations. The panel on the left shows the parishes that would be in the sample in theory. The panel on the right shows the parishes that are complete in the digitized 1930 Swedish census. The paths of the electricity lines from 1926 are extracted from Hjulström (1940).

gions.[10]

Prior to the advent of the electrical grid, the location on a straight line between the two power plants delivered no discernible advantages in terms of economic production. Therefore these areas were mostly agrarian and not particularly advanced in terms of industrialisation. When we compare our sample of "Western Line" parishes (that we observe in 1930) to the Control parishes, we only detect some minor differences in terms of the structural characteristics related to employment composition of farmers and fisher-men and low skilled workers prior to grid construction, in 1880 and 1890.[11]

As mentioned in Section 2, we do not have access to individual-level income data prior to 1930, which prevents us from comparing on income directly. Instead, we look at the occupational structure, as it serves as the best available proxy for economic conditions at the time.

[10]We show in in Table 19 in Appendix B.1 that varying the size of the band makes no meaningful difference to our results.

[11]These minor differences are shown in Tables 13 and 14 in Appendix A.3.

Table 1: Employment growth 1890-1900 after balancing

	Mean (Western Line)	Mean (Control)	Std (Western Line)	Std (Control)	Difference	p-value
Elite	4.68	0.93	15.84	32.47	-3.75	0.47
White collar	-0.19	-0.002	0.62	0.71	0.19	0.11
Foremen	0.85	1.10	1.79	2.46	0.25	0.52
Medium-skilled workers	0.47	0.60	0.93	1.32	0.12	0.57
Farmers and fishermen	1.10	1.11	4.88	2.55	0.01	0.98
Low-skilled workers	-1.81	-0.93	6.44	5.11	0.88	0.31
Unskilled workers	1.61	1.77	5.10	4.96	0.16	0.84
Labour force	-2.03	-3.65	8.22	6.78	-1.62	0.16

Notes: The table compares the mean change in the share of workers across seven HISCLASS groups between 1890 and 1900 for parishes along the Western Line and Control parishes. HISCLASS categories have been condensed into seven groups from the original 12 for simplicity. The changes are expressed as the mean difference in percentage points between the two periods. The "Difference" column reflects the difference in these mean changes between Western Line and Control parishes, while the "p-value" indicates the statistical significance of this difference. Western Line parishes refer to those located along the line between Olidan and Älvkarleby hydroelectric plants, while Control parishes are those within a 300km band around the line, trimmed to best match the characteristics of the Western Line parishes.

In order to ensure that the individuals in our observed Western Line and Control parishes are comparable, we slightly trim our group of Control parishes by removing the 40 parishes (and leaving in 897) that are most dissimilar to the Western Line parishes in terms of occupational characteristics in 1890 and 1900.[12]

Table 1 shows that, after balancing, there are no statistically significant pretrends in employment growth within HISCLASS categories between 1890 and 1900.[13] To further ensure that there are no systematic differences in sectoral composition we also conduct balance tests based on the levels of workers in different HISCLASS groups in 1890 and 1900, as shown in Table 11 for 1890 and Table 12 for 1900 in Appendix A.3.1.

3.3 The shock: Local access to electricity

Since the Western Line balanced power generating sources and ensured stable supply of energy for those areas connected, it is probable that regions located along the line should have had superior access to cheap and stable energy, encouraging them to invest in more energy-using machinery and operations.

One way to document the economic advantage in being located on the Western Line would be to compare energy prices across locations. Unfortunately we have not been able to locate electricity prices at any level of geographic disaggregation for this period. This is due to the fact that there existed more than 30,000 electricity distribution firms in Sweden in the 1920s and 1930s, many of the created as local cooperative associations. With such a large number of energy users, the pricing of electricity in the retail distribution became decentralized and heterogeneous (Bladh, 2020, p.20).

[12] The procedure is described in Appendix A.3.

[13] The condensed version of HISCLASS is as follows: 1+2 Higher managers and professionals; 3+4+5 Lower managers and professionals, clerical and sales personnel; 6+7 Foremen and skilled workers; 8 Farmers and fishermen; 9 Lower-skilled workers; 11 Unskilled workers; 10+12 Lower-skilled and unskilled farm workers.

Instead, we have opted for comparing the quantities of electricity used and installed in the parishes along the Western Line with the quantities used and installed in the control group. Our rationale is that superior access to electricity should result in higher demand for installing power equipment and resulting in larger amount of energy derived from electricity. To support this claim, we leverage the meticulous reports of the Royal Electrification Committee compiled by engineer Nils Ekwall from 1924 to 1926. From this source, we digitized, transcribed, and geocoded the locations of all transformers and power plants across Sweden. This rich dataset provided details on the owner of the plant or transformer, location, power source, and installed generation capacity. We aggregate measures of total power used, transmitted and installed at the parish-level and run the regression based on the Western Line sample and balanced control sample explained in section 2:

$$ln(Y_p) = \beta_0 + \beta_1 Electricity_p + \beta_2 area_p + \beta_3 pop_p + \beta_4 lat + \beta_5 long + u_p \quad (1)$$

Our dependent variable, Y_p, span across two key dimensions of electrification in each parish, p: 1) power availability and transmission, as indicated by total power, power transmission, and local power generation; and 2) infrastructure deployment, captured by the number of connections, transformers, and generators. The coefficient of interest is β_1 relating to the variable $Electricity_p$, which is a dummy that takes the value=1 if the parish is along the 'Western Line'. To avoid influence from confounding variables related to size, industrial specialisation, geography and climate, we add controls for the area, population and rail access of the parish, as well as controls for longitude and latitude with cubic polynomials.

Table 2 demonstrates that parishes situated along the Western Line experienced a substantial increase in their total power and power transmission. In column (1) we learn that Western Line parishes used 0.4 log points (roughly 50 %) more energy on average than the control parishes. The Western Line parishes also transmitted 0.37 log points (roughly 45 %) more energy than similar parishes outside the electricity mainline (see Column 2). On the contrary, the power generation within these parishes, including sources like local hydropower plants, steam turbines, and diesel engines, did not seem to have significantly benefited from the line's construction. The coefficient on total power generated depicted in Column (3) is negative and statistically insignificant, suggesting that the enhanced access to electricity for parishes along the Western Line came predominantly from the increased capacity to consume and transmit power from the hydro-power plants along the line, rather than increased local generation. This strengthens our hypothesis that it was really the localization along the Western Line that induced parishes to use more energy, than any initial advantage in electricity generation locally.

One important consideration in estimating the effect of early access to electricity is that places further from the Western Line eventually gained access to the technology as well, drawing power from the central grid over time. This means that our control group includes areas that received electricity later, which

Table 2: Energy use in Western Line vs. Control parishes

	(1) log(Total Power)	(2) log(Total Power Transmitted)	(3) log(Total Power Generated)
Treated parishes	0.404**	0.371*	-0.003
	(0.20)	(0.19)	(0.11)
Parish Area (km2)	X	X	X
Parish Population (1900)	X	X	X
Railway in Parish	X	X	X
Latitude	X	X	X
Longitude	X	X	X
Latitude^3	X	X	X
Longitude^3	X	X	X
R-squared	0.20	0.22	0.04
Observations	1,684	1,684	1,684
F-stat	51.090	57.421	9.830
Mean Dependent Var	1.56	1.40	0.34

Notes: The table presents the results of OLS regressions where the outcome variables are the log of total installed electricity generation and transmission capacity (Column 1), the log of total transmitted electricity (Column 2), and the log of total generated electricity (Column 3) at the parish level. The primary variable of interest is a dummy variable indicating whether a parish is located along the Western Line. Control variables included in all regressions are parish area (in square kilometers), population (in 1900), a dummy for the presence of a railway line in the parish, as well as latitude, longitude, and their cubes. The data source is the country-level reports of the Royal Electrification Committee compiled by Nils Ekwall between 1924 and 1926, which contain detailed information on the location and installed capacity of generators and transformers for each county in Sweden. Robust standard errors are used in all regressions, and are reported in parentheses.

biases our estimates toward a lower bound of the true effect of early access. Since we measure the impact a decade after the completion of the Western Line, some diffusion of electricity beyond the directly connected parishes has likely occurred.

Table 3 reports the regression analysis results for the impact of infrastructure deployment of the Western Line on the total number of connections, the number of transformers, and the number of water, steam, and diesel generators in the parishes. The regressions clearly illustrate a significant association between Western Line status and the first two outcome variables. Parishes along the Western Line exhibited 0.41 log points (roughly 50 %) more total electricity connections and a similar amount of more transformers. However, as shown in column (3), they did not have more electricity generators deriving energy from water, steam or diesel, than the control parishes. The higher infrastructure capacity of the parishes along the Western Line came solely from a more central location in the electricity network with more transformers installed ensuring that the power transmitted along the network was transformed to the parish for local use. The regressions provide robust evidence that the line's construction had material effects on local access to and quantity of electricity, and that the mechanism for this was transmitted electricity from the hydropower plants at either ends of the Western Line. The Western Line also mitigated the need for duplicated investment (in backup generators) and facilitated the transmission of high-voltage power across long distances.

Table 3: Number of electrical connections in Western Line vs. Control parishes

	(1) log(Total connections)	(2) log(N. transformers)	(3) log(N. generators) (water, steam, diesel)
Treated parishes	0.326***	0.333***	-0.026
	(0.11)	(0.11)	(0.02)
Parish Area (km2)	X	X	X
Parish Population (1900)	X	X	X
Railway in Parish	X	X	X
Latitude	X	X	X
Longitude	X	X	X
Latitude^3	X	X	X
Longitude^3	X	X	X
R-squared	0.19	0.20	0.04
Observations	1,684	1,684	1,684
Mean Dependent Var	0.39	0.36	0.06

Notes: The table presents the results of OLS regressions where the outcome variables are the log of the total number of electricity connections (Column 1), the log of the number of transformers (Column 2), and the log of the number of generators (Column 3) installed in each parish. The primary variable of interest is a dummy variable indicating whether a parish is located along the Western Line. Control variables included in all regressions are parish area (in square kilometers), population (in 1900), a dummy for the presence of a railway line in the parish, as well as latitude, longitude, and their cubes. The data source is the country-level reports of the Royal Electrification Committee compiled by Nils Ekwall between 1924 and 1926, which include detailed information on the number of connections, transformers, and generators installed across Sweden. *= Generators include water, steam, and diesel generators. Robust standard errors are used in all regressions and are reported in parentheses.

4 Estimation of Individual-level Effects

To estimate the effect of being born in a parish on the Western line on various outcome variables at the individual level in 1930, we run the following cross-sectional regression:

$$Y_i = \beta_0 + \beta_1 Electricity_i + \sum_{l=1}^{m} \gamma_l Z_{li} + u_i, \tag{2}$$

where Y_i is the outcome variable for individual i, β_0 is the intercept, β_1 is the coefficient of interest, with $Electricity_i$ as a dummy taking the value of one if the individual was born in any of parishes along the Western Line, γ_l are the coefficients for the control variables Z_{li}, and u_i is the error term for individual i. Standard errors are clustered at the parish level.[14]

Dependent variables include individual outcomes in 1930, such as income and occupation, while the control variables cover a rich set of demographic factors like age, gender, marital status, and labor market characteristics such as educational attainment and occupational class. Some of the control variables, such as labor market characteristics and educational attainment, could potentially be considered as outcomes of early electrification. We will therefore display all regression results with and without controls to allow for an interpretation of potential mediating channels based on the differences in estimate sizes.

[14]Bearing in mind that all parishes along the Western Line had electrified to electricity, we may think of the variable *Electricity* as the reduced form of the endogenous variable access to electricity, where all observations had electrified

Table 4: Western Line on Occupation Listed

	(1) Occupation listed	(2) Occupation listed
Western Line Parish	-0.009	-0.006
	(0.01)	(0.01)
Controls		X
R-squared	0.01	0.38
Observations	847,262	847,262
F-stat	1.21	4751.92

Notes: The table shows the results of OLS regressions where the outcome variable is whether an individual has an occupation listed. The primary explanatory variable is a dummy indicating if an individual was born in a parish along the Western Line. Column (1) presents the unadjusted relationship, while Column (2) adds controls for age and gender as well as marital status, schooling, and the presence of a railway in a parish. Controls for occupational category not possible in this specification, since the outcome variable is being listed with an occupation. Standard errors are clustered at the parish level and reported in parentheses. The sample here includes individuals who do not have an occupation listed, and for this reason the sample is larger than the one used in the remainder of the paper, which drops individuals without an occupation.

5 Results

We start by looking at the impact of the new technology on unemployment, and then move on to examine effects on income.

5.1 Technological unemployment?

Since new electricity-related technology involved a shift towards man-replacing modes of production, a first question is whether individuals born in Western Line parishes experienced higher likelihood of becoming 'technologically unemployed' compared to individuals in the control groups. In Table 4 we depict the β_1 coefficient from our regression outlined in section 4 with the dependent variable being a binary variable for having an occupation listed in the census. The binary nature of the variable means that individuals not listed with occupations, and thus recorded as a zero, comprise both the unemployed ("arbetslös") and individuals that for other potential reasons were not listed with occupations. Column (1) is a univariate regression with the coefficient on being born in a Western Line parish. Columns (2) and (3) sequentially add controls for age and gender, as well as marital status, schooling and occupational status respectively. The results suggest that individuals born in Western Line parishes were not significantly more likely to be out of work compared to the control group.

5.2 Income

How did technological change impact on individuals income? Table 5 reports results from a series of regressions examining the effect of being born in a Western Line parish on an individual's log income. We incorporate in column 2 a variety of controls, including age, gender, marital status, educational attainment, HISCO code at the two-digit level and the presence of railway in parish

Table 5: Western Line Parish on Log Income

	(1) Log Income	(2) Log Income
Western Line Parish	0.417***	0.265***
	(0.10)	(0.05)
Controls		X
R-squared	0.01	0.29
Observations	523,849	523,849

Notes: The table presents OLS regressions where the outcome variable is the log of individual income. The key explanatory variable is a dummy indicating whether an individual was born in a parish along the Western Line. Column 1 shows the unadjusted relationship between being from a Western Line parish and log income. Column 2 introduces controls for age and gender as well as marital status, schooling, presence of rail in parish of birth and HISCO code at the two-digit level. Clustered standard errors (at the parish level) are reported in parentheses.

of birth.[15] Despite the inclusion of these controls, the key result is robust: the coefficient of being born in a Western Line parish remains positive, substantial in its economic magnitude, and statistically significant across all specifications. There is a large income premium to be born in an early electricity-adopting parish, as individuals that were exposed to new technology during their lives earn on average 0.27-0.42 log points (around 32 to 46 percent) higher incomes, a result that persists even when considering a wide range of demographic, socioeconomic, and educational factors.[16]

5.3 Decomposition of income effect

How much of the reported income effects are due to structural shifts in the Western Line parishes, and how much can be attributed to within occupational differences. To decompose the effect we perform a Kitagawa Oaxaca Blinder Decomposition. We compare incomes from individuals born in Western Line parishes to incomes of those born in the control group, while controlling for our standard battery of occupational and demographic characteristics (HISCO code at two-digit level, age, gender, marital status, schooling, rail). The results are found in Table 6. As seen from the Table the large differences in mean income (64 per cent) are due to unexplained differences. The largest part of the effect stems from within the occupational classes. It is evident that electricity raised incomes within all categories of workers.

One might wonder if the effect differs by age category, specifically if younger individuals were more likely to acquire complementary skills to the new technol-

[15]The reason for the smaller sample size compared the the employment regressions above is that the individuals in this regression must have an income (and hence we drop the unemployed).

[16]Robustness results of the income regression, varying the distance from the Western Line are found in Table 19 in Appendix B. In table 20 in Appendix B we further explore whether the effect depends on initial industrial specialization or railway connectivity, but find such interaction effects to be insignificant. This suggests that electricity augmented rural and industrial parishes alike, and that the effects did not increase if the parish was connected to the railway network

Table 6: Kitagawa Oaxaca Blinder Decomposition of Income Differential

	(1) Log Income
Western Line	5.914***
	(0.06)
Control parish	5.497***
	(0.02)
Difference	0.417***
	(0.06)
Decomposition	
Explained	0.152**
	(0.06)
Unexplained	0.265***
	(0.01)
Percentage of Difference	
Explained (%)	36.45%
Unexplained (%)	63.55%
Observations	523,849

Notes: The table presents the results of a Kitagawa Oaxaca Blinder decomposition, comparing the log incomes of individuals born in Western Line parishes to those born in control parishes. The decomposition distinguishes between explained and unexplained differences in income, controlling for occupational (HISCO two-digit code) and demographic characteristics, including age, gender, marital status, schooling and a control for the presence of a railway line in an individual's parish of birth. The explained portion represents income differences due to shifts in occupational and demographic structures, while the unexplained portion reflects within-occupation income differences. Standard errors are clustered at the parish level and reported in parentheses.

ogy and earn higher wages. If the hypothesis is correct, individuals of working age when the Western Line was finalized in 1921 would be more affected than those too young or too old to benefit from the new technology when it was implemented. Considering that outcomes were measured in 1930, we would expect the largest effect among individuals who were about 18-40 years old when the grid was connected in 1921 (and thus around 27-49 years old when reporting incomes in the 1930 census). However, when we estimate the effect by age we find an income gradient that increases almost linearly with age. Since younger cohorts do not surpass older ones in terms of income differentials, this suggests that all individuals benefited from the new technology. The results from the regression on log income by age can be found in Appendix B, Figure 13.

Previous literature suggests that the effect of new technology can be polarizing, potentially benefiting those at the extremes of the income distribution more than those with intermediate skill levels, depending on which jobs are more susceptible to mechanization.[17] To estimate the impact of electricity on the income distribution in local labor markets, we run a quantile regression on a sample, examining the impact of Western Line parish birth from the 5th to

[17]Others suggest that electricity had a skill-biased component which should then have resulted in incomes at the higher end of the distribution to benefit relatively more. Most previous studies suggest that the impact of new technology on local labor markets is to increase overall inequality.

the 95$^{\text{th}}$ percentile of the income distribution.[18]

The results of the quantile regression is presented in Figure 4, as well as Table 21 in the Appendix B. The regression includes all the standard controls for age, gender, marital status, schooling, and also for HISCLASS, and displays that the largest effect is at the bottom of the income distribution.[19]

In this conditional quantile regression model, we observe no statistical difference between the Western Line and control groups at the 5$^{\text{th}}$ percentile of the income distribution. However, at the 15$^{\text{th}}$ percentile, the Western Line group exhibits 0.427 log points higher income than the control group, which equates to approximately 53 percent higher income.[20] At the 25$^{\text{th}}$ percentile of the income distribution, the Western Line group shows a 0.242 log point increase in income (approximately 27 percent). This indicates that the majority of the income increase is concentrated in groups earning below the median income. In the highest deciles (85$^{\text{th}}$ and 95$^{\text{th}}$ percentiles of the conditional income distribution) the income effect is much smaller and not statistically significantly different from zero. Overall, these results suggest that early access to electricity led to increased income for individuals in the lower part of the income distribution.

6 The effect on local labor markets

6.1 Inequality

We noted earlier that on aggregate, individuals born in early electrifying parishes saw higher incomes in the bottom half of the national income distribution, compared to individuals born in control parishes. In this section we shift focus and we examine the effects on the local labor markets in the electrifying parishes in 1930. Figure 5 display Lorenz curve of incomes among inhabitants of Western Line and Control parishes in 1930. As seen from the figure, the level of income inequality is lower in early electricity-adopting parishes than in control parishes. Here, the Lorenz curve closest to the diagonal line is for the inhabitants of Western Line parishes, indicating that there is a more equitable division of total

[18] Quantile regression is a statistical technique used to model the conditional quantile functions of the dependent variable. Unlike ordinary least squares (OLS) regression, which estimates the conditional mean, quantile regression estimates the conditional quantiles. For a given decentile, τ, the quantile regression minimizes the sum of check function, Q_τ, defined as:

$$Q_\tau(\beta) = \sum_{i=1}^{n} \Big(\tau - \mathbf{1}\{y_i - x_i^T\beta < 0\}\Big) \cdot |y_i - x_i, p^T\beta|$$

where β represents the coefficients to be estimated, x_i is the vector of predictors for the i-th observation, y_i is the dependent variable measured across individuals, i, in parish p, and $\mathbf{1}\{\cdot\}$ is the indicator function. Quantile regression allows for a more nuanced understanding of the conditional distribution of the income variable as a response to electrification.

[19] In this specification, we are restricted to control for the broad occupational categories in HISCLASS instead of HISCO at the two-digit level since the regression does not converge with the 75 HISCO dummy variables.

[20] To see a variant of the quantile regression that allows interpretation of the coefficients at the individual level, see Section B.5.

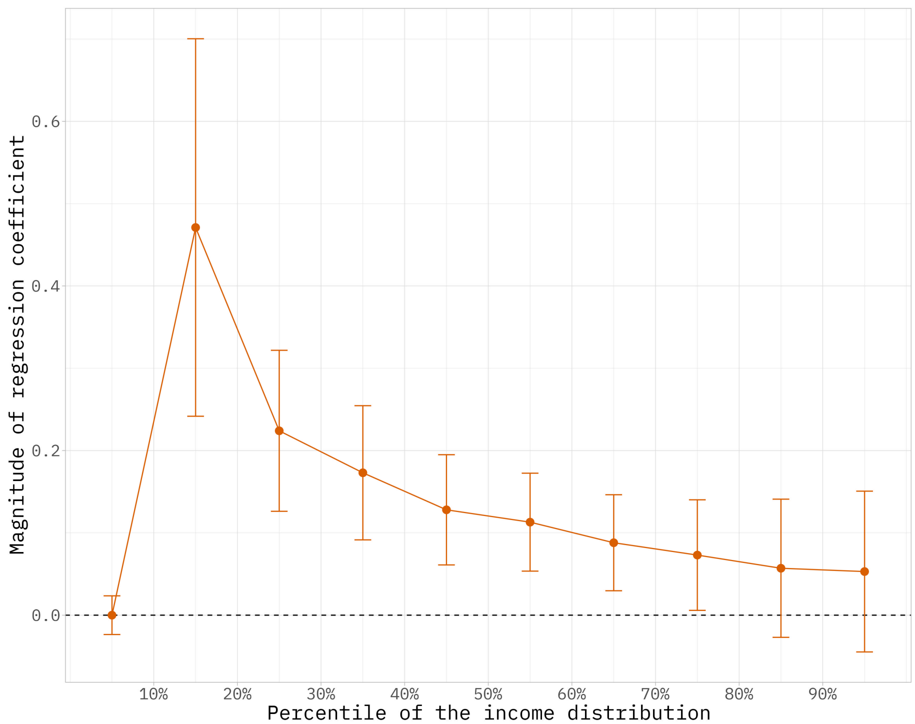

Figure 4: Quantile regression coefficient plot: income and birth in Western Line parish

Notes: The figure presents a coefficient plot from a conditional quantile regression where log income is the dependent variable, and the coefficient of interest is whether an individual was born in a Western Line parish. The regression includes standard controls for age, gender, marital status, schooling, and HISCLASS. The results show that the largest income effects from early access to electricity are concentrated at the lower end of the income distribution. Standard errors are clustered at the parish level.

income within these parishes, compared to Control parishes. The respective Gini coefficients calculated from the Lorenz curves are 0.69 and 0.73. It is worth noting that we restrict the analysis here to individuals with positive income and make no imputations.

6.2 Stayers and movers

The results following from our baseline regression, explained in equation (2) captures the effects of electricity solely on those individuals that were born in the electricity-adopting parishes. This approach is limited insofar as there were substantial internal migration taking place in Sweden in the 1930s. Table 15 in Appendix A shows that this was indeed the case: 37 percent of the individuals in our sample did not live in their parish of birth when registered in the 1930 census. However, the propensity to migrate differed between individuals born

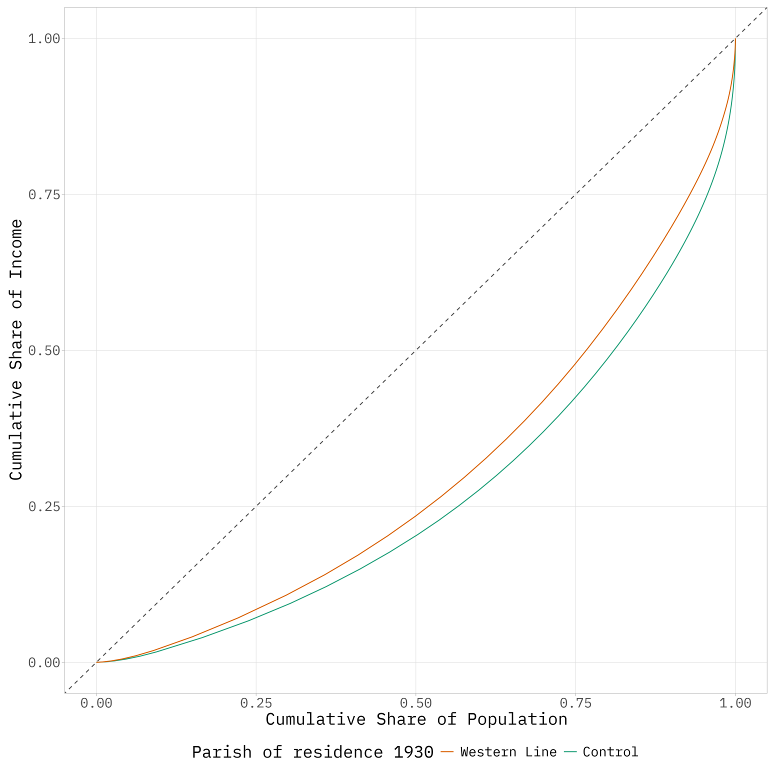

Figure 5: Lorenz curves for inhabitants of Western Line and Control parishes in 1930
Notes: The figure presents Lorenz curves comparing income distribution in Western Line parishes and Control parishes in 1930. The analysis focuses on individuals with positive incomes, and no imputations were made for missing or zero-income data.

in electricity-adopting parishes, compared to the control group. Among those in the Western Line parishes, almost two-thirds (64 percent) still lived in their parish of birth in 1930. In the control group, the corresponding figure was only 57 percent. The differences in migration rates could indicate that Western Line parishes offered more favorable conditions, reducing the incentive for inhabitants to seek better prospects elsewhere.

Moving into an electricity-adopting parish must be considered an endogenous response to the opportunities offered there. To get a better idea about how incomes were affected among the stayers and movers in and into electricity parish, we compare three samples in in Table 7. Column 1 reports the income effect among the individuals born in an electricity parish, compared to individuals born in the control group, regardless of their place of residence in the 1930 census. The coefficient suggests that those individuals that were exposed to new technology early by virtue of being born in along the Western Line earned about 30 percent (0.265 log points) higher incomes than the control group. Interestingly, moving to column 2, were we restrict the treated group to

Table 7: Income regressions, Stayers and Movers

	(1) Baseline	(2) Lives in Parish of Birth	(3) Location in 1930
Born in a Western Line Parish	0.265***	0.366**	
	(0.05)	(0.12)	
Western Line Parish Dweller in 1930			0.195***
			(0.06)
Controls	X	X	X
R-squared	0.29	0.29	0.28
Observations	523,849	188,669	523,849

Notes: The table presents estimates of the the impact of being born in a Western Line parish on log income in column one. Column two restricts the sample just to those who live in 1930 in the parish in which they were born. The third column shows the impact of living in a Western Line parish in 1930, including those born in a Western Line parish and in migrants. Controls include age, gender, marital status, schooling, two-digit hisco code, and an indicator for if an individuals birth parish was connected by rail in 1900. Standard errors are clustered at the parish level.

only those born along the Western Line that stayed in their parish of birth, the coefficient increases to 0.36 log points (roughly 43 per cent). The result suggest that electricity generated better job opportunities for people born in those parishes. Individuals that were replaced by the new technology, or saw their incomes reducing due to replacement effects, are likely to have been pushed out of the parish.

The column 3 looks at the income effects among the residents in the Western Line parishes in 1930, irrespective of their location of birth. As seen from the estimate, their incomes were about 22 per cent (0.195 log points) larger than residents in control parishes, but compared to the "insiders" that were born in the parishes, they earn somewhat smaller incomes. This could be due to network effects, unfair competition or to the fact that those migrants that moved in did not have the same long experience working with electricity-related technology as the stayers had.

Our findings indicate that the income effects we estimate are primarily driven by individuals who were exogenously "shocked" by the introduction of electricity—those born in parishes that adopted electricity due to their strategic location along the direct line between Olidan and Älvkarleby. The effect may reflect the low skill requirements of the adopted technologies, as many electricity-related tasks could be performed with minimal prior knowledge or education. Interestingly, migrants moving into these parishes did not out-perform the local stayers in term of incomes; instead, they appear to have dampened the average income effect somewhat. Our regressions account for demographic and labor market characteristics, suggesting that the results are not driven by compositional changes.

7 Mechanisms

7.1 Occupational upgrading

In Section 5.2, we found that the income effects of getting access to new technology were positive and mainly accruing to individuals at the lower-end of the income distribution, resulting in decreased inequality. Table 6 established that more than two-thirds of the effects were unexplained by the standard controls, particularly within our designated HISCO code measured at two-digit level. While electricity seems to have raised incomes within broad categories of the job distribution, we may miss some direct effects on the job market when using a broad occupational scheme. This is why, in this section, we focus on the occupational titles from the 1930 census that have been coded as jobs directly or indirectly impacted by electricity. The definition of these jobs was explained in Section 2, where we categorize direct electricity jobs as those containing the word 'electricity' in their title, and indirectly related jobs as those involving the operation and management of machinery.

Figure 6 visualizes the coefficients from a regression that measures effects on the likelihood that an individual holds a job directly or indirectly related to electricity in the Western Line parishes compared to the control group. To ensure that there are no pre-electrification trends, we go back to the censuses of 1880, 1890, and 1900 and code the occupations according to our scheme. We do not record any significant pre-trends in the share of people employed in direct or indirect electricity jobs prior to the construction of the Western Line; between 1909 and 1922. It is important to keep in mind that there are very few direct electricity jobs before the 20^{th} century. In 1900, only a handful of people held jobs directly related to electricity. Yet, the difference between Western Line and control parishes (0.07% in Western Line Parishes, and 0.01% in Control parishes) was negligible before the construction of the Western Line. In terms of the indirectly related jobs, we broadly measure jobs in a variety of roles in manufacturing that involve operating and managing machinery, where there are more people employed in the late 19^{th} and early 20^{th} century. Yet, we do not find any pre-trends in the sample.[21] In 1930, about 20 years after the first construction of the Western Line and 8 years after its completion, we see that the likelihood that and individual holds either of these jobs has turned positive and statistically significant.

To illustrate the magnitude of the structural change in the Western Line parishes, Figure 7 shows the average share of workers in the largest direct and indirect job categories related to electricity. The largest direct job categories included electricians, wiremen, electricity generator workers, and linesmen. The figure shows that, although the numbers are relatively small in these newly created occupations, the share is much greater among those born in parishes that gained early access to electricity. Additionally, we observe that, among the indirectly electricity-related jobs (factory laborers, sawmill workers, and

[21] Also, recall that the sample has been balanced to ensure there were no structural differences in job-composition in terms of HISCLASS 1890 and 1900, prior to electrification.

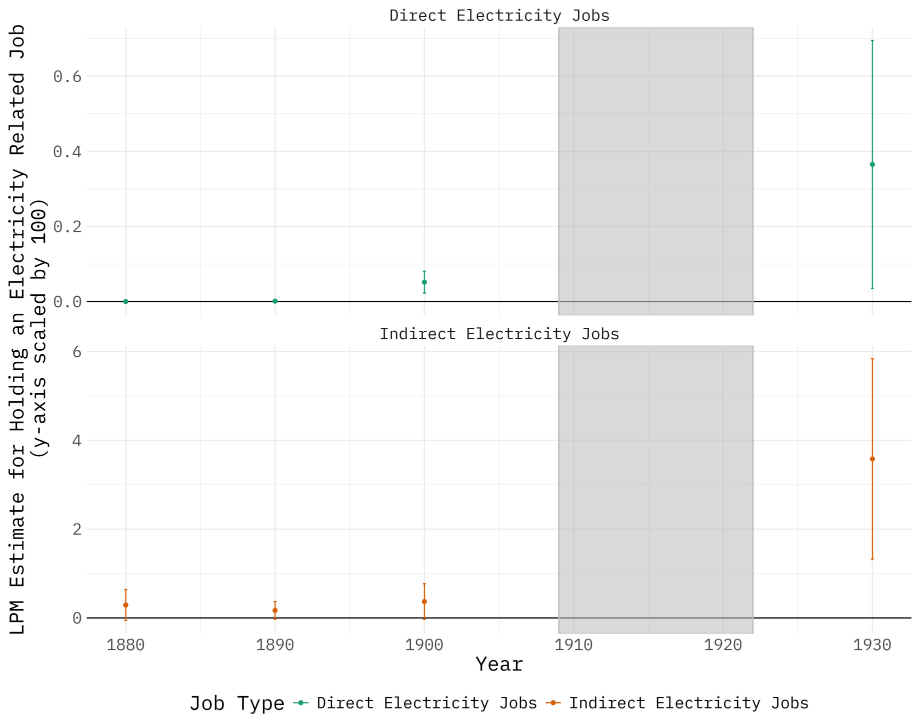

Figure 6: Electricity-related jobs, Western Line vs. Control parishes

Notes: The figure shows a coefficient plot from a linear probability model regression where the outcome variable is a dummy=1 if are an individual holding a direct electricity job, or an indirect electricity job, and the explanatory variable whose coefficient is shown is a dummy for being born in a Western Line parish. The shaded region represents the construction period for the Western Line. Standard errors are clustered at the parish level

textile workers), a higher share of workers born in early-electrifying parishes are employed in these occupations compared to those born in control parishes.

The figure also shows signs of structural change in job categories that are not directly influenced by electricity or the operation and management of machinery in manufacturing. Instead, the largest shift is actually that Western Line parishes had a lower share of manual jobs in traditional industries such as farm workers (16.9 percent compared to 11.2 percent). However, the share of farmers was actually higher in Western Line parishes, suggesting that farmers could potentially substitute farm workers with electricity-driven machinery.[22]

[22] The aggregate effect from the two farming groups presented in 7 suggests a shift away from agriculture with 1.6 percentage points in the Western Line parishes compared to the control group. The effect is relatively similar to the two percentage points previously estimated in Molinder et al. (2021), although the papers deal with different time periods and different job categories. While Molinder et al. (2021) included all jobs related to agriculture and measured the impact from 1900 to 1910, Figure 7 presents the three largest job categories in each electricity-related sector in 1930.

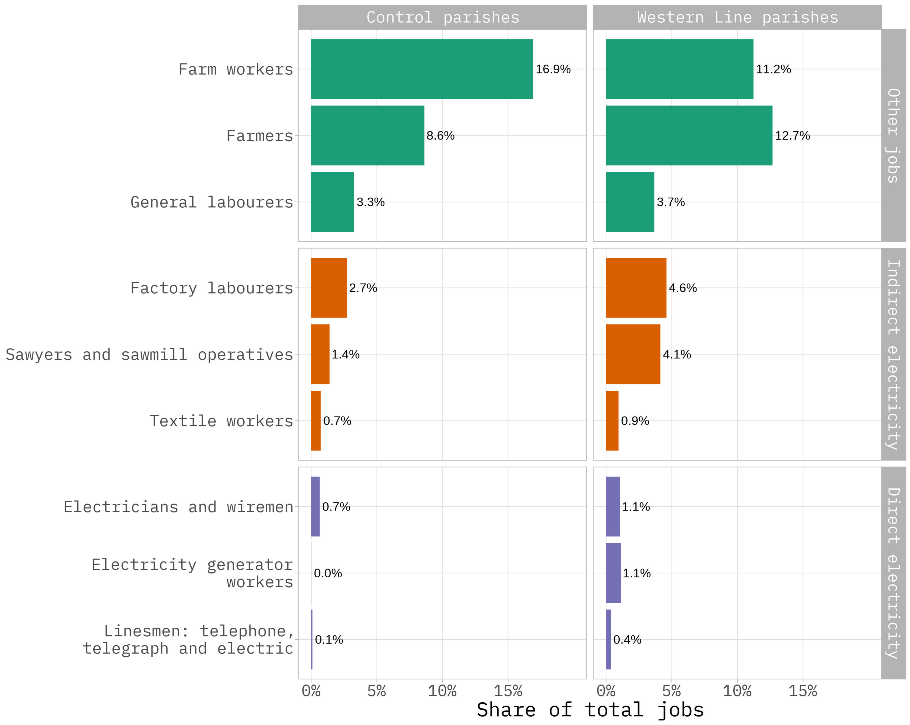

Figure 7: Employment shares in most common job titles in 1930

Notes: The figure compares the share of employment by parish type (Control parishes vs. Western Line parishes) across three main occupational categories: direct electricity jobs, indirect electricity jobs, and other jobs. The three most common occupational titles within each category are shown, with titles translated from Swedish to English based on the The North Atlantic Population Project HISCO - NAPP crosswalk.

The figure does not exhibit any sign of structural change away from agriculture, but it clearly shows how electricity impacted on job processes in agriculture a way that can best be described as occupational upgrading.[23]

Table 8 illustrates average income differences for direct, indirect and other jobs in the Western Line parishes compared to the control group. As seen from the table, electricity-related jobs (direct and indirect) were associated with significantly higher incomes on average. The directly related jobs displayed the

[23] A separate question may concern how long the advantage of early access to new technology lasted. We have conducted tentative estimates on whether the early advantage of the parishes along the Western Line became permanent in terms of employment in electricity-related occupation. Using data from the Swedish industrial calendar of 1947, we do not find such effects. We believe this is due to Sweden's rapid electricity penetration, which meant that by 1947, almost the entire nation was electrified. We digitized the 1947 industrial calendar to geolocate all industrial firms of the time. We tested whether firm type, number of employees, limited company capital, or annual turnover differed by parish type (Western Line or Control). We found no contemporaneous differences between the regions, nor differences when examining firms by the year in which they were founded.

Table 8: Mean incomes by job type and birth parish

	Control Parish (mean)	Western Line (mean)	Difference	p-value	Observations
Electricity Job Direct	2153.17	2489.97	336.79	0.00	2,517
Electricity Job Indirect	1748.10	1816.79	68.69	0.03	57,975
Other Jobs	1331.10	1534.74	203.64	0.00	467,787
All Jobs	1380.53	1577.64	197.11	0.00	528,047

Notes: The table displays the mean incomes by job type for Western Line and Control parishes. Income data is taken from the 1930 census and includes income from all sources, though for most individuals wage income made up the largest component. Income is reported in nominal Swedish Kronor (SEK).

highest premium, but individuals in indirectly related jobs also earned substantially more. Yet, the percentage differences in incomes for these indirectly electricity related jobs in the Western Line parishes compared to the control group are smaller on average, compared to the income differences in the "Other jobs" category, which is close to 40 per cent (SEK 69 compared to SEK 197).

The table shows income differentials within each job category, but the largest relative effects are in the "Electricity Job Direct" category. Thus, while incomes increased for both as a result of occupational upgrading and higher incomes in any given job, the second largest effect was seen among holders of "Other Jobs"; the large group of workers with lower incomes in absolute terms and jobs that were not directly related to electricity or machine operations in manufacturing. In this group we, for example, find the large group of farmers that could increase productivity by replacing manual labor with electricity-driven machinery.

8 Horse-race institutions vs. technology

8.1 Education

As highlighted in the introduction, the literature has often portrayed the impact of technological change on the labor market as a dynamic interplay between technology and education. In Figure 8 we explore to what extent education beyond primary level was essential for workers to benefit from electrification. The figure presents the interaction effect of being born in an early electrifying parish differentiated by educational attainment.[24] The OLS regression includes the same controls as the previous regressions; age, gender, education, HISCO code at the two-digit level and the presence of rail in birth parish. We categorize educational levels into four groups according to highest level attained: less than primary (the baseline), primary, post-primary, and post-secondary. Our analysis reveals marginal differences in income impact across these educational groups of those born in an early electrifying parish. Notably, the effect appears most pronounced among those with primary education only. For this group, being born in an early electrifying parish correlates with an income increase of approximately 0.36 log points (42 percent) in 1930. In contrast, for individuals with post-secondary education, the point estimate of this impact is about

[24]The corresponding regression table is found in Table 22 in Appendix B.

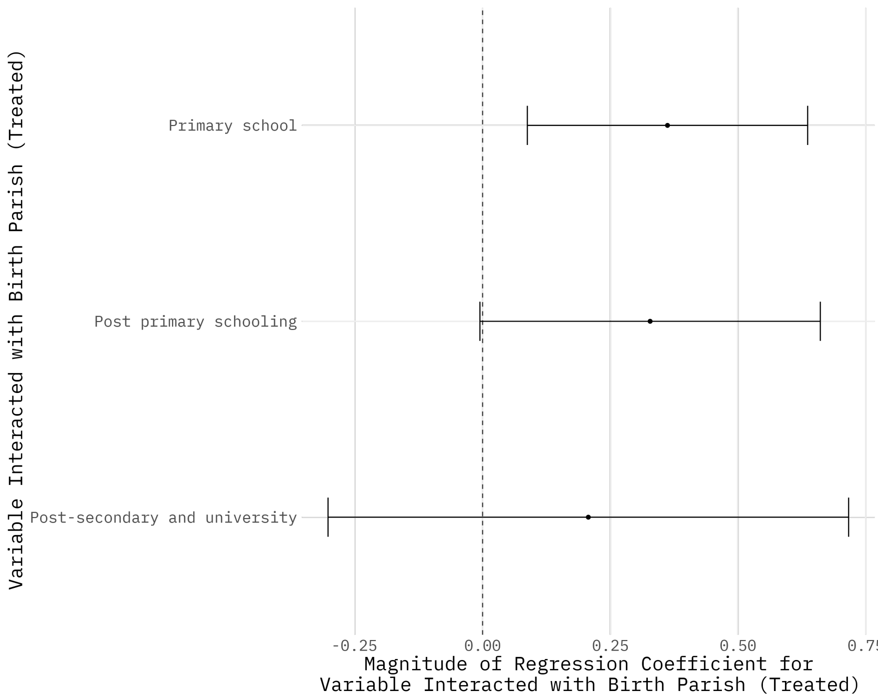

Figure 8: Education interacted with birth in a Western Line parish.

Notes: The figure presents a coefficient plot from a regression where the outcome variable is log income. The variables of interest are interactions between being born in a Western Line parish and different levels of education (Primary school, Post-primary schooling, and Post-secondary/university), with the base education category being "literate." The plot shows the magnitude of the regression coefficients for each interaction term along with 95% confidence intervals. Controls in the regression include age, gender, marital status, and occupational skill level (HISCO at the two-digit level). Standard errors are clustered at the parish level.

half this magnitude, and it is not statistically different from zero. These findings underscore that secondary and higher education were not prerequisites for harnessing the economic benefits of electrification in early 20$^{\text{th}}$ century Sweden. The inclusive nature of electrification's impact becomes evident considering that a majority of the Swedish adult population in 1930 had only completed primary education.

8.2 Unions

Acemoglu and Johnson (2023) posit a crucial role for unions during the Second Industrial Revolution, particularly in Sweden, in ensuring that workers benefited from new technologies. This was achieved through mechanisms like profit-sharing and directing technological advancements toward tasks that augmented labor productivity. Concurrently, this era marked a transition in Sweden from widespread labor unrest and strikes to a more negotiation-based approach for labor peace, as detailed by Enflo and Karlsson (2019). Unions, with their growing strength and organization, effectively negotiated to share the technological dividends, evident in the numerous strikes for higher wages documented by Molinder et al. (2021). Given this backdrop, an intriguing question arises: Were the positive effects on income and reduced inequality more pronounced in unionized parishes along the Western Line?

Unlike the education data in the section above, we do not have access to individual-level information on union membership. Instead, we measure union density as the average membership density for the parish as a whole. While this approach may not capture membership as precisely as individual measures, it offers a broader perspective. It allows us to potentially identify local spillover effects of robust unionization on the entire local labor market, including both unionized and non-unionized workers. Information on union membership has been collected from The Social Movement Archive (Andrae and Lundqvist, 1998). Unfortunately, the data is not complete. Out of the 1,314 parishes in our sample in 1930, only 225 (or 17 percent) recorded union density data in 1900, meaning that the results must be viewed with some caution.[25]

To investigate the joint effect of unionization and technological change on the income distribution, we run conditional quantile regressions that allow for an interaction term between being born in a Western Line parish and the union density of the parishes in a particular year. We include estimates from the union density figures from 1900 and 1910 to avoid any reverse causality from income to unionization. We also include a measure from 1930 to observe the actual outcome effects. Figure 9 displays the coefficient on being born in a Western Line parish, compared to the coefficient on union density and the interaction term between the two, in a regression where log income is the outcome variable, controlling for age, gender, marital status, schooling, and HISCLASS.

Figure 9, we present the coefficients from regression with the 1900 union density measure, which avoids the potential for reverse causality. The appendix contains the coefficient plots for the 1910 and 1930 union density measures. As seen in Figure 9, when standardizing the coefficients, we observe that both higher union density in 1900 (green line) and being born in a Western Line parish (orange line) are positively associated with log income across most of the income distribution, particularly at the lower and middle percentiles. However, there is an offsetting effect from the interaction of the two coefficients, suggesting strong substitution effects between the variables (purple line). That is, individuals born in Western Line parishes with relatively high union density in 1900 do not experience any significant income advantage compared to those born in parishes with either high union density or in a Western Line parish alone. The interaction term indicates that electrification dampens the effect of union membership when both are present at the same time.

How do we reconcile the substitution effect between unions and electrification with Molinder et al. (2021) previous findings of electrification increasing strike activity in Sweden? First of all, Molinder et al. (2021) measures electrifi-

[25]See Table 16 in Appendix A to view union density data completeness over time.

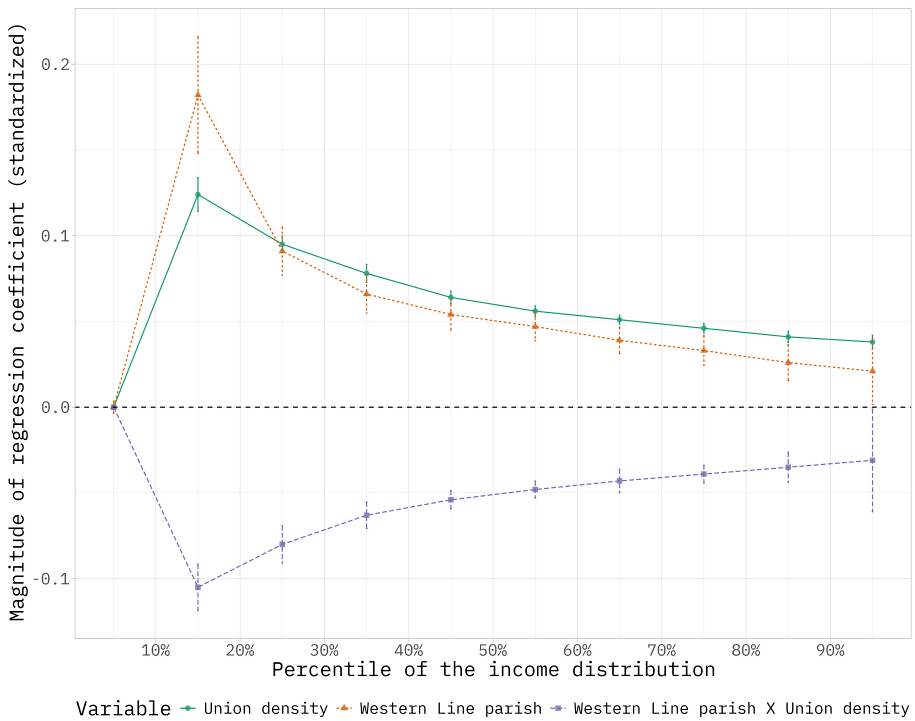

Figure 9: Conditional quantile regression on income with union density in 1900

Notes: The figure shows a coefficient plot from a conditional quantile regression where the outcome variable is log income. The plot shows the interaction between being born in a Western Line parish and the level of union density in the parish in 1900. The coefficients are standardized to aid interpretation. The regression is run at the individual level, with controls including age, gender, marital status, schooling, and occupational skill level (HISCLASS). Standard errors are clustered at the parish level.

cation and strike activity before 1920. This was a period of unprecedented labor conflicts and local wage bargaining. In 1930, unions were becoming more centralized and the struggle between workers and capital had started to shift to the political arena with increased compromises and falling strike activity as a result (Molinder et al., 2022; Enflo and Karlsson, 2019). Table 17 in the appendix shows that unionization was a direct outcome of electrification. Although union density rates were low in 1890, Western Line parishes saw 59 percent higher union density than the control group in 1930. While there is a direct effect of union density on inequality, we can not disentangle any additional effect of the interaction between technological change and union power. This is true even when we measure union density in 1900 to avoid the problem of electricity impacting on unionization.[26]

[26]To rule out that unions only raised incomes among "insiders" born to the electrifying parishes, we ran the regression, excluding all movers in the sample, but the union-interaction

9 Counterfactual impact

Given our finding that electrification had the largest effect on those at the lower end of the income distribution, it is interesting to consider the potential counterfactual impact of the gradual expansion of electricity on inequality. To examine this, we use information on average income by decile among taxpayers, calculated from data in Bengtsson et al. (2021b) for 1900, 1910, 1920, and 1940. We also have information for 1930 from the census data used in this paper. We combine this with an assessment of the share of individuals living in areas with access to electricity, explained in appendix A.6.

To complete the calculation, we need to make a number of assumptions. First, we assume that the share with access to electricity was the same across the income distribution. Second, to estimate the impact on those in the 1st decile of the income distribution, we use the estimated coefficient from the quantile regression for those at the 5th percentile; for the 2nd decile, we use the coefficient estimated for the 15th percentile, and so on.

We estimate the counterfactual impact for each ten-year period using the following formula:

$$\Delta Yc_{d,t,t+1} = \frac{Y_{d,t} \times (\Delta E_{t,t+1} \times \beta_d)}{Y_{d,t}} \tag{3}$$

where: $\Delta Yc_{d,t,t+1}$ is the counterfactual percentage change in income for decile d between time point t and time point $t+1$, $Y_{d,t}$ is the average income in decile d at time point t, $\Delta E_{t,t+1}$ is the change in access to electricity between time point t and time point $t+1$, and β_d is the coefficient on the impact of electricity on income for decile d.[27]

The results for each ten-year period are shown in Figure 10. The counterfactual calculations suggest that there was a substantial impact on the growth of incomes from the expansion of electricity. For the whole 40-year period, the calculations indicate that incomes were lifted by roughly 45 percent for the second decile, while the impact was more muted higher up in the income distribution, being less than 10 percent for deciles seven and above. The largest impact occurred from 1910 to 1920, when electricity access rose by 45 percentage points, and the smallest impact was from 1920 to 1930, when electrification spread much more slowly.

What was the overall impact on inequality? The Gini coefficient among taxpayers in 1900 was 0.472 and had fallen to 0.445 by 1940. If we apply the counterfactual calculation of income growth by decile laid out in Equation 9 to the cumulative change in electricity access over the period from 1900 to 1940 (a 96 percent increase) for each taxpayer in the 1900 sample, it would suggest a fall in the Gini from 0.472 to 0.443, a number very similar to the actually observed decrease in inequality. This is not to suggest that electrification was

effects were absent among stayers and movers alike.

[27] As an example, the impact for the second decile for the 1900 to 1910 period is calculated as: $(579 \times (0.21 \times 0.471))/579 = 0.099$.

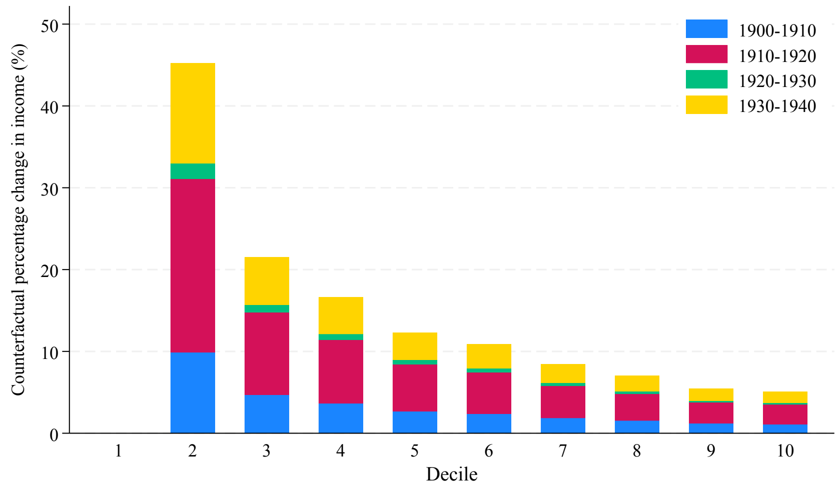

Figure 10: Counterfactual impact of electrification on income, 1900–1940.

Notes: The figure shows the counterfactual percentage change in income by decile due to the expansion of electricity for four ten-year periods: 1900-1910, 1910-1920, 1920-1930, and 1930-1940. The calculation uses average income by decile for each period, as reported by Bengtsson et al. (2021b) and supplemented with census data from 1930. The share of the population with access to electricity is estimated for each decade based on historical data. The counterfactual estimates assume that the share of individuals with access to electricity is evenly distributed across the income distribution. The impact for each decile is derived using the coefficients from the conditional quantile regressions, with adjustments made based on percentile data.

the only factor in reducing inequality. There were, of course, many other factors pushing it in different directions. The counterfactual calculation also rests on a number of assumptions that may or may not hold true in practice. However, it gives an indication of the potential significant impact of electricity in supporting the incomes of those at the lower end of the income spectrum and reducing inequality.

10 Conclusions

New technology in the form of electrification in the early 20$^{\text{th}}$ century did not result in massive lay-offs or technological unemployment. Instead new opportunities were created. Individuals in electrifying parishes earned higher incomes on average, and it was the persons in the lower deciles of the income distribution who saw the largest increases. The benefits were larger for individuals with primary schooling only, and for those born in the parishes, suggesting that the new technology offered new job opportunities for the incumbent, even for those with modest education levels. Although, individuals born in an early adopting parishes were more likely to be employed in electricity-related jobs compared to the control group, about two-thirds of the estimated income effect derived from factors not explained by structural change. The positive impact of electrification was not contingent on the existence of local supportive institutions, but rather the result of the innate characteristics of electrification as a labor-enhancing technology. Our results take into account all sectors at the local labor market and show that the new technology created a positive effect broadly, with declining income inequality as a result.

The great income compression in Sweden in the 20^{th} century is often described as a result of pro-labor institutions and Social Democratic policies that took place in the 1930s and 1940s. This study modifies the claims somewhat. By showing that the penetration of electricity-related technology had served to create new jobs and equalize incomes already by 1930, it suggests that more factors need to be considered. As Sweden, with its lack of competing energy sources (i.e. coal), saw an early roll-out of a state-sponsored electrical hydro-powered grid and high penetration of electrification early on it is possible that the premature involvement in the Second Industrial Revolution helped to pave the way for the emerging technology-friendly labor market institutions that came to characterize Sweden's 20^{th} century.

With a high reliance on a technology whose fundamental impact was pro-labor and pro-job growth, equalizing income distributions resulted from technology adoption. Thus, even before the emergence of the welfare states accelerated the development, the adoption of technology that favored labor and job growth led to more equal income distribution. Together with a willingness to redistribute the gains of new technology to all echelons of society, electrification may have served to compress the income distribution further when it extended to the entire population in the post-war period. In future work, more emphasis should be given to the fundamental features of different technologies and how they impact different segments of the labor market. Although a robust welfare state can surely cushion the blow of modern-day labor-saving technologies, this alone may not sufficiently alter their influence on employment and income dynamics.

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A Appendix A: Definitions and data

A.1 Probability of Inclusion in 1930 Census Sample

The digitization of the 1930 Swedish census is not complete, and as a result, our sample is not a complete representation of the entire population in our region of interest. To understand the implications of this limitation, we perform several tests.

Table 9: Regression for inclusion of parish in 1930 sample

	(1) Parish included in 1930 census
White collar (%) 1900	-0.003
	(0.01)
Foremen (%) 1900	0.011
	(0.02)
Medium skilled (%) 1900	-0.011
	(0.01)
Farmers (%) 1900	-0.001
	(0.01)
Lower skilled (%) 1900	-0.000
	(0.01)
Unskilled (%) 1900	0.004
	(0.01)
Log (1 + Labour Force) 1900	-0.214**
	(0.07)
Constant	1.759
	(1.26)
Observations	2470

Notes: The table presents the results of a regression examining the likelihood of a parish being included in the digitized 1930 Swedish census, based on parish characteristics observed in 1900. The dependent variable is a binary indicator for whether a parish is included in the 1930 census. The independent variables include the percentage of workers in various occupational categories (White collar, Foremen, Medium skilled, Farmers, Lower skilled, and Unskilled) and the logarithm of the labor force size in 1900. Robust standard errors are reported in parentheses.

First, we run a regression to see if there are any systematic differences between the parishes digitized in the 1930 census and those missing in terms of labor market size and structure. We get this information from the (complete) census of 1900. We create a binary variable indicating whether a parish is included in the 1930 census. We then run a regression with parish characteristics observed in 1900, prior to electrification, as control variables and the binary variable for inclusion in the 1930 sample as the outcome variable. The regression output is shown in Table 9. Of the 2470 Swedish parishes we have information on in 1900, 1,165 are digitized in the 1930 census. There are no statistically significant differences between the parishes included in the 1930 sample and the other ones in terms of social composition in 1900. The only difference that we encounter concerns the size of the labor force. There appears to be a slight difference in the size of the labor force in 1900; The parishes in the 1930 census have an average of 575 people in the labor force in 1900, and the parishes not yet digitised have an average of 591 people in the labor force in 1900.

Second, we calculate the probabilities of a parish being on the Western Line within the total number of parishes and our observed sample. Let p_{total} be the probability of being located on the Western Line among the total number of parishes and p_{sample} the probability of being located along the Western Line in the 1930 sample:

$$p_{\text{total}} = \frac{215}{1802 + 215} \approx 10.66\%$$

$$p_{\text{sample}} = \frac{46}{656 + 46} \approx 6.55\%$$

These probabilities show that the likelihood of being Western Line located is lower in our sample than in the total population. This shows we do not have to be concerned that our results are driven by a higher likelihood of Western Line located parishes being included in our sample.

Third, in addition to the parish level, we can examine this on an individual level. In Table 10 we show the number of individuals in our Control and Western Line parishes in the (complete) 1900 and 1910 censuses, as well as the number in the (incomplete) 1930 census. Again, it is clear that there is no increased likelihood of inclusion in the 1930 census by virtue of living in a Western Line parish.

Given the random nature of the digitization of the 1930 census across different parishes, we have no *a priori* reason to believe that Western Line parishes would be more likely to be included in the digitized 1930 census. Thus, while we acknowledge the incomplete nature of our dataset, we contend that it should not bias our findings towards overestimating the effect of being along the Western Line.

Table 10: Share of individuals who are born in Western Line parishes by census

Census Year	Control	Western Line	Percentage Western Line
1900	1,888,098	86,831	4.40%
1910	1,959,477	91,602	4.47%
1930	2,384,594	104,196	4.19%

Notes: The table shows the total count of individuals born in Control and Western Line parishes by census year, along with the percentage of the population born in Western Line parishes. The data covers three census years: 1900, 1910, and 1930. The percentage of individuals born in Western Line parishes remained relatively stable, ranging from 4.19% to 4.47% over the three decades. These figures for 1900 and 1910 are sourced from the Integrated Public Use Microdata Series (IPUMS) dataset, version 7.5, as published by Ruggles et al. (2024). The 1930 census is from Riksarkivet (2023).

A.2 Expansion of the grid 1900-1926

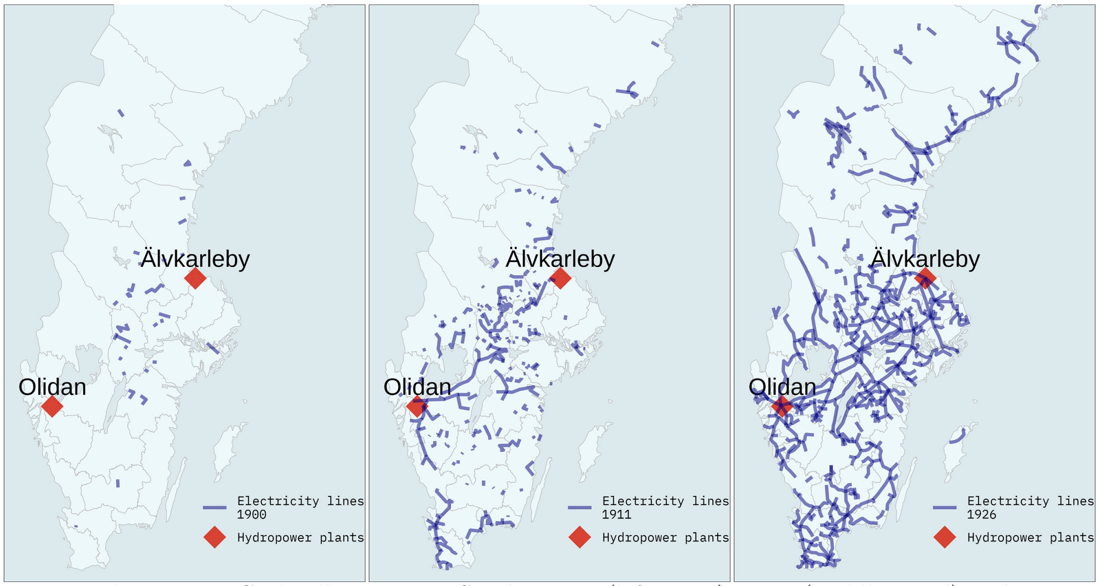

Figure 11: Grid roll-out across Sweden 1900 (left panel), 1911 (middle panel) and 1926 (right panel)

Notes: The maps show the expansion of the electricity grid along the Western Line (orange) between the two hydropower plants Olidan and Älvkarleby (marked with red diamonds). The paths of the electricity lines from 1926 are extracted from Hjulström (1940).

A.3 Method for ensuring that Western Line and control parishes are comparable

We note that the Western Line parishes and Control parishes that we observe in the (incomplete) 1930 census are slightly dissimilar, with a higher share of low-skilled workers and a lower share of farmers and fishermen in the Western Line parishes versus the Control parishes (see Tables 13 and 14).

To overcome this issue, we trim the sample slightly to keep the most similar Control parishes to our Western Line parishes (which we observe in 1930), and conduct the balance tests on these parishes in 1890 and 1900.

Western Line Parishes: Initially, there were 198 Western Line parishes based on the inclusion criteria (along a straight line between the power stations, touching a power line based on the 1921 map and 1926 rural electrification reports). Of these, 123 parishes are complete in the digitized census data from the 1930 census.

Control Parishes: For the control group, 1,400 parishes are considered within a 300km band along the Western Line. Of these 1,400, the 1930 census has data on 937 parishes.

We visualize the comparison between groups in a propensity score framework in Figure 12.

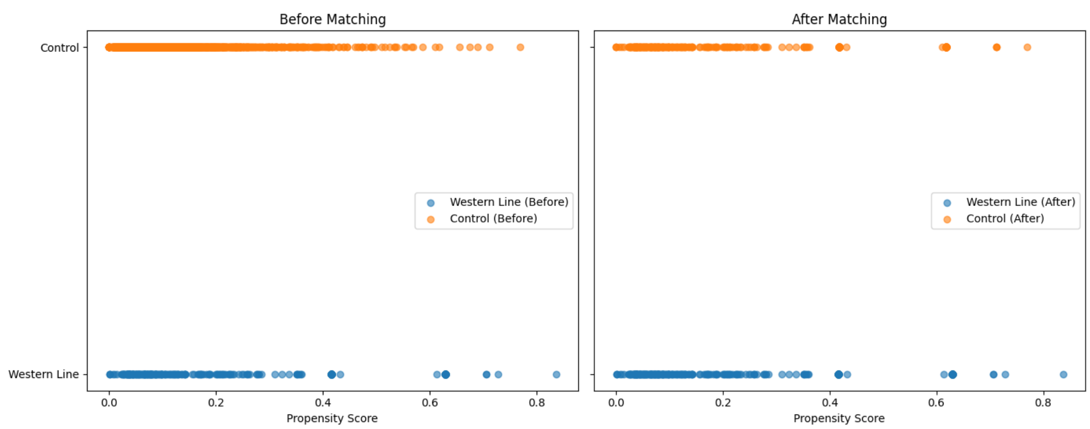

Figure 12: Comparison of Western Line and Control parishes in propensity score framework

A.3.1 Western Line vs. Control parishes: Balance tests from 1890 and 1900

Table 11: After balancing: test for 1890

	Mean (Western Line)	Mean (Control)	Std (Western Line)	Std (Control)	Difference	p-value
Elite	1.19	1.21	0.79	1.09	-0.14	0.89
White collar	5.11	4.91	2.74	3.35	0.37	0.71
Foremen	1.58	1.51	1.13	1.26	0.35	0.73
Medium-skilled workers	6.96	6.97	4.52	4.22	-0.01	0.99
Farmers and fishermen	26.67	26.66	14.28	11.82	0.00	1.00
Low-skilled workers	12.04	9.88	10.34	6.93	1.82	0.07
Unskilled workers	46.45	48.86	11.09	9.28	-1.56	0.12
Labour force	577.83	580.92	127.47	105.11	-0.18	0.86

Notes: The table displays the means and standard deviations of various occupational categories between Western Line parishes and Control parishes, using census data from 1890 to assess whether there are pre-existing differences in labor force composition prior to electrification. The occupational categories are based on a condensed version of the HISCLASS classification, organized into seven groups: Elite, White collar, Foremen, Medium-skilled workers, Farmers and fishermen, Low-skilled workers, and Unskilled workers. The "Difference" column shows the mean difference between Western Line and Control parishes, with the corresponding p-values indicating whether the differences are statistically significant. The sample is the Western Line and Control parishes after balancing.

Table 12: After balancing: test for 1900

	Mean (Western Line)	Mean (Control)	Std (Western Line)	Std (Control)	Difference	p-value
Elite	1.00	1.15	0.77	1.00	-0.91	0.36
White collar	5.96	6.01	2.85	3.80	-0.09	0.93
Foremen	2.05	1.96	1.19	1.54	0.36	0.72
Medium-skilled workers	8.07	7.89	4.55	4.39	0.25	0.80
Farmers and fishermen	24.86	26.42	14.13	11.89	-0.79	0.43
Low-skilled workers	13.65	11.04	10.41	7.61	2.05	0.06
Unskilled workers	44.42	45.54	9.74	9.74	-0.70	0.48
Labour force	582.51	586.01	133.68	96.84	-0.22	0.83

Notes: we use a version of HISCLASS condensed into seven classes.

Notes: The table displays the means and standard deviations of various occupational categories between Western Line parishes and Control parishes, using census data from 1900 to assess whether there are pre-existing differences in labor force composition prior to electrification. The occupational categories are based on a condensed version of the HISCLASS classification, organized into seven groups: Elite, White collar, Foremen, Medium-skilled workers, Farmers and fishermen, Low-skilled workers, and Unskilled workers. The "Difference" column shows the mean difference between Western Line and Control parishes, with the corresponding p-values indicating whether the differences are statistically significant. The sample is the Western Line and Control parishes after balancing.

A.3.2 Ensuring Comparability:

The observed Western Line parishes have more low-skilled workers and fewer farmers than our control parishes. Hence we identify and exclude the 40 control parishes that are most dissimilar to the Western Line group. After dropping these 40 Control parishes, we are left with 897 control parishes, and the two groups are similar in terms of occupational structure in 1890 and 1900, as verified by t-tests in Tables 11 and 12.

Table 13: Before Balancing: test for 1890

	Mean (Western Line)	Mean (Control)	Std (Western Line)	Std (Control)	Difference	p-value
Elite	1.00	1.04	-0.27	0.78	-0.04	0.78
White collar	5.96	5.37	1.05	0.29	0.59	0.29
Foremen	2.05	1.55	2.16	0.03	0.50	0.03
Medium-skilled workers	8.07	6.89	1.78	0.07	1.18	0.07
Farmers and fishermen	24.86	31.24	-2.88	0.00	-6.38	0.00
Low-skilled workers	13.65	8.53	4.02	0.00	5.12	0.00
Unskilled workers	44.42	45.37	-0.57	0.57	-0.95	0.57
Labour force	582.51	575.21	0.48	0.63	7.30	0.63

Notes: we use a version of HISCLASS condensed into seven classes.

Notes: The table displays the means and standard deviations of various occupational categories between Western Line parishes and Control parishes, using census data from 1890 to assess whether there are pre-existing differences in labor force composition prior to electrification. The occupational categories are based on a condensed version of the HISCLASS classification, organized into seven groups: Elite, White collar, Foremen, Medium-skilled workers, Farmers and fishermen, Low-skilled workers, and Unskilled workers. The "Difference" column shows the mean difference between Western Line and Control parishes, with the corresponding p-values indicating whether the differences are statistically significant. The sample is the Western Line and Control parishes before balancing.

Table 14: Before Balancing: test for 1900

	Mean (Western Line)	Mean (Control)	Std (Western Line)	Std (Control)	Difference	p-value
Elite	1.00	1.04	-0.27	0.78	-0.04	0.78
White collar	5.96	5.37	1.05	0.29	0.59	0.29
Foremen	2.05	1.55	2.16	0.03	0.50	0.03
Medium-skilled workers	8.07	6.89	1.78	0.07	1.18	0.07
Farmers and fishermen	24.86	31.24	-2.88	0.00	-6.38	0.00
Low-skilled workers	13.65	8.53	4.02	0.00	5.12	0.00
Unskilled workers	44.42	45.37	-0.57	0.57	-0.95	0.57
Labour force	582.51	575.21	0.48	0.63	7.30	0.63

Notes: we use a version of HISCLASS condensed into seven classes.

Notes: The table displays the means and standard deviations of various occupational categories between Western Line parishes and Control parishes, using census data from 1900 to assess whether there are pre-existing differences in labor force composition prior to electrification. The occupational categories are based on a condensed version of the HISCLASS classification, organized into seven groups: Elite, White collar, Foremen, Medium-skilled workers, Farmers and fishermen, Low-skilled workers, and Unskilled workers. The "Difference" column shows the mean difference between Western Line and Control parishes, with the corresponding p-values indicating whether the differences are statistically significant. The sample is the Western Line and Control parishes before balancing.

A.4 Movers and Stayers in the sample

Table 15: Movers and stayers cross tabulation

Mover	Western Line Parish		Total
	0	1	
0	138,238 (30.08%)	17,450 (37.58%)	155,688 (30.76%)
1	321,394 (69.92%)	28,989 (62.42%)	350,383 (69.24%)
Total	459,632 (100.00%)	46,439 (100.00%)	506,071 (100.00%)

Notes: The table shows the cross tabulation of number of people born in the birth parishes that were along the Western Line (Western Line parish=1) compared to the control group (Western Line parish=0), by those residing in their parish of birth (Mover=0) compared to those residing elsewhere in 1930 (Movers). Source: Swedish census of 1930

A.5 Union Density Data Completeness

Table 16: Share of Parishes with Union Membership Data

Year	Data Present	Data Missing	Share Complete	Total number of Parishes
1880	0	1,314	0.00%	1,314
1890	46	1,268	3.50%	1,314
1900	225	1,089	17.12%	1,314
1910	513	801	39.04%	1,314
1930	451	863	34.32%	1,314

Notes: The table shows the share of parishes that report data on union density by year from Folkrörelsearkivet 1881-1950 (the social movement archive). Source: Andrae and Lundqvist (1998)

Table 17: Union Density by Parish Type

Year	Control	Western Line
1880	-	-
1890	0.81%	0.13%
1900	2.73%	4.21%
1910	3.56%	4.26%
1930	7.01%	11.24%

Notes: The table shows average measures of union divided by population (union density) in the control parishes and the Wester Line parishes, by year. The data was calculated from Andrae and Lundqvist (1998)

A.6 Assumption: Share of population with access to electricity

We make a very basic back-of-the-envelope calculation on the share of the population that had access to electricity in 1900, 1910, 1920, and 1940. Based on visual inspections of maps from Vattenfall and data on the location of energy generators, we assume a faster increase in the share of population that had access to electricity in urban areas compared to rural areas. To get to the total share in the population, we multiply the share of electricity users in urban and rural areas with their relative shares in the population. The assumptions are summarized in Table 18.

Table 18: Electricity share

Year	Electricity Share Urban	Electricity Share Rural	Population Urban	Population Rural	Total Estimated Electricity Users
1900	0	0	0.2	0.8	0.00
1910	0.7	0.03	0.27	0.73	0.21
1920	1	0.4	0.43	0.57	0.66
1930	1	0.42	0.49	0.51	0.70
1940	1	0.9	0.55	0.45	0.96

Notes: This table summarizes the assumptions about access to electricity in urban and rural areas, and the share of the population belonging to each category. *Sources:* Vattenfall (1948): Vattenfallsstyrelsen och distributionsföreningarna, Statistics Sweden (2015-03-03): Urbanisering, från land till stad.

B Appendix B: Robustness

B.1 Threshold for control parishes

Table 19 shows that our main result in Table 5 is not sensitive to the threshold chosen for the distance from the Western Line that dictates our control parishes.

Table 19: Income (Varying distance threshold - km from Western Line)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	100	150	200	250	300	350	400	450	500
Western Line Parish	0.149**	0.153***	0.181***	0.246***	0.263***	0.299***	0.307***	0.312***	0.329***
	(0.07)	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Age	X	X	X	X	X	X	X	X	X
Gender	X	X	X	X	X	X	X	X	X
Marital Status	X	X	X	X	X	X	X	X	X
Schooling	X	X	X	X	X	X	X	X	X
HISCO 2 digit	X	X	X	X	X	X	X	X	X
Railway in Parish	X	X	X	X	X	X	X	X	X
R-squared	0.30	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28
Observations	260,511	379,335	421,047	476,967	528,047	594,420	611,105	635,334	660,459

Notes: The table presents regression results showing the effect of varying the distance band around the Western Line parishes on the estimated income premium for individuals residing in those parishes in 1930. The band distances range from 100 to 500 kilometers, as indicated in the columns. The dependent variable is log income, and the key independent variable is whether an individual resides in a Western Line parish. The controls include age, gender, marital status, schooling, and HISCLASS. Standard errors are clustered at the parish level.

B.2 Interaction effects industrial specialization and railway connectivity

Table 20: Interaction effects

	(1) Baseline	(2) Urban Parish 1910	(3) Railway in Parish 1900
Western Line Parish	0.265***		
	(0.05)		
Western Line Parish=1		0.351***	0.173**
		(0.05)	(0.08)
Parish has more non-farming households than avg in 1910=1		0.164***	
		(0.05)	
Western Line Parish=1 × Parish has more non-farming households than avg in 1910=1		-0.137	
		(0.09)	
Railway in Birth Parish=1			0.021
			(0.05)
Western Line Parish=1 × Railway in Birth Parish=1			0.126
			(0.10)
Age and Gender	X	X	X
Marital Status, Schooling and Railway in Parish	X	X	X
R-squared	0.29	0.29	0.29
Observations	523,849	523,849	523,849
F-stat	.	.	.

Notes: The table presents estimates of the the impact of being born in a Western Line parish on log income in column one, the baseline regression from Table 5. Column two introduces an interaction with a variable for if the individual's parish of birth was in the top half of the distribution of urban parishes in 1910 (more precisely, fewer than 49.4 percent of the households in the parish in 1910 were involved with farming). The third column shows the impact of being born in a Western Line parish interacted with the presence of a railway in the parish of birth in 1900. Controls include age, gender, marital status, schooling, two-digit hisco code, and an indicator for if an individual's birth parish was connected by rail in 1900. Standard errors are clustered at the parish level.

B.3 Age profile of the impact of being born in a Western Line parish

The figure shows the income effect estimated in Table 5 separated by age (yearly intervals) in 1930.

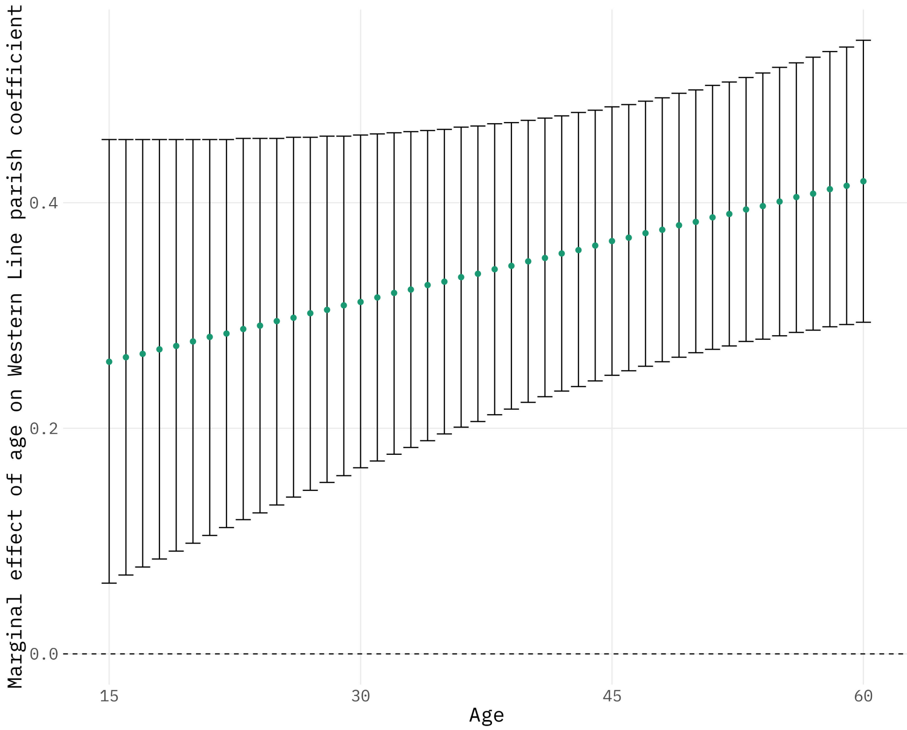

Figure 13: Coefficient plot for impact of being born in a Western Line parish on log income by age

B.4 Conditional quantile regression coefficients

Table 21: Comparison of Conditional and Ritualized Quantile Regressions

	(1) 5th Pctl.	(2) 15th Pctl.	(3) 25th Pctl.	(4) 35th Pctl.	(5) 45th Pctl.	(6) 55th Pctl.	(7) 65th Pctl.	(8) 75th Pctl.	(9) 85th Pctl.	(10) 95th Pctl.
Conditional QR	0.000	0.471***	0.224***	0.173***	0.128***	0.113***	0.088**	0.073*	0.057	0.053
	(0.01199)	(0.11700)	(0.04990)	(0.04159)	(0.03416)	(0.03035)	(0.02976)	(0.03427)	(0.04283)	(0.04983)
Residualized QR	0	7.28e-10	0.703***	0.153***	0.118***	0.097***	0.154***	0.112***	0.043***	0
	(0.00140)	(0.00221)	(0.03179)	(0.00690)	(0.00653)	(0.00655)	(0.00650)	(0.00602)	(0.00518)	(0.00000)
Observations	343 488	343 488	343 488	343 488	343 488	343 488	343 488	343 488	343 488	343 488
Controls:	X	X	X	X	X	X	X	X	X	X

Clustered standard errors in parentheses for conditional QR. Controls are Age, Gender, Marital Status, Schooling, HISCLASS

Notes: The table presents results comparing a conditional quantile regression to a residualized quantile regression where the outcome variable is log income. The regressions are run across different percentiles of the income distribution, from the 5th to the 95th percentile. Controls in both models include age, gender, marital status, schooling, and HISCLASS. There is also a control for the presence of a railway line in the parish of birth. We opt for HISCLASS in this instance over HISCO code at two-digit level because the regressions did not converge with HISCO code at two-digit level as a control, owing to there being 73 different dummy variables. The standard errors in the conditional quantile regression are clustered at the parish level, while in the residualized quantile regression, the standard errors are robust but not clustered at the parish level because the command did not allow for this. The results indicate that the income premium associated with the treatment is more pronounced in the lower and middle parts of the income distribution and diminishes in the higher percentiles.

B.5 Residualized quantile regression results

If we are interested in interpreting the coefficients from our quantile regressions in the same way as OLS regression coefficients – that the coefficient represents the impact of being born in a Western Line parish on an individual, we must use a specific type of quantile regression. Here, we explain the use of a quantile treatment effect (QTE) model to attain this interpretation at an individual level.

In conditional quantile regression, we estimate the effect on the distribution as a whole, since we cannot know where an individual will be in the income distribution before and after treatment (Firpo et al., 2009). This is because, according to Borgen et al. (n.d.), conditional treatment effects are based on the conditional distribution of the outcome variable.

Using the residualized quantile regression (RQR) model, the RQR coefficients are derived using a two-phase method. Initially, the treatment (being born in a Western Line parish) is regressed on control variables using ordinary least squares (OLS) technique to acquire the treatment variable's residuals. This phase effectively splits the treatment variable's variance into a portion accounted for by the control variables and a residual portion that is independent of the controls. Following this, the second phase involves regressing the outcome on the treatment variable, which has been adjusted for residuals, using the same conditional quantile methods as in the body of the article (Borgen et al., n.d.).

The results of the quantile regressions are presented in Figure 14, as well as Table 21. The regression includes all the standard controls for age, gender, marital status, schooling, and HISCLASS. It displays that the largest effect on income is at the lower end of the income distribution.

For the conditional quantile regression model we see that while at the lowest 5 percent of the conditional income distribution there difference between the Western Line and Control groups, at the 15^{th} percentile of the conditional distribution the treatment group exhibit 0.427 log points higher incomes than the control group, or approximately 53 percent higher incomes. Since at the 25^{th} percentile of the conditional income distribution exhibit 0.242 log point increase in income (roughly 27 percent), the bulk of the income increase is found in lower than median income groups. In the highest deciles the income effect is much smaller and not statistically significant (85^{th} and 95^{th} percentiles of the income distribution).

The pattern is similar when examining the quantile treatment effects estimated with the residualized quantile regression. Here we can interpret these effects in the same way that we would OLS coefficients – at the individual level. We find that for individuals at the 25^{th} percentile of the income distribution, birth in a Western Line parish is associated with 0.7 log points higher incomes, or 101 percent. Individuals at the 35^{th} percentile of the income distribution in the Western Line parish group see 0.15 log points higher income, or 16 percent. The effect diminishes at the top of the income distribution.[28]

[28]It is worth noting that the 'rqr' command in Stata which implements the residualized quantile regression model does not allow us to cluster standard errors at the parish level, hence why the confidence intervals are narrower than the conditional quantile regression.

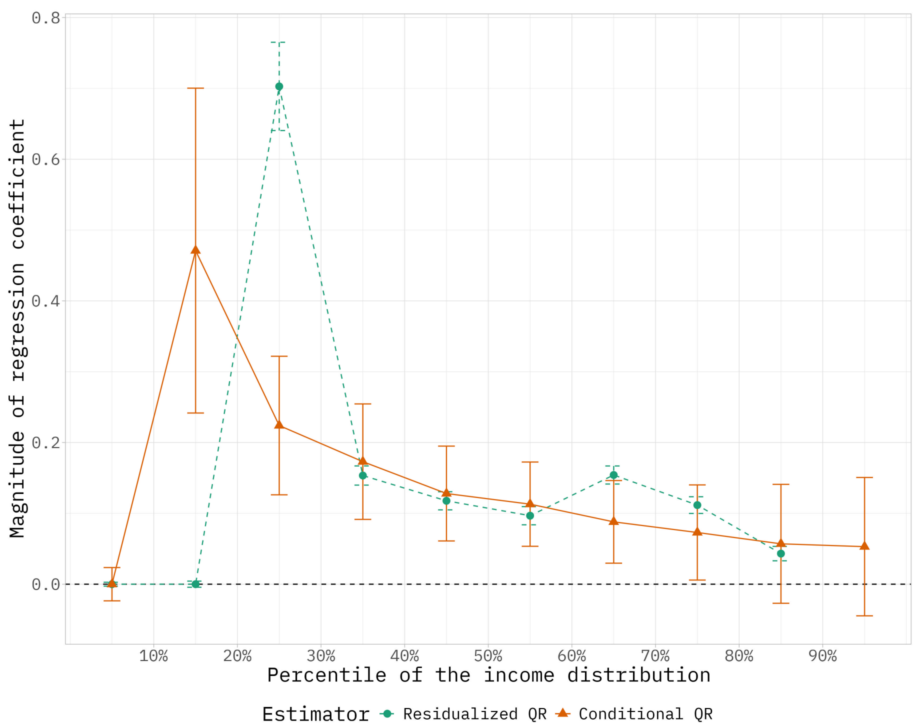

Figure 14: Coefficient plot from conditional and residualized quantile regression with log income as dependent variable and the coefficient of interest is an individual's birth parish being located along the Western Line. Controls include age, gender, education, marital status, schooling, and HISCLASS. Note that due to data paucity, the 95$^{\text{th}}$ percentile estimation for the RQR could not be estimated.

B.6 Education interaction

Table 22: Education interaction

	(1)
	Log Income
Primary school	0.291***
	(0.06)
Post primary schooling	1.006***
	(0.06)
Post-secondary and university	1.594***
	(0.09)
Western Line Parish=1 × Primary school	0.362*
	(0.14)
Western Line Parish=1 × Post primary schooling	0.328*
	(0.17)
Western Line Parish=1 × Post-secondary and university	0.207
	(0.26)
R-squared	0.29
Observations	523,849

Notes: The table presents the results of an OLS regression where the outcome variable is log income, and the main variables of interest are interactions between being born in a Western Line parish and the individual's level of education. The education levels include Primary school, Post-primary schooling, and Post-secondary or university education. The base level (excluded) is Literate. The interaction terms assess whether the income premium associated with being born in a Western Line parish varies by educational attainment. Controls include age, gender, marital status, schooling, and HISCO at the two-digit level. Standard errors are clustered at the parish level.

B.7 Union density interaction

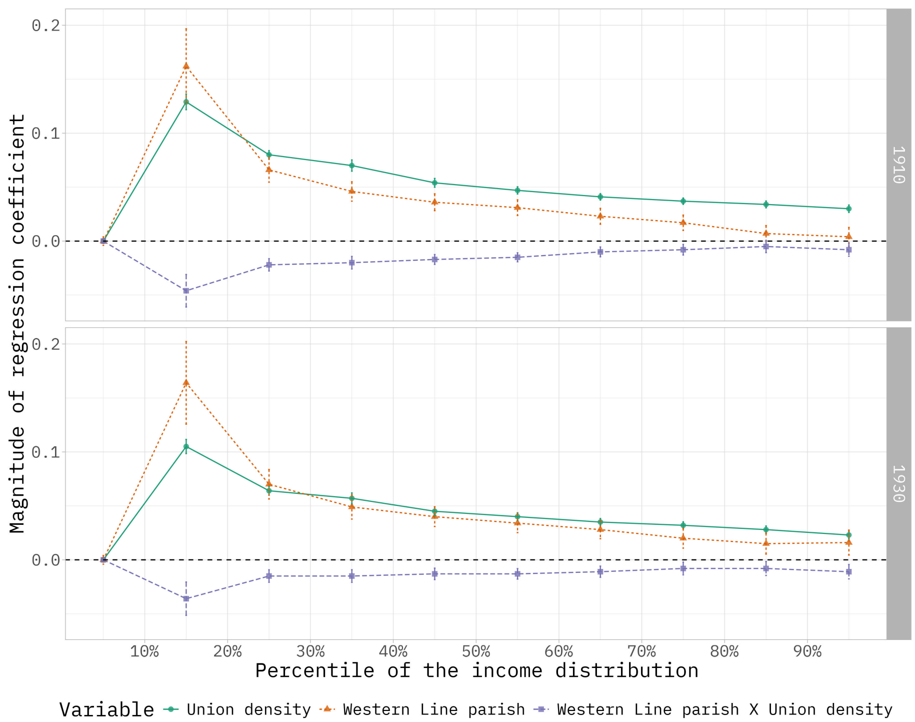

Figure 15: Coefficient plot for conditional quantile regression: 1910 and 1930

Notes: The coefficient plot presents results from a conditional quantile regression that investigates the effect of being born in a Western Line parish, union density in 1910 and 1930, and their interaction on log income across various percentiles of the income distribution (percentile 5 through percentile 95). The regression controls for age, gender, marital status, schooling, and occupational skill level (HISCLASS), with standard errors clustered at the parish level

Table 23: Union density interaction: 1900

	(1) Pctile 5	(2) Pctile 15	(3) Pctile 25	(4) Pctile 35	(5) Pctile 45	(6) Pctile 55	(7) Pctile 65	(8) Pctile 75	(9) Pctile 85	(10) Pctile 95
Western Line parish	0.000	0.182***	0.091***	0.066***	0.054***	0.047***	0.039***	0.033***	0.026*	0.021
	(0.00351)	(0.03398)	(0.01408)	(0.01110)	(0.00892)	(0.00820)	(0.00777)	(0.00866)	(0.01049)	(0.01941)
Union density	0.000	0.124***	0.095***	0.078***	0.064***	0.056***	0.051***	0.046***	0.041***	0.038***
	(0.00078)	(0.00991)	(0.00487)	(0.00528)	(0.00369)	(0.00303)	(0.00260)	(0.00276)	(0.00325)	(0.00397)
Western Line parish X Union density	0.000	-0.105***	-0.080***	-0.063***	-0.054***	-0.048***	-0.043***	-0.039***	-0.035***	-0.031
	(0.00128)	(0.01345)	(0.01089)	(0.00775)	(0.00537)	(0.00495)	(0.00686)	(0.00527)	(0.00878)	(0.02994)

Clustered standard errors in parentheses. Controls are Age, Gender, Marital Status, Schooling, HISCLASS

Notes: The table presents results from a conditional quantile regression that investigates the effect of being born in a Western Line parish, union density in 1900, and their interaction on log income across various percentiles of the income distribution (percentile 5 through percentile 95). The regression controls for age, gender, marital status, schooling, and occupational skill level (HISCLASS).

Table 24: Union density interaction: 1910

	(1) Pctile 5	(2) Pctile 15	(3) Pctile 25	(4) Pctile 35	(5) Pctile 45	(6) Pctile 55	(7) Pctile 65	(8) Pctile 75	(9) Pctile 85	(10) Pctile 95
Western Line parish	0.000	0.162***	0.066***	0.046***	0.036***	0.031***	0.023**	0.017*	0.007	0.004
	(0.00392)	(0.03469)	(0.01138)	(0.00896)	(0.00778)	(0.00724)	(0.00734)	(0.00708)	(0.00738)	(0.00865)
Union density	0.000	0.129***	0.080***	0.070***	0.054***	0.047***	0.041***	0.037***	0.034***	0.030***
	(0.00061)	(0.00726)	(0.00383)	(0.00521)	(0.00406)	(0.00336)	(0.00299)	(0.00291)	(0.00316)	(0.00343)
Western Line parish X Union density	0.000	-0.046**	-0.022**	-0.020**	-0.017**	-0.015**	-0.010*	-0.008	-0.005	-0.008
	(0.00211)	(0.01507)	(0.00569)	(0.00579)	(0.00454)	(0.00416)	(0.00455)	(0.00488)	(0.00566)	(0.00600)

Clustered standard errors in parentheses. Controls are Age, Gender, Marital Status, Schooling, HISCLASS

Notes: The table presents results from a conditional quantile regression that investigates the effect of being born in a Western Line parish, union density in 1910, and their interaction on log income across various percentiles of the income distribution (percentile 5 through percentile 95). The regression controls for age, gender, marital status, schooling, and occupational skill level (HISCLASS), with standard errors clustered at the parish level

Table 25: Union density interaction: 1930

	(1) Pctile 5	(2) Pctile 15	(3) Pctile 25	(4) Pctile 35	(5) Pctile 45	(6) Pctile 55	(7) Pctile 65	(8) Pctile 75	(9) Pctile 85	(10) Pctile 95
Western Line parish	0.000	0.164***	0.070***	0.049***	0.040***	0.034***	0.028***	0.020*	0.015	0.016
	(0.00399)	(0.03826)	(0.01367)	(0.01123)	(0.00911)	(0.00876)	(0.00842)	(0.00914)	(0.00967)	(0.01158)
Union density	0.000	0.105***	0.064***	0.057***	0.045***	0.040***	0.035***	0.032***	0.028***	0.023***
	(0.00055)	(0.00654)	(0.00412)	(0.00501)	(0.00412)	(0.00359)	(0.00328)	(0.00320)	(0.00337)	(0.00333)
Western Line parish X Union density	0.000	-0.036*	-0.015**	-0.015*	-0.013*	-0.013**	-0.011*	-0.008	-0.008	-0.011
	(0.00184)	(0.01545)	(0.00579)	(0.00582)	(0.00531)	(0.00483)	(0.00517)	(0.00588)	(0.00645)	(0.00665)

Clustered standard errors in parentheses. Controls are Age, Gender, Marital Status, Schooling, HISCLASS

Notes: The table presents results from a conditional quantile regression that investigates the effect of being born in a Western Line parish, union density in 1930, and their interaction on log income across various percentiles of the income distribution (percentile 5 through percentile 95). The regression controls for age, gender, marital status, schooling, and occupational skill level (HISCLASS), with standard errors clustered at the parish level

B.8 Conley Standard Errors

A potential concern when working with geographic data is the presence of spatial autocorrelation, which can lead to underestimated standard errors and inflated significance levels if not properly accounted for. In our main analysis, we conduct regressions at the individual level rather than the parish level. This approach allows us to capture within-parish heterogeneity, leverage a larger sample size, and provide a more granular view of the relationship between birthplace, residence, and income.

To assess the robustness of our findings, we aggregate the data to the parish level by collapsing individual-level variables to their means and estimate the same regression. In this specification, we account for spatial dependence by using Conley standard errors, where we take the centroid of each parish as its geographic coordinate and set a threshold distance of 100 km for defining spatial correlation. Table 26 presents the results, showing that the key coefficients remain large and statistically significant. This suggests that the effects we identify are also hold at a more aggregated level, reinforcing the robustness of our conclusions.

Table 26: Parish-Level Income Regression with Conley Standard Errors

	(1) (mean) log_income	(2) (mean) log_income
A. Western Line	0.387***	
	(0.10)	
B. Western Line		0.236***
		(0.08)
Controls	X	X
R-squared	0.40	0.31
Observations	475	2,148

Notes: This table presents two regressions estimated at the parish level. The dependent variable is the mean log income in each parish, aggregated by parish of residence (specification A.) or by parish of birth (specification B). The regressions are estimated using the 'acreg' command in Stata, which accounts for spatial correlation in the error terms by computing Conley standard errors. The centroids of each parish are used as geographic coordinates, with a threshold distance of 100 km for defining spatial correlation. Column (1) examines the effect of residing in a Western Line parish in 1930, while Column (2) assesses the effect of being born in a Western Line parish. The number of observations differs between specifications because the 1930 census is not fully transcribed, leading to fewer observations in Column (1). However, individuals born outside the parishes included in the 1930 census are observed if they moved into these parishes, resulting in a larger sample in Column (2). Both specifications include controls for parish level means of age and of gender (where female is equal to one), as well as the mean share of individuals with schooling above primary level. We include a dummy for the presence of a railway in the parish, and controls for the share of each HISCLASS group in the parish. We do not use HISCO two-digit occupational controls here owing to the sparsity of this data compared to HISCLASS, which is aggregated to seven levels. Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.