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More Power to the People: Electricity Adoption, Technological Change and Social Conflict

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Abstract

There is a wide-spread concern that technical change may spur social conflicts, especially if workers are replaced with machines. To empirically analyze whether technological disruption drives protests, we study a historical example of a revolutionary new technology: the adoption of electricity. Focusing on the gradual expansion of the Swedish electricity grid between 1900 and 1920 enables us to analyze 2,470 Swedish parishes in a difference-in-differences framework. Exploiting the fact that proximity to large-scale hydro-powered electricity plants shaped the network layout, independently of previous economic conditions, our results indicate that the adoption of electricity was followed by an increase of local conflicts in the form of strikes. But displaced workers were not likely to initiate conflicts. Instead, strikes were most common in sectors with employment growth. Similarly, we find that the strikes were of an offensive rather than a defensive nature. Thus electrification did not result in rebellions driven by technological anxiety, but rather provided workers with a stronger bargaining position from which they could voice their claims through strikes.

Key words: technological change; electrification; labor demand; labor conflicts; strikes; infrastructure investments

JEL Codes: N14; N34; N74; O14

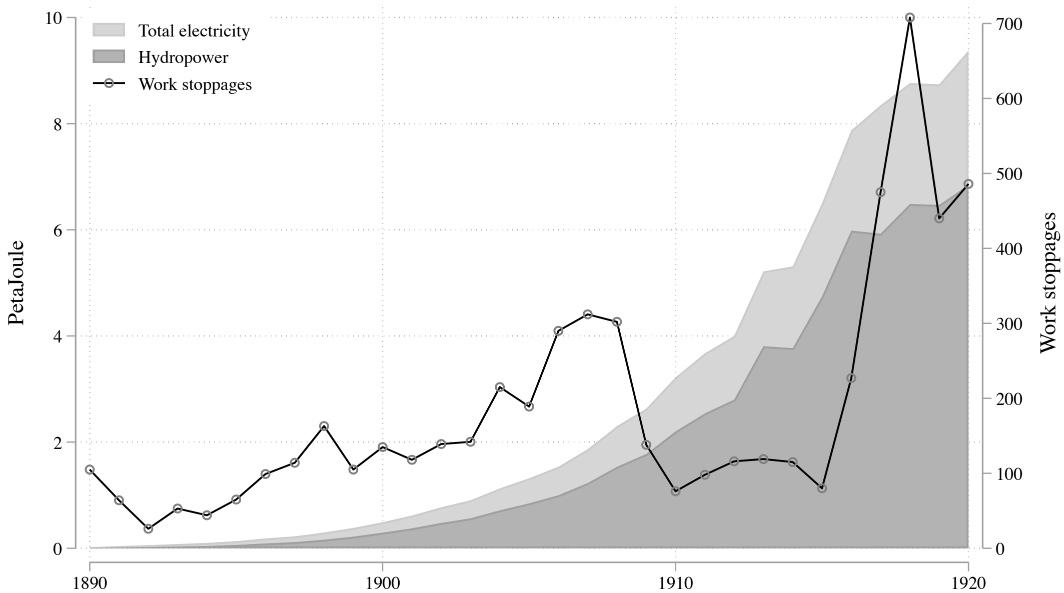
1 Introduction

The current debate on technological change and the labor market is ridden by anxiety. Empirical evidence suggests that middle-class or medium-skilled workers have been the most vulnerable to job loss during the last decades (Goos and Manning, 2007; Autor et al., 2006). A recent study warns that 48 percent of the American workforce could be replaced by computers within a few decades or so (Frey and Osborne, 2017). Some scholars have suggested that "technological anxiety" is channeled through the political system and manifested in increasing support for right-wing populism (Dal Bo et al., 2017; Frey et al., 2017).

Given the potentially large societal impact inherent in the introduction of new technology, we might expect potential losers to try to use non-market means to hinder the adoption of new technology (Mokyr, 1992; Mokyr et al., 2015). These non-market means have had different expressions. The most well-known historical examples are probably the Luddite uprising and the Captain Swing Riots in the wake of the First Industrial Revolution. It is easy to be caught by the dramatic and colorful stories of machine breaking. The question is, however, how representative anti-machine protests have been in the overall spectrum of workers' responses to technological change. The Second Industrial Revolution was not associated with machine breaking. Frey (2019) suggest that the main reason for the absence of such conflicts was the increasing supply of good jobs that were relatively easy to learn. Although this explanation seems reasonable with hindsight, what really mattered was how contemporary workers understood the situation. New technologies often involve the disruption of established practices and may therefore appear threatening (Shorey, 1976). Moreover, technological change may also put some categories of workers in a better bargaining position. These potential winners have the opportunity use non-market means to improve their jobs and wages. When assessing the societal impact of technological change, these "offensive" protests are easily disregarded, since they are rarely explicitly linked to machines.

In this study we analyze the relation between technological change and social protests in 2,487 parishes in early 20$^{\text{th}}$ century Sweden. More precisely, we study the adoption of electricity and how it influenced labor conflicts in the form of strikes. Electricity was one of the cornerstones of the Second Industrial Revolution and enabled the mechanization of production and new ways of organizing it. Lacking domestic coal deposits, Sweden experienced an early and influential shock from electrification. This makes Sweden an interesting case study for the impact of new technology and labor market unrest, especially since the penetration of electricity coincided with a documented increase in labor conflicts. Figure 1 presents the development of electricity consumption and the number of work stoppages around the turn of the last century. As can be seen in the figure, electrification was pervasive from the late 19$^{\text{th}}$ century onward and this development was mainly driven by the expansion of hydroelectric power.[1]

Figure 1: Electricity use and Work Stoppages in Sweden, 1890–1920



Note: This figure shows the development of electricity use in Sweden between 1890 and 1920 measured in number of petajoule, as well as the share of electricity generated from hydropower. Shown in the figure is also the number of work stoppages over the same period.
Sources: Work stoppages: Enflo and Karlsson (2019), Karlsson (2019), Svensk Nationell Data Service, SND:1088; Electricity consumption in petajoules: Kander (2002), Hjulström (1940) and official industrial statistics (SOS Industristatistik 1912–1920).

Our analysis proceeds in two steps. First, we establish the impact of the adoption of electricity on strikes in local labor markets. Second, we dig into the mechanisms by providing evidence of its effects on labor demand and structural change. The frequency of strikes at the parish level has been drawn from a recently geo-coded and digitized dataset on work stoppages in Sweden and allows distinguishing between strikes based on offensive claims and those based on defensive claims.[2] Information on the occupational structure of each parish is based on full-count census data from IPUMS International (Minnesota Population Center, 2019). We proxy access to the electricity grid by digitizing contemporary survey maps. To control for the potential endogeneity of the adoption of electricity with respect to conflicts and labor demand, we exploit the fact that the connection of two large hydro-powered plants shaped the layout of the electricity grid in a way that was independent of pre-existing local characteristics.

Our results speak primarily to the debate about technological change and social unrest. In the Luddite

[1]Between 1890 and 1920 the share of electricity derived from hydro increased from 32 percent to 73 percent, meaning that water power gradually overtook steam as the primary source of electricity.

[2]See Enflo and Karlsson (2019) and Molinder et al. (2018). The dataset is stored at the Swedish National Data Service as SND:1088 (https://snd.gu.se/en/catalogue/study/snd1088), from where it can be obtained upon request.

uprisings, the protests took a radical turn when textile workers physically destroyed the machines they feared would replace their labor. Whether new technology really was the root of the uprisings has been questioned. Mokyr et al. (2015), for example, have suggested that the Luddite Riots in fact may have been driven by a "multitude of causes" not necessarily caused by technological change. Potentially bi-directional causation between technology and protests and limitations in the available data pose severe challenges to an empirical identification. Indeed, the research specializing in strikes has often overlooked technological change as an explanatory variable (Franzosi, 1989). A recent study by Caprettini and Voth (2020) has moved the research front by convincingly exploiting instrumental variable techniques to establish a causal link from technology to protests during the Captain Swing riots— when agricultural workers demolished threshing machines in 1830s England. The study shows that threshing machines were an important source of unrest, but that protests were amplified where workers were impoverished or saw few alternative employment opportunities, suggesting that context matters for the relation. Although concerning a different context, our study resembles that study in that we seek to establish a causal link from new technology to protests, and we corroborate that this new technology did increase conflicts. However, we document the fact that conflicts following electrification were "offensive" (higher wage demands, etc.) rather than "defensive" (demonstrations against job losses, wage decreases, etc.) and that offensive strikes were particularly frequent in sectors with increasing demand for labor. The strikes appear to be manifestations of workers' improved bargaining position due to new labor market conditions. Thus, we argue that electrification did not result in rebellions driven by "technological anxiety."

Our results also contribute to the literature on technological change and the skill-composition of jobs in various historical epochs. Echoing modern studies on the effects of computerization (Frey and Osborne, 2017) and the Braverman (1974) thesis of the "degradation" of labor, we find that technological change influenced labor demand in different ways across the occupational structure. We find that labor demand increased in the parishes that adopted electricity early, but that jobs were mainly created for low to medium skilled workers, suggesting a "hollowing in," rather than a "hollowing out," of the distribution of skills. Similarly to Leknes and Modalsli (2020), we find that electricity drove increases in labor demand and structural change into non-agricultural sectors. This pattern contrasts with studies of early rural electrification in the US Kline and Moretti (2013); Lewis and Severnini (2020) and Kitchens and Fishback (2015) that instead find gains in agriculture.

The rest of this paper is organized as follows. Section 2 lays out the conceptual framework, explaining how we think about electricity adoption as an exogenous impulse to local technological change, its impact on the demand for labor, and subsequent protests in the form of strikes. Section 3 explains the empirical strategy and data. Section 4 presents the results. Section 5 concludes the paper.

2 Historical Background and Conceptual Framework

The arrival of electricity was a technological shock with potentially revolutionary social and economic consequences. Yet its actual impact on the patterns of social protest were likely to be shaped by the historical context, as well as the nature and pace of the electrification. The impact may well have differed between labor market segments, depending on previous traditions of collective action and how electrification changed the bargaining position of workers and employers. In this section we firstly survey the literature on Sweden's industrialization and labor market evolution with a focus on strikes. Thereafter, we explain how the state-led expansion of the electricity network constituted an exogenous local shock to the incentive to adopt a new technology in some regions. Finally, we discuss how electricity affected the local labor markets and explain our expectations about who would be the winners and losers of the new technology.

2.1 Industrialization and the Labor Market

In the decades around 1900, Sweden was approaching an industrial breakthrough, but with huge proportions of the population still residing in the countryside. In 1900, almost 60 percent of the gainfully employed population were found in agriculture, compared to less than 20 percent in manufacturing and handicrafts (Schön, 2012). A clear majority of those employed in manufacturing were also found in the countryside, for example in rural iron mills (Berger et al., 2012). As time passed, increasing proportions of the population were attracted to the cities and employment in manufacturing, construction, transport, and private services. Due to the new methods of steel making and better transport, the rural iron industry underwent a process of structural rationalization, with fewer and larger production units, while dissolving the previous patriarchal bonds between employers and workers. More generally, large firms had played a dominating role already from the start of Sweden's industrialization and the period 1870–1914 saw "concurrent growth in both small and large companies" (Magnusson, 2000, p. 154). Overall, this development seems to have continued well into the 20$^{\text{th}}$ century, although the size structure of firms is difficult to determine from the official industrial statistics. Big businesses were eventually matched by trade unions and patterns of social protests associated with industrial societies.

In the latter half of the nineteenth century, riots and spontaneous popular protests, typically performed in times of distress, gave way to organized strikes (Karlbom, 1967; Cederqvist, 1980). In contrast to the pre-industrial pattern of social conflict, strikes were pro-cyclical (Mikkelsen, 1992), as workers learned that they had the best chance to succeed when putting forward their claims in good times. Unionization began in the 1870s in some occupations and union density grew rapidly to about 17 percent in the early twentieth century, a comparatively high level, internationally (Åmark, 1986). As elsewhere, the early unions were typically based on craft membership, but the dominating form of organization would eventually become the industrial union (Åmark, 1998). Although there were some tendencies towards increasing centralization of industrial relations apparent in the early twentieth century, recent research suggests the continuing importance of local conditions for strike behavior (Molinder et al., 2018) well into the inter-war period.

In the literature on strikes, early twentieth-century Sweden is often mentioned as one of the most strike-prone countries in the industrial world (Shorter et al., 1974). Table 1 summarizes all strikes in Sweden, categorized by sub-period and cause. In the table, and in the remainder of the paper, we distinguish between offensive and defensive strikes, where the former concerns demands for wage increases and the latter concerns protests against wage cuts or layoffs. We define these two categories narrowly, leaving a relatively small category of strikes for union recognition and a relatively big category of 'other' causes. In the latter, we include conflicts concerning collective agreements, hours, personal issues, as well as those with multiple causes and other causes. Most of these events would probably have been classified as "offensive" if we had applied a broader definition.[3]

As shown in the table, a majority of the strikes concerned offensive claims, whereas defensive claims were much less common. Strikes for union recognition can only be discerned in a small minority of cases, whereas strikes for "other" causes were frequent, but became less common in the two latter sub-periods.[4]

The use of violence is a dimension that is not included in Swedish statistics on work stoppages, and thus not shown in Table 1. As elsewhere, violence in labor conflicts was associated with strike breaking (Fishback, 1995). Some Swedish employers tried to break unions by hiring replacement workers. This strategy, typically implemented by bringing in foreign workers, was halted after the bombing of a ship with British strikebreakers in Malmoe in 1908. Instead, the main strategy of Swedish employers, possibly facilitated by the dominance of large firms, was to form organizations of their own to meet the challenge of the trade unions (Swenson,

[3]In Table A6 of Appendix B we show that our results are robust to the inclusion of strikes for other causes in the offensive category.

[4]An important event to bear in mind when reading Table 1 is the General Strike of 1909 (Schiller, 1967). This conflict began as a lockout initiated by the Swedish Confederation of Employers (SAF), but spread as the Confederation of Blue-Collar Workers (LO) launched a strike. The number of workers involved came to exceed 300,000. The workers lost the showdown and many unions were weakened for years to come, explaining the comparably low frequency of strikes in the period 1911–1915 seen in Table 1 (and in Figure 1).

2002). Although the main Swedish employers' organization came to accept collective bargaining relatively early, industrial conflicts surged in the period from around 1890 to 1920 (with a pause during World War I).

Table 1: Number of Strikes and Strikes by Cause

		Cause: % of total			
	(1)	(2)	(3)	(4)	(5)
Year	Total	Offensive	Defensive	Union Recognition	Other
1891–1896	252	44	15	2	40
1896–1900	616	38	10	4	47
1901–1905	803	37	15	4	44
1906–1910	1,118	40	15	2	43
1911–1915	528	51	15	1	34
1916–1920	2,336	66	7	0	26

Note: This table shows the number of strikes and the share of strikes by cause between 1891 and 1920. An offensive strike is defined as a conflict over wage increases; defensive strikes are all conflicts caused by wage decreases or layoffs. "Other" includes strikes over collective agreements, hours, personal issues, as well as those with multiple and other causes.
Source: Enflo and Karlsson (2019), Karlsson (2019), Swedish National Data Service, SND 1088.

2.2 Electrification and the State-Led Expansion of the Power Grid

Electrification for motive purposes, that is to drive machines and appliances, began slowly in the late nineteenth century and accelerated in the first decades of the twentieth century, when different parts of the country became connected to the power grid.[5] Although private businesses were active in developing and building an infrastructure for the transmission of electricity, the Swedish state came to take a key role already from the early twentieth century.

With the three-phase system, it became feasible to take advantage of the large Swedish rivers that ran from the mountains in the north down to the eastern coast and the lakes in the south. The Swedish state was the first in the world to become involved in the commercial operation of power plants (Stymne, 2002, p.10). A public company, The Royal Waterfall Board, (*Kungliga Vattenfallsstyrelsen*) was set up with the purpose of exploiting water power for the generation of electricity. The power plants were operated by a central authority, rather than by separate units, and their location came to play a key role in the expansion of the national system that developed. Because local and regional networks suffered from seasonal variations in electricity generation, the state early on had the ambition to create a national network of electricity distribution. The coordinated actions of the state stands much in contrast to the disjoint initiatives taken by individual firms and municipalities to electrify certain locations.

Figure 2 depicts the electricity grid in the years 1906, 1911, and 1916, based on digitized survey maps

[5] With regard to lighting, Sweden was largely electrified already by the turn of the 20$^{\text{th}}$century (Hjulström, 1940). Most factories had installed some source of electric power that could generate enough electricity to light its interior using light bulbs.

provided by the Swedish National Archive, *Riksarkivet*. The rapid expansion of the network is striking: in 1906, less than 5 percent of parishes were connected to the grid; by 1916, the number had increased to more than 40 percent. Through the construction of three plants for hydropower generation, the state accelerated the expansion of the use and generation of electricity and determined much of its shape.

Figure 2 also shows the location of the three state-run hydropower plants that were constructed during this period. Olidan was the first to be built. It was selected on the basis of its great water power resources, and began generating electricity for users throughout western Sweden in 1908. By 1911, the grid had expanded from what it had been in 1906, and the area surrounding the power plant had achieved a significant increase in access. By 1916, the state built two additional plants: Älvkarleby in the east and Porjus in the north. Älvkarleby was selected for topographical reasons and for its potential to supply surrounding towns with electricity. Its relative closeness to the capital city, Stockholm, was also considered an advantage, but the city had actually already built its own power plant at Untra, just a few kilometers away. Porjus was selected to supply the iron ore mines and railroads in the far north of Sweden with electricity, and to create the basis for new industries in the region. Olidan, Älvkarleby, and Porjus were the biggest power plants of their time and gave The Royal Waterfall Board a leading role as the giant of the business.

The locations for the state-run hydroplants were firstly selected due to the availability of large waterfalls and secondly due to their strategic location in a network intended to cover the entire country. Olidan was the most powerful source of energy in the country, and after three expansions it had a total capacity of 100 MW. In order to equalize production and transfer surplus energy to the parts of the system that had the highest demand, there was an explicit plan to connect Olidan to the second largest plant, Älvkarleby, from the very start of the century. The resulting connecting grid became the first corner stone in a strategic electricity network called "the electric mainline system." While this mainline system was planned to have four lines crossing the country, the first and foremost priority was the Western Line (*Centralblocket*) between Olidan and Älvkarleby, which was finalized in 1921. (Stymne, 2002, p.9).

As a result of the construction of the Western Line, 192 parishes between the two power stations Olidan and Älvkarleby got early access to stable, state-supplied electric power from the national grid. These regions got an early advantage in energy provision, but they did not enjoy any other obvious benefits prior to their connection. In fact, Table 2 shows that many rural and relatively backward locations got a head start only by virtue of their strategic location between the power plants. Columns 1 and 2 compare parishes connected along the Western Line with all other parishes in the year 1900, which is prior to the construction of the network. Column 3 shows the mean differences of key variables, with standard errors in parentheses. As seen in the table, the Western Line parishes were similar in terms of the average size of their labor force (638 workers in unconnected vs. 651 in the parishes that were only connected later on). They were also essentially similar in terms of their occupational composition, with only two exceptions: the Western Line parishes had a lower share of farmers while having a somewhat higher share of low-skilled workers. However, although statistically significant, the differences are relatively small and we will be able to control for the pre-existing skill structure in our empirical specifications later. Most importantly, the parishes of the Western Line hardly differed from the others in terms of our main variable of interest: strikes per period. While the average number of strikes per parish was 0.25, the corresponding figure along the Western Line was 0.35, but the means are surrounded by large standard deviations (about 3–4 times the average) and the test shows that their difference is not statistically significant.

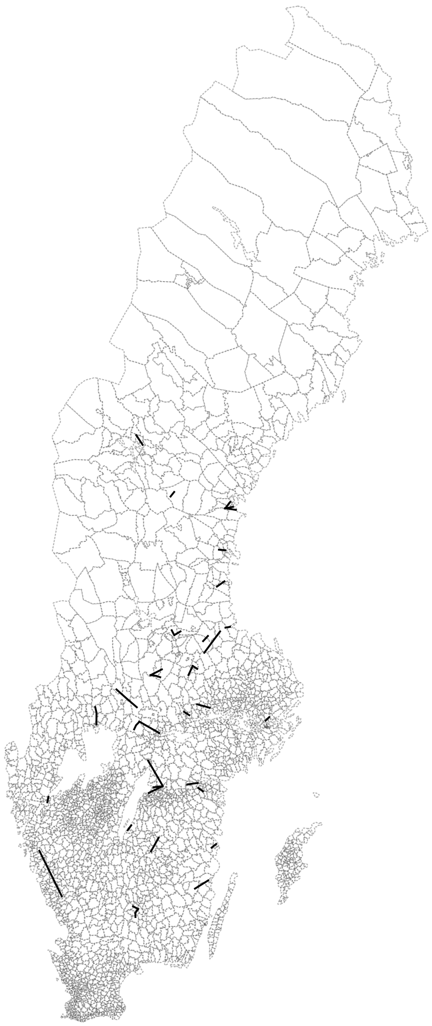
The extension of the Western Line grid from the strategic path between the two power stations is shown in red in Figure 2. The sample from the Western Line consists of the 192 parishes that were connected to either Olidan or Älvkarleby and appeared within a 60-km buffer along a straight line between the two plants.

Table 2: Differences Between Connected and Unconnected Parishes Prior to Access to the Grid, 1900

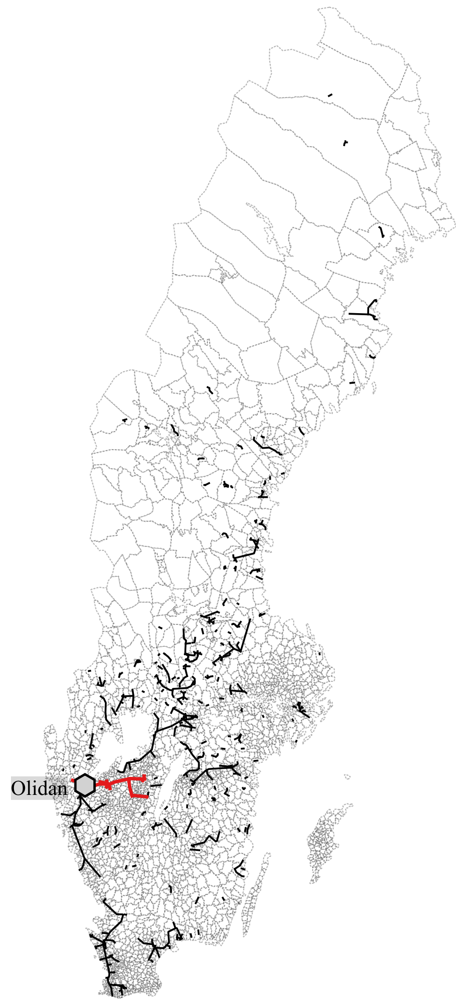
	(1) Western Line	(2) Other	(3) Difference (1) – (2)
Labor force	651	638	13
	(966)	(2239)	[43]
1. Elite (%)	0.012	0.011	0.0014*
	(0.113)	(0.009)	[0.0002]
2. White collar (%)	0.058	0.056	0.0023
	(0.036)	(0.369)	[0.0007]
3. Foremen (%)	0.017	0.015	0.0017
	(0.015)	(0.014)	[0.0002]
4. Medium skilled (%)	0.078	0.075	0.003
	(0.049)	(0.044)	[0.0009]
5. Farmers (%)	0.288	0.316	-0.028**
	(0.141)	(0.146)	[0.003]
6. Lower skilled (%)	0.113	0.091	-0.022**
	(0.093)	(0.079)	[0.002]
7. Unskilled (%)	0.434	0.437	-0.003
	(0.095)	(0.108)	[0.002]
No. of strikes	0.349	0.25	0.099
	(1.23)	(1.62)	[0.32]
No. of offensive strikes	0.144	0.110	0.034
	(0.67)	(0.66)	[0.013]
No. of defensive strikes	0.036	0.033	0.0031
	(0.187)	(0.284)	[0.006]
No. of Parishes	192	2,278	2,470

Note: Columns 1 and 2 report mean pre-electricity grid access characteristics and standard deviations (in parentheses) for parishes with and without access to the Western Line electricity grid. Column 3 shows difference-in-means and corresponding standard errors (in parentheses). All the characteristics before access to the electricity grid are measured for the year 1900. Occupational group employment is calculated as a percentage of the total labor force in 1900. Statistical significance is denoted by: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

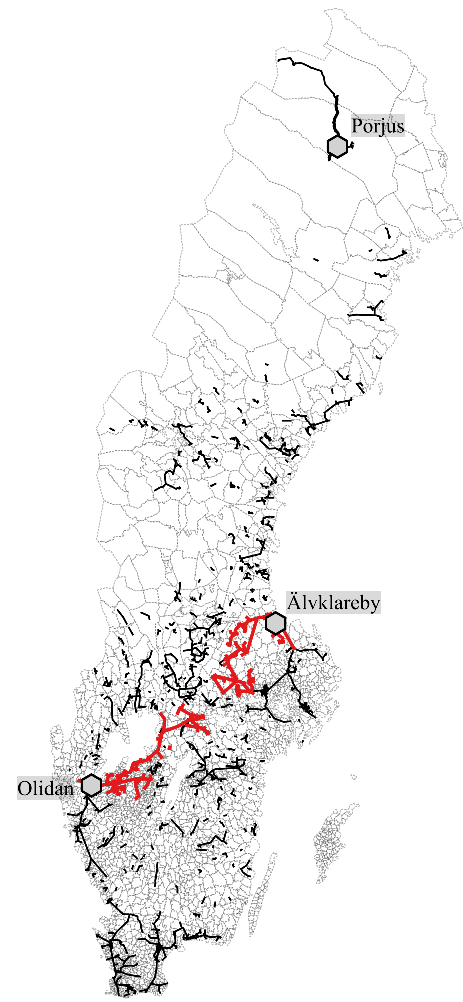
Figure 2: Expansion of the Swedish Electricity Grid, 1906–1916.



(a) 1906



(b) 1911



(c) 1916

Note: This figure shows the expansion of the Swedish electricity grid between 1906 and 1916. Markers denote the three state-run hydropower plants, Olidan, Älkarleby, and Porjus. Lines in red denote the Western Line, which was constructed to connect Olidan and Älvkarleby.

2.3 Potential Winners and Losers from Electrification

The economic motives to invest in the new technology once connected to the grid were strong. Electric motors had become relatively affordable by the early 20$^{\text{th}}$ century. The cost of a motor with three horsepower would amount to some 420 SEK, less than half of the average yearly income for a business owner in manufacturing. The cost of a motor was also less than the alternative cost, the wage for an industrial worker.[6] Such a motor could perform the most common tasks around farms and in rural industry. They were often installed in wheeled containers, which made them portable and suitable for multiple purposes (ASEA, 1912, pp. 14–27).

From the perspective of owners of firms or farms, access to the electricity grid provided a reliable and powerful source of electrical power. Before the grid, many industries could potentially connect to a local water-power source to generate electricity. But there is wide-spread evidence that local water power sources were unreliable and often seasonal. The lack of water-power was especially prevalent in many local waterfalls during the summer months. Surveys that were carried out among firms at the beginning of the 20$^{\text{th}}$ century reveal the problems. The instability or absence of energy supplies were stated as one main reason why firms could not expand production or modernize their machine park (Hjulström, 1940, 266).

The potential of electricity is manifest in that firms and farms closer to the power grid were more electrified than those further away. ASEA (1912) details the farms which had installed electrical equipment for running the farm. The lists clearly indicate that estates located near the Olidan power plant made heavier use of electrical equipment. Morell (2001) report that the construction of the Älvkarleby plant explains why farms were electrified to a greater extent in the Uppland region, where the plant was located.

The impact on the labor market of the early grid differed across sectors and branches. In agriculture, electrification had a clear potential for making unskilled jobs redundant. If the farm moved directly from manual labor to machines in the processes of threshing, cleaning, and crushing, the change was radical. Even in the rare cases when many operations had already been mechanized through the use of steam and hand power, electric motors could save on labor (Morell, 2001). The labor-saving potential was particularly big at large farms, where most of the work was performed by hired laborers, than at at yeoman farms, where the family of the owner made up the majority of the labor force.

For farm laborers, electrification may have threatened jobs. They would have had obvious reasons for going on strike, but poor prospects of success. Farm laborers have generally been considered as hard to

[6] This calculation is based on the 140 SEK per horsepower around 1906–07 cited in Ljungberg (1990). The average yearly cost of an unskilled agricultural worker was about 600 SEK, according to data for 1907 presented in the Historiska lönedatabasen (HILD) at Göteborgs universitet. This can also be compared to the average income per business owner in agriculture in 1907, which was 600 crowns, and for business owners in manufacturing, which was 969 SEK (Edvinsson, 2005).

organize (Kjellberg, 1983). Swedish farm laborers formed a national union in 1908, but is was dormant for almost a decade after the General Strike until it re-awoke in 1918 (Back, 1961). Yet farm laborers did leave some imprint in the strike records well before successful unionization; most notably with a series of conflicts in Southern and Middle Sweden 1890–91, and later in 1906–08 and in 1918–22 (Johansson, 2008). The claimed causes of discontent documented in the official statistics that covered these latter episodes often concerned wages or simply "better working conditions" (Karlsson, 2019). Although farm laborers were potential losers from electrification, this is not a central theme in the literature on this group of workers.

Outside agriculture, electrification stimulated mechanization and may have given rise to new products and occupations, as well as influencing the pattern of the location of enterprises, thus freeing enterprises from their previous geographic constraints. In the late 1930s, a government inquiry (Rationaliseringsutredningen, 1939) established that "The firms have become less dependent on proximity to previously used energy sources [and that] small-scale industry has been able to emerge in locations which previously had lacked the opportunities for manufacturing activities." In contrast to agriculture, employment in manufacturing, transport, and other services grew substantially in the first half of the 20th century.

Firms in mechanical engineering were among the early adopters of electricity (Norgren, 1992). Here, electrification meant a gradual replacement of previous systems for transmitting power. Ultimately, each machine was either connected to or integrated with an electric motor (Devine, 1983). In some firms, such as Munktells in Eskilstuna, this transition was basically completed already in the late 1910s (Magnusson, 1987).

The decreased reliance on a single power source meant that the physical layout of the shopfloor could be more flexible (Magnusson, 1987). Machines no longer had to be placed along central shafts. Shopfloors became less crowded and brighter, as machines were removed from windows. Electricity also facilitated transport within factories, using cranes and traverses. While these changes may have been regarded as improvements of the working environment, electrification also meant an intensification of the pace of work. Electrical lathes could, for example, be run at twice the speed of the old semi-manual lathes. This meant an increased risk of workplace injuries and that piece rates had to be renegotiated. The latter was a common source of discontent.

Along with changes in the organization of production and general expansion, came changes in the relative demand for different kinds of occupations. Referring to Swedish mechanical engineering generally, Olsson (1979) observes that the share of non-skilled workers increased. Machine workers and laborers increased in relative numbers, whereas craft workers decreased. Magnusson (1987) argues that an overall expansion of production brought about “more material to handle, more spaces to clean, more products to wrap and unpack.”

Metal workers formed the backbone of the Swedish labor movement for a good part of the 20$^{\text{th}}$ century. Already around 1900, they had a union density of about 50 percent. The Swedish Metal Workers’ Union also formed the model for other unions in its adoption of industrial unionism, and in their success in achieving a collective agreement with national coverage in 1905 (Lundh, 2020).

For the relatively well-organized metal workers, electrification may have affected the working environment and job content. These changes may have been for the better or worse, and it is hard to tell whether they would have any net effect on strike behavior. Labor historians have often attributed the collective action of Swedish metal workers to changes in the work process, but not to electrification per se (Berggren, 1991; Magnusson, 1987).

In the late 19$^{\text{th}}$ and early 20$^{\text{th}}$ centuries, urbanization, market integration, and economic growth more generally, also meant an increased demand for workers in construction and transportation (Schön, 2012). With the exception of electricians,[7] workers in these activities were seldom directly influenced by electrification, but often had a strategic position in the labor market that they could take advantage of. Building workers and dock workers, in particular, appear frequently in the recorded strikes. Referring to dock workers, Hamark (2013) argues that they may not necessarily have been more strike prone, but that their capacity to disrupt chains of supply has called more attention to their strike activities. This argument, which draws upon the notion of positional power originally articulated by Perrone (1984), is interesting for our purpose. As mentioned above, the firms’ main motive for introducing electricity was to avoid disruptions in production. This means that electrification may have improved the positional power of certain categories of workers. Whether this translates into actual strikes is not obvious. According to Wright (1984), the relation between workers’ disruptive power and strike behavior is curve-linear: workers with a medium-level of disruptive power are most likely to strike.

3 Data and Empirical Strategy

We construct a panel dataset based on 2,470 parishes from three benchmark years. A map of historical administrative borders provided by the National Archive *Riksarkivet* was used to construct parish-level data at unchanging historical borders. We combine data from three sources:

[7]This is perhaps the most obvious example of an occupation that arose as a consequence of electrification. In our period of observation, Swedish electricians were mainly employed in construction. They formed their own craft-based union in 1906 (Kjellberg, 2017).

First, for electricity adoption, digitized survey maps of the Swedish electricity grid in 1906, 1911, and 1916, give us a spatially coded dataset for the geographical location of all power lines in existence. From these maps, we construct a dummy that equals 1 if the parish is connected with a power line belonging to the Western Line, on a straight line between Olidan and Älvkarleby. This is our main treatment variable, and is depicted in red in Figure 2. We also construct a control variable that takes the value of 1 if the parish is connected by any other power line, and 0 otherwise.

Second, the data on industrial conflicts comes from Enflo and Karlsson (2019) and includes information on the place of the conflict, the cause of the dispute, as well as the industry that the striking workers belonged to. We assign geographical coordinates to every location where there was a strike and then construct three indicators of strike activity. The first counts the total number of strikes, while the second and third count the number of offensive and defensive strikes, respectively. Following the categorization in Table 1, we define offensive strikes as those concerning demands for wage increases.[8] Defensive strikes are those that were induced either by layoffs or attempts to avoid wage cuts. All strike data was coded by the sector of economic activity. For temporal coherence with the survey maps, we aggregate the strike data to cover four years following the benchmark year provided by the digitized map (i.e., 1907–1910, 1912–1915 and 1917–20).

Third, we collect data on the occupational structure of each parish by aggregating census information on the number of persons involved in different activities. The digitized census from NAPP was used for this. Unfortunately, this data is only available for 1890, 1900, and 1910, so the scope of the analysis concerning the employment structure is limited to those years. The occupations recorded in the census are assigned to different categories of skill, using the HISCLASS class scheme. This is a system that divides historical occupations into 12 categories, ranging from elite to unskilled farm workers. To make the interpretation of our results easier, we use an abbreviated version of HISCLASS, with only seven groups. These are: "1. Elite," "2. White collar," "3. Foremen," "4. Medium skilled," "5. Farmers," "6. Low skilled," and "7. Unskilled." The HISCLASS scheme and our aggregate categories are described in more detail in Appendix C.

It would have been useful to assign the occupations to the main economic sectors, but we are unfortunately limited to the information embedded in the occupational titles in the censuses, where it is not possible to distinguish activities in manufacturing from those carried out in services.[9] It is, however, much more straightforward to distinguish agricultural occupations from the other economic sectors. Thus, we are able

[8]In Table A6 of Appendix B we show that the effect on offensive strikes is robust to including strikes for other causes in the offensive category.

[9]This is in contrast to the Norwegian census used by Leknes and Modalsli (2020), which provides information on both the occupational titles and the economic sectors. This data shows that, outside of agriculture, there is a significant overlap of occupations and sectors, making it exceedingly difficult to infer the economic sector from the occupational title in the Swedish census.

to look at shifts in labor demand from agriculture to the rest of the economy. This is still a useful distinction since agriculture remained the largest sector in the Swedish economy until the 1930s, and a shift from agriculture to other sectors suggests that a structural change was taking place.

3.1 Regression Framework

The panel data structure with a plausibly exogenous treatment variable allows a difference-in-difference interpretation of the estimates. Our regression specification takes the form:

$$y_{i,t} = \alpha + \beta_1 \; WesternLine_{i,t} + \; Controls_{i,t} + \mu_i + \lambda_t + \theta_j t + \epsilon_{i,t}, \qquad (1)$$

where $y_{i,t}$ is 1 + the logarithm of the outcome variables relating to strikes or employment structure in parish i at year t. Note that t refers to an aggregate of strikes in the years following the benchmark or at the census year for the employment structure, as explained in Section 2.[10] If parish i in year t was connected to the grid on the Western Line, the dummy variable $WesternLine_{i,t}$ takes the value 1, and 0 otherwise. The main coefficient of interest is β_1.

The specification is intended to address the potential endogeneity of electricity adoption by only analyzing the impact of electricity in parishes that were connected to the network through the Western Line, and thus exogenously shocked by this early technical advantage. The idea behind the identification is that the cost of gaining connectivity differed significantly between areas after the construction of the Western Line, since the price of access was fundamentally dictated by the distance to the power-generating source. This method is similar to the approach taken by Kitchens and Fishback (2015) and Lewis and Severnini (2020), who argue that the potential costs of distributing electricity are strongly correlated with the distance to the existing electricity grid.[11]

The time varying controls are there to wash out any confounding effects of other structural transformations in the parishes. First and foremost, we control for the potential impact of relevant major infrastructures, such as the railway and the impact of electricity outside the scope of the Western Line. By adding controls for the lagged effects of the occupational structure we also take into account initial differences in employment

[10] The aggregation was constructed to pick up the lagged effects of gaining access to electricity and to even out short-term fluctuations. We tried different specifications with regards to aggregating the data, for example covering census years instead, or adding five years following the map. The results are not sensitive to alternative forms of aggregation. Table A5 in Appendix B shows, for example, how the results change if a five-year period including the benchmarks was chosen instead.

[11] As an alternative, we have dealt with endogeneity by using the distance to the power plants as an instrumental variable in a two-stage regression predicting electricity adoption. The results from this approach are qualitatively similar to the results in the present paper and can be found in Molinder et al. (2019)

structure before the arrival of electrification. Parish-fixed effects, μ_i, ensure that variation in the model is restricted to parishes that actually experienced a change in access to the grid, while holding all other non-varying parish-specific effects constant, and a full set of time dummies, λ_t, control for common time trends and wash out the overall potentially confounding effects of major events in our period, such as World War I. Region-by-period fixed effects $\theta_j t$ are added by interacting time-dummies with dummies for the 24 Swedish counties to take into account region-specific shocks. Standard errors are clustered at the parish level throughout.

4 Results

Our analysis proceeds in two steps. Firstly, we estimate the effect on strikes of access to the Western Line electricity grid. The main results are estimated from the regression in Equation 1 and organized into three outcome variables relating to the number of strikes: the total number of strikes, the number of offensive strikes, and the number of defensive strikes. The outcome variable in this respect is a count variable. There are, however, alternative ways of measuring strike activity. A complementary way is to look at how electricity affected the number of workers going on strike. Even though we are not able to separate the number of striking workers involved in offensive strikes from those involved in defensive strikes, such an alternative measurement can indicate something about the relative increase in the strength of the protests, and complements our main measure.

Secondly, to pin down how much electrification contributed to labor demand and structural change, we estimate the regression explained in Equation 1, but replace the strike outcomes with the total labor force and the share of the population engaged in agriculture, respectively. These measures are intended to give an indication about how electrification affected structural change and the demand for labor.[12] To analyze labor demand more deeply, we also estimate the impact of electricity on occupational change following the HISCLASS census-titles. Finally, we investigate whether the relation between electricity and strikes differs between sectors.

[12]Ideally, we would have liked to estimate the effects of structural change more directly, but as explained in the Data section, it is unfortunately not possible to distinguish between employment in manufacturing and services in the historical Swedish censuses.

4.1 How Electricity Influenced Strikes

The impact of electricity on strikes is presented in Table 3. The top line of column (1) suggests that access to the Western Line electricity grid increased strike activity by about 12 percent. This increase is substantial, given that the average number of strikes per parish in the period around 1900 was 0.3, as indicated in Table 2. Parishes on the Western Line were thus more likely to see protests increase in the years after they got connected, despite being similar to other parishes prior to electrification.

The observed connection between electricity and strikes would make it tempting to draw the conclusion that the arrival of electricity was followed by a wave of protests against new technology. To understand the nature of the protests better, we separate the causes of the strikes into those that were of an offensive nature (asking for higher wages) and defensive ones (avoiding wage cuts or layoffs). Looking at the offensive and defensive strikes separately tells a different story. Column (2) in the table shows that the lion's share of the increase comes from the offensive strikes, with the point estimate suggesting an almost 11 percent increase. If workers were trying to block or protest the new technology, we would rather expect most of the increase to be in the category labelled as defensive. The effect on defensive strikes is shown in column (3) and is much more modest than the impact on offensive conflicts, suggesting an increase of only 4 percent following electrification.

Columns (1)–(3) showed the estimated impact of electricity on the number of strikes. The effect presented in column (4) suggests that the number of striking workers increased as well, in this case, by some 42 percent.

Most of the control variables in the regression are not significantly linked to higher strike activity. In part, this is explained by the fact that parish-, time-, and region-by-time fixed effects pick up a lot of unaccounted variation. There is, for example, no estimated effect on strikes from other forms of infrastructure, such as non-Western Line electricity or access to a railroad. However, the impact of the labor force in the preceding period has a positive effect, especially for total and offensive strikes, suggesting that such strikes were more common in faster growing parishes, all else equal. The controls for occupational employment shares are in almost all cases not statistically significant. This is not surprising, given that we only use within-parish variation to identify the impact of access to the Western Line electricity grid.

While our specification is designed to allow a causal interpretation of the impact on strikes of the access to electricity, there could still be a worry that the relation is determined by some other underlying factor not properly controlled for. To rule out this possibility, we test whether the effect on strikes was present already before a parish gained access to the Western Line. To ensure that the pre-trends in strike activity are balanced between parishes, we add a forward lag to the specification in Equation 1. If our assertion

Table 3: Main Results

Dependent Variable:	(1) Log(1+Total Strikes)	(2) Log(1+Offensive Strikes)	(3) Log(1+Defensive Strikes)	(4) Log(1+No. of striking workers)
Electricity grid access, Western Line (Dummy=1)	12.26***	10.83**	4.138**	42.52***
	(3.463)	(3.421)	(1.494)	(12.09)
Controls				
Electricity, outside Western Line (Dummy=1)	-1.039	-0.0470	-0.834	1.860
	(1.966)	(1.594)	(1.511)	(6.046)
Railroad (Dummy=1)	-2.032	-0.458	-0.623	-16.10
	(2.091)	(1.878)	(0.855)	(8.919)
Log(1+Labor Force), $t-1$	0.149**	0.166**	0.0186	0.386**
	(0.0497)	(0.0562)	(0.0215)	(0.140)
2. White collar, $t-1$ (%)	0.662	0.403	0.399	4.234
	(0.658)	(0.645)	(0.312)	(2.914)
3. Foremen, $t-1$ (%)	-0.860	-1.303	0.211	-0.244
	(0.671)	(0.669)	(0.338)	(3.055)
4. Medium skilled, $t-1$ (%)	-1.090	-1.344*	0.146	0.928
	(0.643)	(0.630)	(0.316)	(2.922)
5. Farmers, $t-1$ (%)	-0.683	-0.962	0.194	1.313
	(0.607)	(0.587)	(0.299)	(2.733)
6. Lower skilled, $t-1$ (%)	-0.579	-0.875	0.183	2.056
	(0.605)	(0.592)	(0.299)	(2.765)
7. Unskilled, $t-1$ (%)	-0.891	-1.180*	0.147	0.714
	(0.597)	(0.589)	(0.296)	(2.716)
Mean dependent variable	12.0	8.0	2.2	51.5
St. dev. dependent variable	42.7	34.2	14.3	159.8
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County X Year FE	Yes	Yes	Yes	Yes
Observations	7,410	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470

Note: This table shows the results of estimating the effect of access to the Western Line electricity grid using Equation 1 for the four main outcome variables: total strikes, offensive strikes, defensive strikes and the number of striking workers. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

that the effect on strikes is indeed related to electricity access, and not to pre-existing differences between parishes, we should expect the impact of the forward lag to be insignificant. [13]

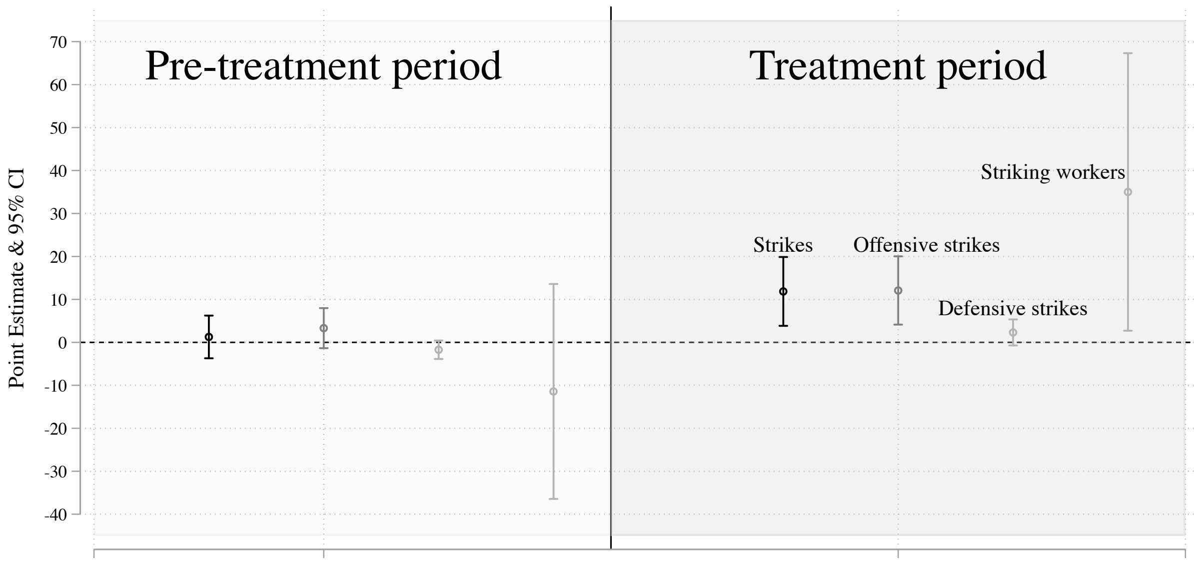
Figure 3 shows that there were no pre-existing trends for any of the strike variables in the Western Line parishes. The left-hand side of the figure shows the forward lags of all four outcome variables. Reassuringly, all coefficients shown at the left are close to zero and in all cases not statistically significant, suggesting that strike activity did not differ in the parishes that would later gain access to the grid. The corresponding coefficients for the treatment period after controlling for the forward lag are displayed to the right, and convey that the impact appears solely in the treatment period, thus suggesting an impact running from electricity to strikes.

4.1.1 Robustness of the Main Results

Our main specification measures Western Line access as a binary variable that is equal to 1 when a parish is connected to the grid by a line. This specification only measures the impact of electricity relatively crudely.

[13]Indeed, coefficients should only turn significant in the treatment period, when the grid was in place. Recall that our t constitutes the benchmark year and the four years following it, hence our pre-treatment effectis the impact in the period prior to access to the network. To match our occupational data, we use the periods 1890–1894 and 1900–1904.

Figure 3: Effect of Access to Electricity Grid on Strikes in the Treatment and Pre-Treatment Periods



Note: This figure shows point estimates and 95 % confidence intervals for the impact of access to the Western Line electricity grid in the treatment and pre-treatment periods for the four main outcome variables: total number of strikes, offensive strikes, defensive strikes and the number of striking workers. The full regression results can be found in Table A1 in Appendix A.

It is clear that factories or farms that are located far from the line but still remain inside of a treated parish are probably unaffected by the potential for the new technology, meaning that part of the variation of the outcome comes from units that were not properly exposed to the treatment. In theory, this caveat would bias our results downwards, but to really pin down the micro-level effects we would need more fine-grained data. Unfortunately we are not able to collect specific electricity rates for individual firms and factories for this period, but we can try to address this issue by varying the strength of the treatment by taking the relative electricity exposure by parish into account. This means replacing the binary electricity variable with two alternative measures: (i) the number of power lines in a parish and; (ii) the total length of the power lines inside the parish. The results of this check are found in Table 4, where we can see that the estimated coefficients in this alternative specification are qualitatively similar to the main regression in Table 3. While the top row indicates that each additional line increases the number of strikes by about 13 percent, the bottom row suggests that a percentage increase in the total length of the lines of the Western Line grid within the parish increases strikes by about 1.5 percent. In both cases, the increase is larger for offensive strikes than for defensive. Similarly, an additional line increases the number of striking workers by some 40 percent, and each percentage point growth of the grid lines by some 5 percent. These alternative estimates confirm the suspicion that the binary variable is biasing our estimates downward by not fully picking up the true impact of the electrification effect.

Table 4: Alternative Measurement of Treatment

	(1)	(2)	(3)	
Dependent Variable:	Log(1+Total Strikes)	Log(1+Offensive Strikes)	Log(1+Defensive Strikes)	Log(1+Striking workers)
Log(1+No. of grid lines, Western line)	11.81**	11.41**	5.958***	42.61***
	(4.128)	(4.397)	(2.017)	(12.66)
Log(1+Length of grid lines, Western line)	1.389**	1.274**	0.493**	5.397***
	(0.428)	(0.434)	(0.189)	(1.479)
Mean dependent variable	12.0	8.0	2.2	51.5
St. dev. dependent variable	42.7	34.2	14.3	159.8
Controls	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County X Year FE	Yes	Yes	Yes	Yes
Observations	4,934	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470

Note: This table shows the results of estimating the effect of access to the Western Line electricity grid using Equation 1 for the four main outcome variables, using the number of grid lines and the length of grid lines as alternative measurements of treatment. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Another concern relates to the potentially direct effects on local demand stemming from the construction of the large hydro-plants. Previous studies have demonstrated that early electricity investment stimulated local economies and generated spillovers in terms of a general increase in demand. Studies from the US have indicated large gains in employment and growth effects from early infrastructure investments such as electricity generating dams and grid lines (Kline and Moretti, 2013). Thus, economies of agglomeration could appear in early developing regions, especially if electricity investments were accompanied by complementary infrastructure investments that signalled a general faith in the region and helped to coordinate expectations and fuel a surge in building activities. Such agglomeration economies could potentially be driving strikes for reasons other than technical change due to the arrival of electricity. To rule out the possibility that the impact on strikes was driven by the areas in the direct vicinity of Olidan and Älvkarleby, we exclude all the parishes closest to the power plants and re-run the regressions.[14] The results are found in Table 5 and are qualitatively similar to the main results. It seems therefore that our estimates are picking up the effect of new technology along the entire Western Line grid, and not just in the closest proximity to the large power plants.

In the appendix we consider two additional robustness checks. First we run our main regression with weights for parish population. Second we run a regression where strikes are measured as a dichotomous

[14]A similar approach to alleviate concerns of direct effects from plant construction on general demand was carried out in Lewis and Severnini (2020).

Table 5: Excluding Parishes Closest to Power Plants

Dependent Variable:	(1) Log(1+Total Strikes)	(2) Log(1+Offensive Strikes)	(3) Log(1+Defensive Strikes)	(4) Log(1+No. of striking workers)
Electricity grid access, Western Line (Dummy=1)	11.22**	10.08**	2.078	39.97**
	(3.795)	(3.510)	(3.301)	(12.57)
Mean dependent variable	12.6	8.6	2.1	50.2
St. dev. dependent variable	41.7	33.3	14.1	147.4
Controls	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County X Year FE	Yes	Yes	Yes	Yes
Observations	7,410	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470

Note: This table shows the results of estimating the effect of access to the Western Line electricity grid using Equation 1 for the four main outcome variables, excluding parishes with a power plant or bordering a parish with a power plant. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

dummy variable, assessing the effect of access to the Western Line electricity grid on the chance that any strike took place. The full results can be found in Table A7 and Table A8 of Appendix B. In both cases, the results are similar to the ones reported in our main regression.[15]

4.2 Mechanisms: Structural and Occupational Change

One of the obvious effects of the adoption of electricity is its impact on structural change and the demand for labor. Previous studies of early electrification have reported varying results. On the one hand, studies on rural areas in the US have generally indicated the existence of an increased demand for labor, an increase in agricultural productivity that led farmers to seek employment off the farm less often (Kitchens and Fishback, 2015), and short-run agricultural specialization (Kline and Moretti, 2013; Lewis and Severnini, 2020). On the other hand, a recent study of Norway documents a modest increase in the demand for labor and finds that structural change drove workers away from agriculture and towards non-agricultural activities (Leknes and Modalsli, 2020).

We analyze how the Western Line affected structural change and the demand for labor by running the regression in Equation 1 with the log of the labor force and the share of workers in agriculture as outcome variables. Table 6 presents the results. Column (1) suggests that electricity led to an increase in the labor force of about 11 percent. Consequently, the arrival of electricity did not result in overall technological unemployment. But it seems that the composition of jobs changed. In column (2), the share of the population in agriculture declined by about 2.3 percentage points following electrification. The size of the effect is similar to the fixed-effect estimate by Leknes and Modalsli (2020) of about -4 percentage points for Norway in the

[15] The effect on total strikes, offensive strikes and defensive strikes are somewhat larger in the weighted regression: 29.9, 42.3 and 18.4, respectively. When we measure strikes as a dichotomous variable the effect on total strikes, offensive strikes and defensive strikes are 0.083, 0.059 and 0.036, respectively.

early twentieth century, and suggests that electrification caused a structural change away from agriculture also in the short run. The results are consistent with the previous literature emphasizing the importance of electrification for rural industrialization in Sweden (Berger et al., 2012).

Table 6: Effect on Labor Demand and Structural Change

	(1)	(2)
Dependent Variable:	Log(1+Labor force)	Share of population in agriculture (%)
Electricity grid access, Western line (Dummy=1)	11.11**	-2.257*
	(3.566)	(0.992)
Mean dependent variable	591.7	47.8
St. dev. dependent variable	92.5	19.1
Controls	Yes	Yes
Parish FE	Yes	Yes
Year FE	Yes	Yes
County X Year FE	Yes	Yes
Observations	4,934	4,934
No. of parishes	2,470	2,470

Note: This table shows the results of estimating the effect of access to the Western Line electricity grid using Equation 1 for two measures of labor demand and structural change: the size of the labor force and the share of the population in agriculture. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

To further understand how electricity changed labor market conditions locally, we turn to analyzing occupational changes among different skill groups. Again, there is a lack of consensus in the existing literature about electricity's impact on the distribution of skills. Whereas Goldin and Katz (1998) argue that the Second Industrial Revolution was associated with an increased demand for skilled labor,[16] Gray (2013) find that the skill structure was "hollowed out," since the demand for white collar and unskilled jobs increased while the demand for semi-skilled work decreased, while Leknes and Modalsli (2020) find evidence for skill-biased technological change.

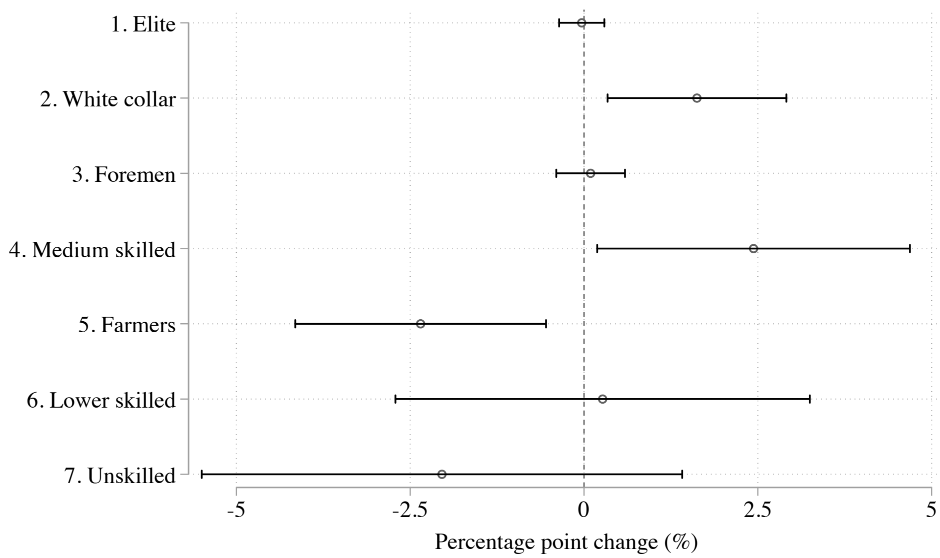
This time we estimate the regression with the share of employment in each of the seven HISCLASS-coded occupational groups, and for ease of interpretation we present the results in a figure. The full regression table is presented in Table A2 in Appendix A. The pattern in Figure 4 can at best be described as occupational upgrading. Looking at the three highest skilled groups (the elite, white collar workers, and foremen) in the figure, we do not detect any sign of electricity being a skill-biased technology. Instead, the increase in employment shares occurred for medium-skilled workers, who saw their proportion increase by about 2 percentage points. The decreases in share of employment are concentrated among farmers, again indicating that structural change away from agriculture created new jobs outside this sector.[17]

[16] Prado and Theodoridis (2017) present results in the same direction for Sweden, but of smaller magnitude.

[17] The results for absolute employment growth, showing statistically significant increases in the demand for white collar

The results do not directly mirror either the notion of electricity as a skill-biased technology (Goldin and Katz, 1998) or as a driver of occupational hollowing out (Gray, 2013). Our pattern regarding the impact of electricity can rather be described as "hollowing in," with relative employment growth in medium and lower skilled occupations. However, it is possible to reconcile our "hollowing in" with the previous results by remembering that the above-mentioned studies focus on the manufacturing sector only. Looking at the American economy in the same period more broadly, Katz and Margo (2014) found neither deskilling nor hollowing out, emphasizing that it may not be correct to infer economy-wide patterns of occupational change from those occurring in manufacturing alone.

Figure 4: Regression Results for Change in Occupational Groups' Shares



Note: This figure shows point estimates and 95% confidence intervals for the impact of a parish's gaining access to the Western Line electricity grid on the growth of employment shares by skill group. Standard errors are clustered at the parish level. Full regression results can be found in Table A2 of Appendix A.

4.2.1 Sectoral Patterns

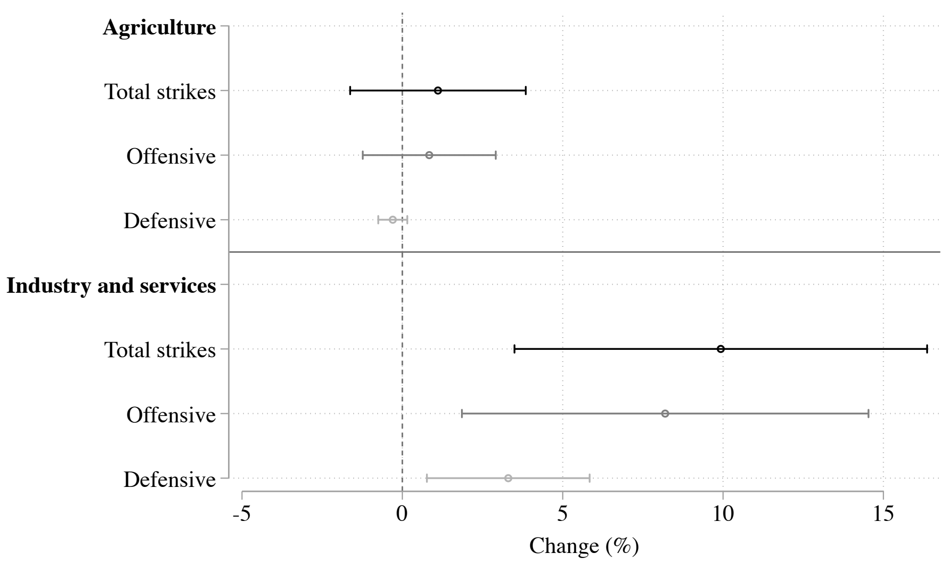
Given the effects on structural change and occupational upgrading presented in the previous section, it is possible that the results in Table 3 are driven by a changing sectoral composition in parishes that gained access to the Western Line electricity grid. Electrification increased the speed of industrialization in the adopting parishes, and since there are differences in the degrees of organization between sectors, as discussed in Section 2, the effect could be the composite result of structural change towards sectors with higher strike

professionals, medium skilled workers, and lower skilled workers, can be found in Figure A2 in Appendix B.

propensity. Ideally, we would like to separate the within- and between-sector effects by a decomposition of the kind performed in Gray (2013), but we are restricted by the data in two ways: firstly, we only have access to data on the employment structure until 1910 and, secondly, we neither know industry- nor region-specific electricity intensities. We can, however, still look at the effects of electricity adoption separately between sectors.

To find out whether electricity had differing impacts on the propensity to strike, we start by running our main regression separating the agricultural sector from the rest of the economy. As shown in Figure 5, there are large differences in the impact when analyzing agriculture separately from the rest of the economy.[18] While electricity did not generate any significant increase in the number of strikes by agricultural workers, the effects are large and significant outside agriculture. This result could be driven by a larger propensity to go on strikes in the industrial and services sector, but it still contradicts the idea that the workers losing from structural change are more likely to protest using strikes. Instead, sectors with increasing labor demand are the ones with more conflicts. In addition, the strikes are of an offensive nature. These results suggest that the expanding sectors saw their labor market position improving and could claim the benefits by asking for more from employers.

Figure 5: Regression Results for Strikes by Sector



Note: This figure shows point estimates and 95% confidence intervals for the impact of a parish's gaining access to the Western Line electricity grid on the increase in the number of strikes by sector. Standard errors are clustered at the parish level. The full regression table can be found in Table A3 of Appendix A.

[18] Figure A1 of Appendix B shows a further separation between industry and services, and indicates that the effects on strikes are similar in the industrial and service sectors.

If workers were able to use strikes as a bargaining tool to strengthen their position, we should expect to see more strikes in areas with less scope for alternative sources of labor. To test this idea we wish to assess whether the impact on strikes is attributable to heterogenous effects in initial sectoral composition. Intuitively, it could be harder for firms to combat strikes by hiring outside labor in regions with higher industrial concentration. Therefore, we would expect already industrial parishes to show up as the most strike-prone with the arrival of electricity. Figure 6 investigates the potential effects by separating the parishes that were initially industrial in terms of being above the median in terms of the share of manufacturing in total employment in 1900 from other parishes. We run the main regression with strikes as an outcome variable and an interaction between the Western Line dummy and a dummy that is 1 for parishes with above-median industrialization in 1900. The figure shows the interacted coefficient, a crude measure of the "pure" effect of electrification in parishes that had already gone relatively far in the process of industrialization, suggesting that the effects on strikes are pronounced in the already industrial parishes, but non-existent in the others. Again, the effects are larger for offensive strikes. Thus, even when we compare the most industrial parishes with each other, gaining access to electricity is the decisive factor that spurs offensive strikes, not being industrial *per se*, reinforcing the message that the action is taking place in the expanding sectors where demand for labor is higher and sources of alternative workers limited. Gaining access to electricity in agricultural parishes, on the other hand, does not increase the propensity of workers to go on strike.[19]

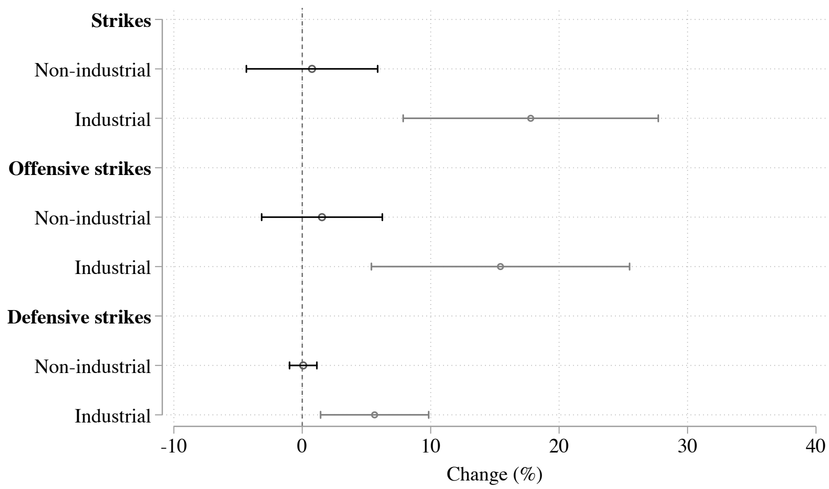
5 Conclusions

Recent advances in robotization and automation have spurred interest into the relationship between technological change and social unrest in the past. While workers use of non-economic means to block mechanization is a common theme in the literature on the First Industrial Revolution, it is not prominent in accounts of the Second Industrial Revolution. In this paper, we have analyzed the relationship between electrification and strikes in Sweden, at the local level, focusing on a period of intense expansion of the grid for power distribution.

We established an increase in strikes following access to the electricity grid. However, the conflicts caused by electrification were typically not conflicts with the intention of blocking technological development. Conflicts with the openly declared intention to resist mechanization were extremely rare. Electrification was

[19]To check that industrial parishes are not different in terms of strike capacity due to them being more densely populated or urban, we also ran a regression interacting instead a coefficient that takes the value 1 if the parish was above the median in terms of population density in 1900. The results are seen in Figure A3 in Appendix B. The result indicates that electricity increased strikes in urban and rural parishes alike. We conclude from this that what mattered was their sectoral composition, and not whether they were urban r not.

Figure 6: Results for Strikes by Type of Parish: Non-Industrial/Industrial



Note: This figure shows results of interacting Western Line electricity grid access with an indicator for whether a parish is non-industrial or industrial. Industrial parishes are defined as the 50 percent of parishes with the highest share of industry in total employment in 1900. Standard errors clustered at the parish level. The full regression table can be found in Table A4 of Appendix A.

more commonly associated with workers demanding higher wages and better working conditions, rather than workers defending their status quo. In that sense, the grid did not only bring more motive power to firms, but also more bargaining power to large segments of workers. This is a perspective that is has been called attention to referring to labor conflicts in modern, "post-industrial societies", but more seldom with regard to the formative years of labor movement and labor market institutions in Western societies.

The connection between grid connectivity and strikes that we establish can easily escape observation since workers did not explicitly relate their demands and actions to electrification. Looking at the past two centuries, offensive worker responses to technological change have probably been much more common than protests of the same kind as the early nineteenth-century riots, although the latter have made a huge imprint in the popular understanding of history.

In addition to contributing to the literature on technological change and social unrest, our paper also shed light on changes in the labor demand and skill distribution during the Second Industrial Revolution. Rather than widespread technological unemployment, we find that electrification increased the overall demand for labor and was associated with a shift in demand from unskilled agricultural workers to lower and medium skilled manufacturing workers. Instead of leading to vast technological unemployment, electrification spurred structural change. Thus, we do not find evidence of a "hollowing out" of the skill distribution, at least not when looking at the entire structure of the economy.

Our findings concerning technological change and conflicts point to a couple of issues worth further research. Future research should pay closer attention to the role of unions as strategic inter-actors in the response to technological change. Labor mobility is a related question that needs further scrutiny to fully understand union politics and the bargaining power of workers. To what extent could, and did, workers move between regions, sectors, industries, and occupations, and how did mobility influence the bargaining power of the workers? Future studies should also consider how employers responded to the increased bargaining power of specific groups of workers, as well as to the economic consequences of work interruptions.

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Appendix A Regression Tables (Main Results)

Table A1: Main Results with Check for Pre-Trends

Dependent Variable:	(1) Log(1+Total Strikes)	(2) Log(1+Offensive Strikes)	(3) Log(1+Defensive Strikes)	(4) Log(1+No. of striking workers)
Electricity grid access, Western Line (Dummy=1)	11.9**	12.1**	2.3	35.0*
	(4.087)	(4.052)	(1.546)	(16.480)
Pre-Trend: Electricity grid access, $t-1$ Western Line (Dummy=1)	1.3	3.3	-1.7	-11.4
	(2.535)	(2.378)	(1.094)	(12.763)
Mean dependent variable	12.0	8.0	2.2	51.5
St. dev. dependent variable	42.7	34.2	14.3	159.8
Controls	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes
Observations	7,410	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470

Note: This table shows results for the treatment and pre-treatment period from access to the Western Line electricity grid on the four main outcome variables. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A2: Regression Results for Change in Occupational Groups' Shares

	(1) Elite	(2) White collar	(3) Foremen	(4) Med. skilled	(5) Farmers	(6) Low skilled	(7) Unskilled
Electricity grid access, Western Line (Dummy=1)	0.1	0.6	0.0	1.4*	-2.5**	1.4	-1.0
	(0.119)	(0.377)	(0.294)	(0.574)	(0.917)	(0.831)	(1.162)
Mean dependent variable	1.1	6.2	2.2	7.7	31.1	10.9	40.8
St. dev. dependent variable	1.1	4.2	2.0	4.4	15.0	9.3	11.1
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,931	4,931	4,931	4,931	4,931	4,931	4,931
No. of parishes	2,470	2,470	2,470	2,470	2,470	2,470	2,470

Note: This table shows results for the impact of access to the Western Line electricity grid on occupational groups' share of employment. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A3: Regression Results for Strikes by Sector

	Agriculture			Industry and services		
	(1) All	(2) Offensive	(3) Defensive	(4) All	(5) Offensive	(6) Defensive
Electricity grid access, Western Line (Dummy=1)	1.1	0.8	-0.3	9.9**	8.2*	3.3*
	(1.397)	(1.058)	(0.231)	(3.282)	(3.234)	(1.294)
Mean dependent variable	1.0	0.6	0.1	12.2	8.9	2.4
St. dev. dependent variable	9.3	7.2	2.5	41.5	34.1	15.1
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,410	7,410	7,410	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470	2,470	2,470

Note: This table shows results for the impact of access to the Western Line electricity grid on strikes divided between agricultural and non-agricultural activities. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A4: Regression Results for Strikes by Type of Parish: Non-Industrial/Industrial

	(1) All strikes	(2) Offensive	(3) Defensive
Electricity grid access, Western Line (Dummy=1)	0.8	1.5	0.1
	(2.607)	(2.397)	(0.543)
Electricity grid access, Western Line (Dummy=1) ×	17.0**	13.9**	5.6**
Industrial parish (Dummy=1)	(5.247)	(5.240)	(1.933)
Mean dependent variable	12.0	8.0	2.2
St. dev. dependent variable	42.7	34.2	14.3
Controls	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes
Observations	7,401	7,401	7,401
No. of parishes	2,470	2,470	2,470

Note: This tables shows results of interacting Western Line electricity grid access with an indicator for whether a parish is non-industrial or industrial. Industrial parishes are the 50 percent of parishes with the highest share of industry in total employment in 1900. Standard errors clustered at the parish level. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Appendix B Additional Results

Table A5: Results with Strikes Aggregated over a Five-Year Period

Dependent Variable:	(1) Log(1+Total Strikes)	(2) Log(1+Offensive Strikes)	(3) Log(1+Defensive Strikes)	(4) Log(1+No. of striking workers)
Electricity grid access, Western Line (Dummy=1)	11.92***	8.070**	7.608**	43.61***
	(3.325)	(3.068)	(2.320)	(11.87)
Mean dependent variable	17.5	11.7	4.4	67.0
St. dev. dependent variable	50.7	39.7	22.6	170.5
Controls	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County X Year FE	Yes	Yes	Yes	Yes
Observations	7,410	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470

Note: This table shows results when estimating the effect of access to the Western Line electricity grid on the four main outcome variables when aggregating strikes over a five-year period following the observation year. Standard errors clustered at the parish level. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A6: Effect on Offensive Strikes when Including Strikes for Other Causes

Dependent Variable:	(1) Log(1+Offensive+other strikes)
Electricity grid access, Western line (Dummy=1)	12.331**
	(4.137)
Mean dependent variable	12.0
St. dev. dependent variable	40.9
Controls	Yes
Parish FE	Yes
Year FE	Yes
County X Year FE	Yes
Observations	7,410
No. of parishes	2,470

Note: This table shows results of estimating the effect of access to the Western Line electricity grid on offensive strikes when including strikes for other causes. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A7: Results with Regression Weighted by Parish Population

Dependent Variable:	(1) Log(1+Total Strikes)	(2) Log(1+Offensive Strikes)	(3) Log(1+Defensive Strikes)	(4) Log(1+No. of striking workers)
Electricity grid access, Western Line (Dummy=1)	29.949*	42.336*	18.423**	38.329
	(13.282)	(17.061)	(6.676)	(24.537)
Mean dependent variable	51.0	36.4	14.3	156.6
St. dev. dependent variable	99.0	81.2	43.5	260.2
Controls	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County X Year FE	Yes	Yes	Yes	Yes
Observations	7,401	7,401	7,401	7,401
No. of parishes	2,470	2,470	2,470	2,470

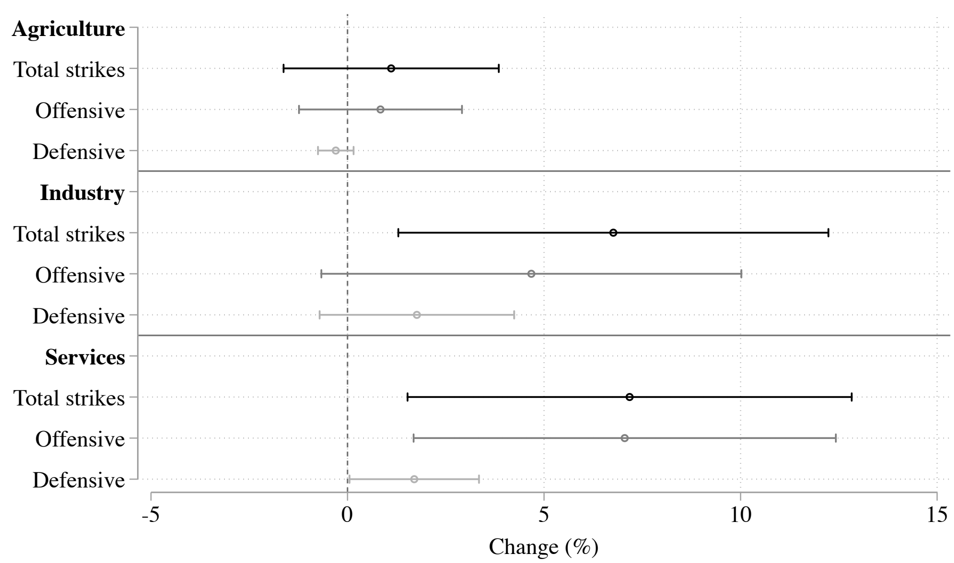
Note: This table shows results when estimating the effect of access to the Western Line electricity grid on the four main outcome variables when weighting the regression by parish population in 1900. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table A8: Results with Strikes Measured as a Dichotomous Dummy Variable

	(1)	(2)	(3)
Dependent Variable:	Total Strikes (Dummy=1)	Offensive Strikes (Dummy=1)	Defensive Strikes (Dummy=1)
Electricity grid access, Western line (Dummy=1)	0.083**	0.059*	0.036*
	(0.028)	(0.027)	(0.017)
Mean dependent variable	0.11	0.08	0.03
St. dev. dependent variable	0.32	0.28	0.16
Controls	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County X Year FE	Yes	Yes	Yes
Observations	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470

Note: This table shows results of estimating the effect of access to the Western Line electricity grid when strikes are measured as a dichotomous dummy variable taking the value 1 if any strike took place and 0 otherwise. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Figure A1: Regression Results for Strikes by Sector, Industry and Services Separately



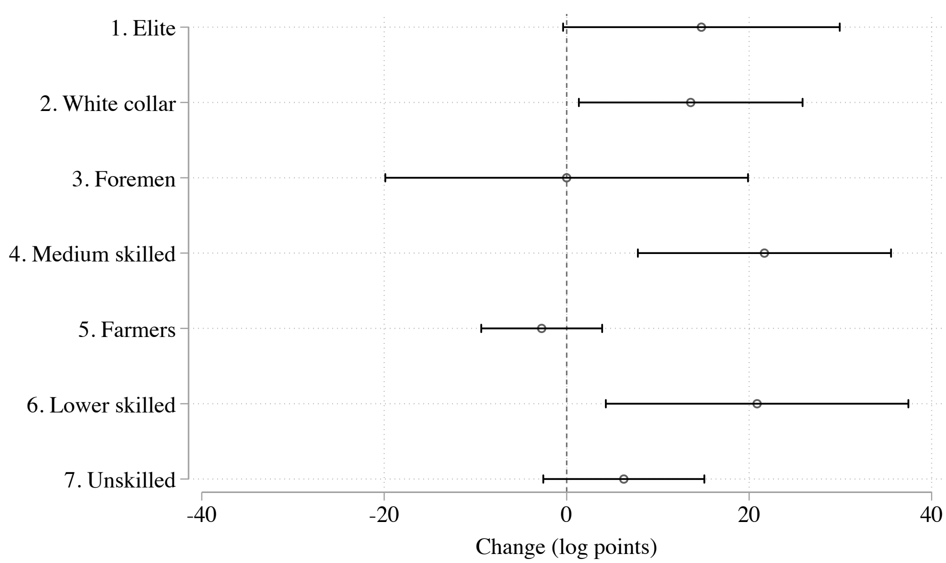
Note: This figure shows point estimates and 95% confidence intervals for the impact of a parish's gaining access to the Western Line electricity grid on the increase in the number of strikes by sector, with a division between industry and services. Standard errors are clustered at the parish level. The full regression table can be found in Table A3 of Appendix A.

Table A9: Regression Results for Strikes by Sector, with Industry and Services Separately

	Agriculture			Industry			Services		
	(1) All	(2) Offensive	(3) Defensive	(4) All	(5) Offensive	(6) Defensive	(7) All	(8) Offensive	(9) Defensive
Electricity grid access, Western line (Dummy=1)	1.1	0.8	-0.3	6.8*	4.7	1.8	7.2*	7.1*	1.7*
	(1.397)	(1.058)	(0.231)	(2.791)	(2.726)	(1.263)	(2.883)	(2.741)	(0.841)
Mean dependent variable	1.0	0.6	0.1	9.7	6.8	2.0	4.7	3.5	0.5
St. dev. dependent variable	9.3	7.2	2.5	35.6	28.6	13.6	24.6	20.2	6.5
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,410	7,410	7,410	7,410	7,410	7,410	7,410	7,410	7,410
No. of parishes	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470

Note: This table shows results for the impact of access to the Western Line electricity grid on strikes divided between agricultural and non-agricultural activities. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Figure A2: Regression Results for Absolute Growth of Occupational Groups



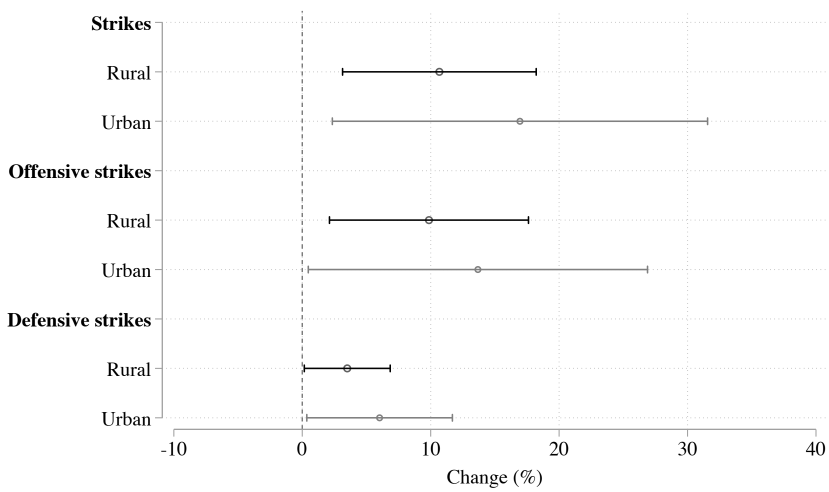
Note: This figure shows point estimates and 95% confidence intervals for the impact of a parish's gaining access to the Western Line electricity grid on the growth of employment by skill group. Standard errors clustered at the parish level. The full regression tables can be found in Table A10 of Appendix A.

Table A10: Regression Results for Absolute Growth of Occupational Groups

	(1) Elite	(2) White collar	(3) Foremen	(4) Med. skilled	(5) Farmers	(6) Low skilled	(7) Unskilled
Electricity grid access, Western Line (Dummy=1)	14.8	13.6*	0.0	21.7**	-2.7	20.9*	6.3
	(7.738)	(6.253)	(10.142)	(7.078)	(3.386)	(8.459)	(4.502)
Mean dependent variable	152.2	312.0	201.7	332.6	460.4	352.5	505.0
St. dev. dependent variable	107.1	118.1	122.5	119.1	92.6	138.1	93.9
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,931	4,931	4,931	4,931	4,931	4,931	4,931
No. of parishes	2,470	2,470	2,470	2,470	2,470	2,470	2,470

Note: This table shows results for the impact of access to the Western Line electricity grid on the increase in the number of strikes by sector, with a division between industry and services. Robust standard errors clustered at the parish level are given in parentheses. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Figure A3: Results for Strikes by Type of Parish: Rural/Urban



Note: This figure shows results of interacting Western Line electricity grid access with an indicator for whether a parish is rural or urban. Urban parishes are defined as the 50 percent of parishes with the highest population density in 1900. Standard errors clustered at the parish level. The corresponding regression tables are found in Table A11 of Appendix A.

Table A11: Regression Results for Strikes by Type of Parish: Rural/Urban

	(1) All strikes	(2) Offensive	(3) Defensive
Electricity grid access, Western Line (Dummy=1)	10.4**	9.7*	3.4*
	(3.830)	(3.944)	(1.702)
Electricity grid access, Western Line (Dummy=1) × Urban parish (Dummy=1)	2.7	1.1	0.3
	(8.425)	(7.847)	(2.966)
Mean dependent variable	12.0	8.0	2.2
St. dev. dependent variable	42.7	34.2	14.3
Controls	Yes	Yes	Yes
Parish FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
County × Year FE	Yes	Yes	Yes
Observations	7,401	7,401	7,401
No. of parishes	2,470	2,470	2,470

Note: This tables shows results of interacting Western Line electricity grid access with an indicator for whether a parish is rural or urban. Urban parishes are the 50 percent of parishes with the highest population density in 1900. Standard errors clustered at the parish level. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Appendix C Occupational Classification

We have used an abbreviated version of the HISCLASS scheme to denote the level of skills embedded in different occupations. The HICLASS scheme, introduced in van Leeuwen and Maas (2011), builds on the Historical International Standard of Classification of Occupations (HISCO), where historical occupations are coded into six-digit codes indicating one of 1,600 possible unit groups (van Leeuwen et al., 2002). Examples of six-digit codes include 02220 "Building Construction Engineer" and 61110 "General Farmer." HISCO also allows the coding of three additional variables: Status, Relation, and Product. The most relevant for social class analysis is the Status variable, which provides details on ownership, stages in an artisan's career, and whether someone is a principal or subordinate, information which is sometimes indicated in the original occupational strings but does appear in the occupational code itself. HISCLASS uses the HISCO codes together with the Status variable to sort each occupational unit group into one of twelve social classes. The twelve groups are shown in Table A12.

The HISCLASS 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. Groups one through five are all non-manual. Within this set of non-manual classes, members of the first group, "Higher managers," have a higher level of skill than, for example, those of the fifth group, "Lower clerical and sales personnel." Those in the first group, "Higher managers," have, in turn, a higher status than the second group of "Higher professional," since even though they are both considered highly skilled, the position of the former also involves a supervisory role. As a corollary, among manual workers, "foremen," since they also have a supervisory role, are given a higher social status than medium, lower and unskilled manual workers. While the HISCLASS scale running from one to twelve is nominal, it can be read as a ranking where "Higher managers" have the highest social status and "Unskilled workers" the lowest. An exception to this rule is "Farmers and fishermen," which constitute their own social class. The occupations included in this group involve persons holding a wide range of skills and exercising a wide rang 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.

For our empirical analysis, we used an abbreviated version of the system, where we aggregated categories to arrive at seven groups. This classification is also displayed in Table A12. Since we are mainly interested in the skill dimension of social class, we have aggregated groups one and two into the elite, and three, four, and five into white collar workers. These middle class groups were very small in Sweden at the beginning of

Table A12: Occupational Classification Schemes: HISCLASS and our abbreviated categorization

HISCLASS		**Abbreviated**	
Number	*Title*	*Number*	*Title*
1	Higher managers	1	Elite
2	Higher professionals		
3	Lower managers	2	White collar
4	Lower professionals, clerical and sales personnel		
5	Lower clerical and sales personnel		
6	Foremen	3	Foremen
7	Medium-skilled workers	4	Medium-skilled workers
8	Farmers and fishermen	5	Farmers and fishermen
9	Low-skilled workers	6	Low-skilled workers
10	Low-skilled farm workers		
11	Unskilled workers	7	Unskilled workers
12	Unskilled farm workers		

the twentieth century, so the number of people coded into any of these two groups is very small even after this aggregation. Because of the focus on skills, we also aggregated into one the two groups of low-skilled workers, who were in the original scheme split between the primary sector and the other sectors, and we do the same for unskilled workers.