

Geography of Power: Electrification, Industrial Location and Labour Conflict in Liberal Italy (1878–1911)

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Abstract

New technologies reshape the balance of power between workers and employers, and the direction of that shift depends on the technology itself. One dimension along which technologies differ is spatial: whether they tie capital to a particular location or leave it free to relocate. Electricity offers a useful case because its two principal generation sources in this period, water and fossil fuels, differed precisely on that dimension. This paper studies Liberal Italy between 1878 and 1911, matching municipal-level data on power-plant activations with strike records from the *Bollettino dell'Ufficio del Lavoro* and the 1911 Industrial Census. Using a staggered difference-in-differences design, I distinguish between offensive strikes, in which workers demand improvements, and defensive strikes, in which they resist changes imposed by employers. Municipalities that adopted hydroelectric power experienced an increase in offensive strikes and striker participation, without a corresponding rise in defensive strikes. Municipalities reliant on fossil-fuel electricity saw the opposite: an increase concentrated in defensive strikes. Hydroelectric plants were tied to specific watercourses and, absent long-distance transmission, had to be consumed in proximity to generation, which limited employers' exit options when workers pressed demands. Fossil-fuel plants, by contrast, could be sited near existing industrial demand and retained the possibility of relocation. This asymmetry is consistent with Malm's (2016) account of the geography of power, in which the mobility of capital shapes labour's bargaining position. The data do not permit a direct test of the mechanism, but the results are robust to controls for industrial concentration, transmission technology, and regional differences. The findings suggest that electrification did not affect labour uniformly: whether a new technology strengthened or weakened workers' bargaining power depended, at least in part, on the spatial constraints it imposed on capital.

1. Introduction

When societies adopt new technologies, understanding how workers respond to them is as important as studying their economic impact. Throughout the 19th century, workers across Europe often destroyed machinery, organized strikes, and mobilized collectively against innovations that threatened their livelihoods (Mokyr et al., 2015; Caprettini & Voth, 2020). The history of technology is therefore also the history of how workers organized to redefine their place within it, and examining when and why workers resisted or embraced new technologies reveals as much about social relations as it does about the technologies themselves.

Electricity provides a revealing case of a General Purpose Technology (GPT), a class of innovations characterized by pervasiveness and potential for technical improvement across different sectors (Bresnahan & Trajtenberg, 1995). Although electricity is usually treated as a technological breakthrough because it allowed the separation of power generation from its use, early industrial electrification was characterized by spatial fixity in the absence of long-distance transmission. From this point of view, the primary energy source of electricity plays a fundamental role: if early electrification was based on water, the location of areas covered by electricity depended on the availability of water sources and hydroelectricity potential; on the other hand, if it was based on fossil-fuels, which were more transportable than water, energy-based industries had no constraints on where to locate. These characteristics, along with the fact that electricity revolutionized production processes, make it especially suitable for examining the interaction between technological change and labour conflict.

Italy provides an interesting setting for studying the spread of electricity because it lacked domestic coal, and sustained industrial growth accelerated with the expansion of hydroelectric power in the 1880s. Unlike the coal-based economies of north-western Europe, reliance on waterpower tied Italian industry to rivers and waterfalls, making energy availability a determinant of industrial geography (Missiaia, 2019). Electricity also spread alongside the consolidation of industrial production and the growing organisation of the working class, with strike activity intensifying around the turn of the twentieth century.

The central research question of this paper is whether the adoption of electric power influenced the relationship between workers and employers, altering both the frequency and the character of strikes, and whether the type of primary energy used in generation mattered for that effect. Strikes explicitly motivated by technological change are rare in the historical record; the focus of the analysis is therefore not on how electrification directly provoked labour conflict, but on how it changed the conditions under which conflict took place.

To assess changes in worker bargaining power empirically, we follow the literature in using strike activity as a proxy of workers' leverage capacity (e.g. Cramton & Tracy, 1992; Card & Olson, 1995; Molinder et al., 2021). Following Molinder et al. (2021), strikes are distinguished into offensive and defensive. Offensive strikes are those in which workers demand changes to the workplace and push for an improvement of their conditions; defensive strikes are those in which workers react to a change imposed on them, resisting the erosion of conditions already in place. While offensive strikes signal increased bargaining power expressed through demands for better terms, defensive strikes reflect attempts to defend the status quo.

There are three reasons why the choice of primary energy source may translate into different patterns of labour conflict. The first concerns the industrial organisation that each technology supports, since differences in the technical requirements of water and coal, particularly in fixed costs and economies of scale, can produce different outcomes in industrial concentration and firm size (Reichardt, 2025), and these differences in market structure shape monopsony power in the labour market, which in turn affects workers' bargaining position (Azar & Marinescu, 2024).

The second is about the geographic properties of the energy source itself. As Malm (2016) argues, the shift from water to steam power in early industrial Britain was motivated in part by the freedom it gave employers over where production could be located, since water power tied factories to specific sites and strengthened the position of workers who knew that production could not easily be moved, while steam power allowed factories to be established closer to sources of cheap or less organised labour and so gave employers a new instrument of discipline in the form of a credible threat to relocate.

The third concerns the same physical constraint seen from the workers' side. Where the energy source dictates the site of production, the firms that depend on it are drawn to a small number of locations, and the workers they employ are concentrated into fewer and larger workplaces than they would be if production could be dispersed. Concentration reduces the cost of collective action, since information travels more easily, participation is more readily observed, and mutual support is easier to organise among workers who share a workplace and a settlement (Olson, 1965). The same spatial fixity that removes an employer's outside option therefore also improves the conditions under which workers can organise. The empirical strategy cannot distinguish between these channels, but this does not undermine the central claim: all three imply that spatial fixity shifts the balance of power, whether by constraining employers or by facilitating worker organisation.

Applying this logic to Italy's early electricity industry, when electricity was not yet easily transmissible, hydroelectric plants reproduced the geographic fixity of the earlier water-powered

economy. Because they depended on access to water, these plants tied capital to particular locations, physically constraining employers' exit options and leaving workers facing capital that could not easily move. Fossil-fuel plants, by contrast, could be built near areas of established industrial demand and retained the possibility of relocation. The prediction that follows is that hydro electrification should shift the balance of power towards labour, producing more offensive mobilisation, while fossil electrification should leave the employer's outside options largely intact, producing defensive conflict or none at all.

While this framework emphasizes the threat of relocation as a disciplinary device, the archival record provides some evidence of actual factory closures in response to labour conflict. Examination of strike records reveals instances where firms closed operations, though documentation of subsequent relocation to other municipalities is sparse and difficult to establish definitively. These closures are theoretically noteworthy: they represent moments when the exit option was exercised, even if relocation patterns themselves remain unclear. The *possibility* of closure, whether followed by relocation or not, likely influenced workers' expectations about bargaining power.

This paper contributes to three strands of literature: research on technological adoption and labour conflict (e.g. Caprettini & Voth, 2020; Molinder, Karlsson, & Enflo, 2021); work on the determinants of industrial location in Italy (e.g. Basile & Ciccarelli, 2015; Missiaia, 2019); and the debate on capital mobility and its implications for labour (Malm, 2016). While the economics literature has devoted considerable attention to the employment and productivity effects of technological change and electrification (e.g. Autor & Salomons, 2018; Leknes & Modalsli, 2020), comparatively less attention has been paid to how the primary energy source, and the degree of capital mobility it enables, shapes labour outcomes and the dynamics of industrial conflict.

The empirical analysis rests on a new combination of sources that have not previously been used together. By linking municipal-level data on power plant diffusion, the first national Industrial Census of 1911, and a newly assembled dataset on strike activity, this study offers the first granular analysis of electricity adoption and labour conflict in Liberal Italy. The spatiotemporal reconstruction of power plant expansion tracks the municipal-level spread of electricity while accounting for the technical and geographical constraints of the era, including the limitations of early high-voltage transmission and the distinct geographies of fossil and hydroelectric generation. Strike activity between 1878 and 1911 is assessed using a staggered difference-in-differences design, which exploits the timing of power-plant activations to evaluate how electrification affected the incidence and nature of labour unrest. To account for the level of industrialisation that emerges under fossil-based or hydroelectric-based regimes, the reconstructed grid is then combined with the 1911 Industrial Census to investigate how

electrification shaped industrial location, with an OLS strategy testing whether connected municipalities attracted different manufacturing activity.

The results reveal that municipalities adopting hydroelectric power experienced an increase in offensive strikes and in striker participation, without a corresponding rise in defensive strikes. Municipalities relying on fossil-fuel electricity, by contrast, saw an increase mostly concentrated in defensive strikes. The mechanism behind this effect appears to be capital immobility: municipalities served by plants with shorter transmission capacity generated the same pattern of offensive conflict as hydroelectric plants, regardless of the primary energy source. Industrial concentration, on the other hand, does not differ systematically between hydro and fossil municipalities, ruling out the most natural alternative explanation: it is not differences in the scale or organisation of local manufacturing that drive the labour conflict gap. The findings suggest that when energy infrastructure is geographically fixed, it weakens the employer's credible threat of exit and strengthens the workers' bargaining position, shifting the character of industrial conflict.

The paper is structured as follows. Section 2 outlines the historical background of Italian industrialisation, with attention to the spread of electricity and the early development of the labour movement. Section 3 reviews the theoretical and empirical literature on technological change and labour, focusing on electricity as a general-purpose technology and a determinant of industrial location, and develops the conceptual framework linking technology to strike activity and bargaining power. Section 4 presents the data, while Section 5 details the empirical strategy. Section 6 presents the main results, and Section 7 concludes.

2. Historical Background

2.1 Industrialization and the spread of electricity

At Unification in 1861 more than two-thirds of the labour force still worked in agriculture, productivity lagged behind the leading Western European economies, and manufacturing remained largely artisanal and locally oriented, concentrated in urban centres serving regional elites (Broadberry, 2013; Malanima & Zamagni, 2010; Ciccarelli & Fenoaltea, 2011). Geography shaped where industry could emerge: terrain, water access, and proximity to trade routes conferred first-nature advantages whose effects on regional wealth persisted beyond the early phase of industrialisation (Cermeño et al., 2026). The process was uneven, and the North-South divide widened as initial endowments interacted with differences in literacy, market access, and social capital.¹

Although the reasons for Italy's late industrialization are multiple, Bardini (1997) suggests that the lack of coal in the country during a time when the steam engine was the main technology explains the case of this slow catch-up. Indeed, in the early phase of industrialization, the absence of a energy transport system meant that manufacturing location depended heavily on local power sources, so early factories clustered where rivers were steepest, using direct waterpower or steam to move motors. Even though lignite deposits were scarce, coal was imported and, in smaller quantities, produced domestically. Despite the expansion of the railway network in the 1880s, transportation costs remained high: the cost of moving coal could double its price at the port (Licio, 2022). These constraints limited the availability and affordability of coal, making the adoption of steam power costly. Mechanization was therefore constrained, but it was not absent.

The expansion of manufacturing around the turn of the century was accompanied by a rapid increase in steam-powered capacity. Table 1 reports the stock of steam engines used as prime movers in 1890 and 1911. The increase indicates that, despite continued constraints on coal supply, Italian manufacturing was increasingly adopting steam power. This expansion remained concentrated in a relatively narrow range of industries, with textiles and food processing accounting for the majority of horsepower.

¹ On literacy, Ciccarelli and Weisdorf (2019); on market access, A'Hearn and Venables (2011); on social capital, Felice (2018).

Table 1 Motive power in Italian manufacturing by sector, 1890 and 1911

Sector	Steam, 1890		All sources, 1911		Electric
	HP	Share (%)	HP	Share (%)	1911 (%)
Foodstuffs	27,739	25.4	296,538	27.0	18.1
Metalmaking	15,642	14.3	273,552	24.9	44.2
Textiles	38,215	35.0	206,501	18.8	46.5
Chemicals	8,215	7.5	107,339	9.8	47.5
Non-metallic minerals	3,930	3.6	73,534	6.7	38.3
Paper	5,783	5.3	66,321	6.0	42.9
Wood	1,796	1.6	51,975	4.7	47.2
Leather	1,096	1.0	12,470	1.1	53.6
Sundry manufacturing	4,966	4.5	3,434	0.3	68.1
Clothing	1,288	1.2	3,306	0.3	59.3
Tobacco	511	0.5	2,366	0.2	57.6
Manufacturing, total	109,181	100	1,097,336	100	37.8

Notes: Statistica delle caldaie a vapore esistenti nel Regno (1890) and the industrial census of 1911. The 1890 column reports installed steam horsepower in boilers used for motive power; the 1911 columns report motive power from all sources. The final column gives electricity as a share of the sector's 1911 motive power, counting power produced and consumed on site together with power purchased.

An important technological shift came with the adoption of electric power in the 1880s. Across Europe, early electrification was dominated by local coal-fired plants supplying urban lighting and specialized industrial needs, with systems based on direct current that limited transmission distances and required generators to sit close to their loads (Hughes, 1993). Advances in alternating current technology in the 1890s extended transmission over tens of kilometers, but electrification remained uneven, shaped by each country's resource endowments and industrial demand.

Hydroelectric plants began to spread only in the 1890s, and Italy's first long-distance transmission, connecting the Tivoli plant to Rome over 28 kilometers, occurred in 1892 but remained exceptional well into the 1900s. Electricity systems in this phase were largely localized, since power was generated and consumed within the same municipality or industrial site, with factories running their own generators or drawing supply from small municipal providers (Nitti, 1905; AEIE, 1911). Thermal electricity was for the most part self-produced by manufacturers for their own use, whereas hydroelectricity, which required a State concession to derive water from public watercourses, was more often generated by a specialized enterprise and sold on to other firms. The diffusion of hydroelectric capacity did not replace the use of steam, and Nitti (1905) attributed its persistence to the fact that hydroelectric generation was economically viable only where a sufficient fall of water was available, so that the siting of the plant was dictated by the geography of the river network, while a steam plant could be placed wherever manufacturers found demand and production most convenient.

Figure 1 shows that fossil fuel dominated the early phase, accounting for most of the capacity through

the late 1880s, reflecting Italy's reliance on coal-powered urban plants. The share of hydroelectric capacity began rising sharply around 1892, coinciding with advances in alternating current transmission, and crossed above fossil fuel for the first time in that year. By 1911, hydroelectric plants accounted for 71% of total installed capacity, while thermoelectric plants accounted for a further 26%. Figure 2 shows the rapid diffusion of power plants over the period and their increasingly widespread distribution across the country. Their geographical distribution remained uneven: hydroelectric capacity was more concentrated in northern Italy, where suitable water resources were more abundant, while thermoelectric plants were more prevalent in the South.

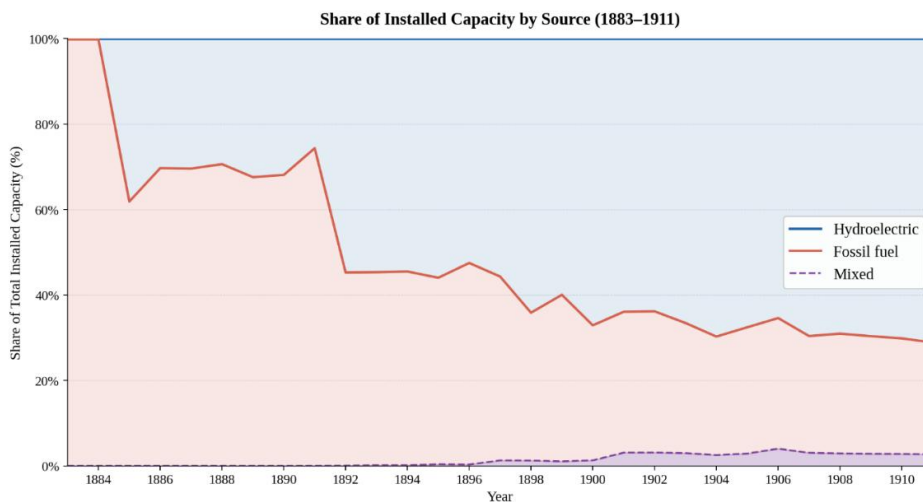


Figure 1 Cumulative share of installed capacity (kw) in electricity generation plants by primary energy source.

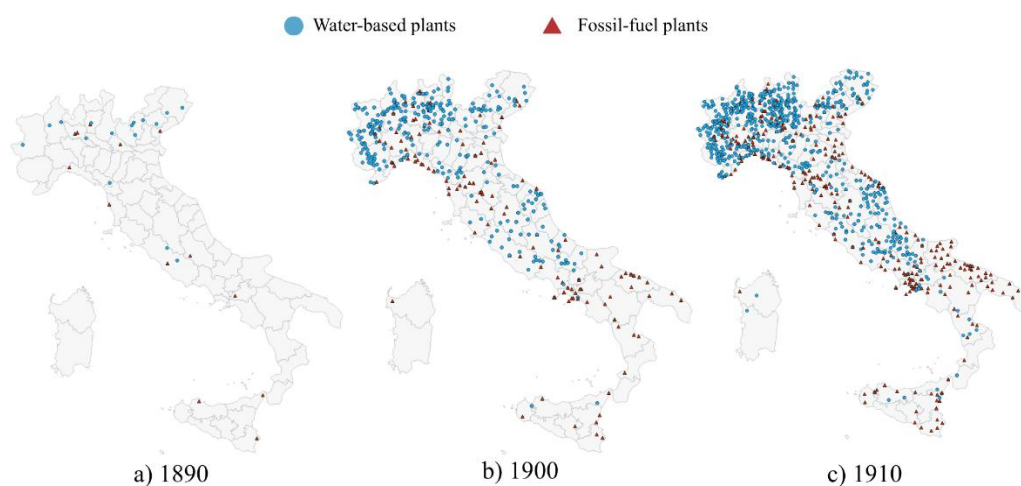


Figure 2 Active powerplants in the years 1890, 1900, 1910.

Source: own elaborations from MAIC (1901, 1911) and AEIE (1911).

Despite the presence of many plants in the country, there were still many municipalities lacking electricity, as Table 2 shows. The “pure” municipalities are the ones hosting only one type of

powerplants: hydro-based or fossil-based. Among the electrified municipalities, the purely hydroelectricity category is the largest. The predominantly fossil category stands out with the highest mean of workers and population, reflecting the concentration of large industrial cities in this group. Table 3 reports the distribution of power plants by source and transmission technology. Within hydroelectric municipalities, plants are predominantly alternating-current (AC) installations, which are technically capable of long-distance transmission, although a substantial share rely on direct-current (DC) systems suited only for local consumption. The pattern is reversed for fossil-fuel plants, which are mostly DC and oriented towards local supply, with a smaller though non-negligible share employing AC technology.

A second feature emerging from the table concerns the scale of installed capacity. The great majority of plants produce modest kilowattage, less than sufficient to power a small municipality or a limited number of industrial establishments. This implies that although the AC category was, in principle, technically equipped to transmit electricity beyond municipal boundaries, most installations did not generate the capacity required to sustain a developed inter-municipal grid.

Table 2 Municipalities and their energy source, 1911

Electricity category	N	%	Municipality	Manufacturing		Installed capacity (mean kW)	
			Mean pop.	Mean workers	Mean estab.	Hydro	Fossil
Not electrified	7,747	88.7	2,836	110	15	0	0
Purely hydro	644	7.4	6,379	509	44	484	0
Pred. hydro ($\geq 75\%$)	21	0.2	23,834	3,231	254	2,735	149
Mixed	40	0.5	29,340	4,380	269	155	146
Pred. fossil ($\geq 75\%$)	23	0.3	80,261	11,973	830	70	1,041
Purely fossil	258	3.0	24,220	1,697	179	0	305

Notes: Electricity categories are defined by majority share of installed capacity: purely hydro = 100% hydro; predominantly hydro = $\geq 75\%$ hydro; mixed = both sources $< 75\%$; $\geq 75\%$; predominantly fossil = $\geq 75\%$ fossil; purely fossil = 100% fossil; not electrified = no recorded plant or grid connection. Mean workers and establishments are from the 1911 Industrial Census. Mean population refers to 1911. Installed capacity is mean kW by source across municipalities in each category.

Table 3 Power plants summary by source and transmission technology, 1911

Category	N plants	Mean kW	Min. kW	Max. kW	% < 500 kW	% > 500 kW
Hydroplants	832	392.12	0.6	10500	89.52%	10.48%
Hydroplants × AC	465	456.26	2.5	11260	85.60%	14.40%
Hydroplants × DC	367	29.72	0.6	758.8	99.7%	0.3%
Fossil plants	395	307.70	1	6580	90.7%	9.3%
Fossil plants × AC	120	378.35	3	6580	90.9%	9.1%
Fossil plants × DC	275	210.41	1	4700	93%	7%

Notes: AC (Alternating Current) plants include monophasic and three-phase installations, both of which use alternating current and are technically capable of long-distance transmission. Direct current plants (DC) are suitable only to local distribution. % < 500 kW reports the share of plants in each category producing less than 500 kW; % > 500 kW the share producing more.

2.2 Working conditions and labour conflict

Although industrial activity remained concentrated in the northwestern cities, economic activity was changing across the whole country. This transformation was accompanied by increasing labour conflict, particularly as the expansion of industrial employment altered working conditions and relations between workers and employers. The working class was heterogeneous, spanning an urban industrial proletariat, a large artisan class, landless rural labourers, and various strata of peasant farmers but, across these groups, some common conditions prevailed: workers were typically paid hourly, lacked collective rights or formal contracts, and faced economic insecurity severe enough that all family members, including children, were often required to contribute to household income (Musso, 2002).

Mutual aid societies emerged as an early response to these conditions, their main purpose was to provide financial aid from a common fund to workers in need in the absence of adequate labour legislation, but they also supported strikes by distributing subsidies to workers during conflicts. The number and membership of mutual aid societies grew steadily after 1861, reaching over 200,000 members by 1873 (Musso, 2002). This 'pre-syndicalist' phase laid the organizational groundwork for the more militant labor conflicts that followed.

More active labour mobilization began in the early 1880s, spreading across multiple sectors, though it was frequently met with State repression and employer retaliation through lockouts and the use of strikebreakers. The late 1890s were marked by violent state repression of popular movements, such as the *fasci siciliani*, a federation of agricultural workers and artisans demanding fair land rents and higher wages, that was suppressed in 1894. Similarly, the Milan riots of 1898, triggered by rising food

prices and violent repression of strikes, ended in a massacre. These events prompted a shift toward greater state neutrality² in 1901, creating a more permissive environment for strikes and labor organization, though violent repression did not entirely cease.

Figure 3 illustrates the number of strikers across all sectors during the period. Strikes without union backing were mostly unsuccessful (Musso, 2002), but the first recognized labour union would emerge only in 1906³, which justifies the surge in the graph. Defensive strikers, which are those aimed at resisting workplace changes, remain steady over time, while offensive strikers demanding improvements in their conditions make up the majority of cases.

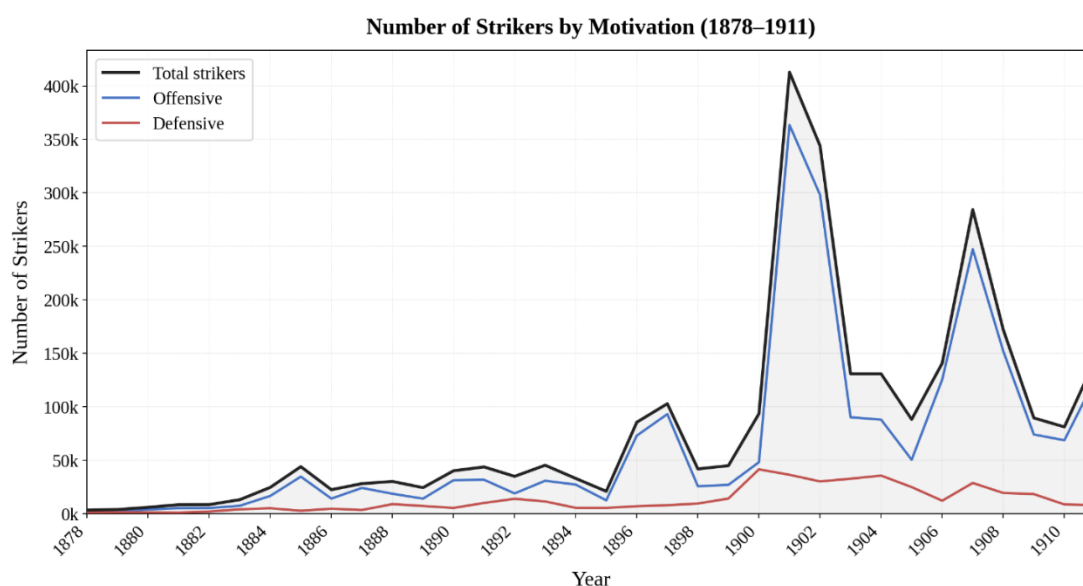


Figure 3 Trend of strikers motivated by offensive, defensive and other reasons (1878-1911).

Source: own elaborations from Bollettino dell'Ufficio del Lavoro.

Note: total strikers include the strikes not categorized in the defensive or offensive categories, such as the ones motivated by solidarity or other causes.

During this period, the nature of industrial unrest began to change. Most strikes were still driven by wage demands, fitting for a time when real industrial wages were rising, although unevenly across different regions (Federico et al., 2019). Beyond wage demands, strikes in this period increasingly reflected a broader ethic of solidarity, as workers frequently demanded the return of disciplinary fines

² The liberal turn associated with Giolitti's appointment as Minister of the Interior in 1901 marked a shift away from the more repressive handling of labour unrest that had characterized the previous decade. The government increasingly adopted a policy of non-intervention in industrial disputes, provided that public order was maintained. This created a more permissive environment for strikes and labour organization, without implying that the state actively supported workers' demands.

³ The General Confederation of Labour (*Confederazione Generale del Lavoro*, CGdL) was founded in 1906, marking a key turning point in the institutionalization of the Italian labour movement. Its creation aimed to coordinate the various local chambers of labour (*camere del lavoro*) and industrial federations into a national body

to mutual aid funds for sick or unemployed colleagues. This extension of demands beyond immediate self-interest suggests the emergence of class consciousness as a motivating force in labor conflict.

Table 4 shows the main characteristics of industrial strikes for different periods. Noticeably, the frequency of strikes increases in each period, and they keep concentrated mostly in the North. The median number of strikers decreases over time, indicating that although strikes became more frequent, they became smaller. Two other elements stand out: first, the median number of days increases over time, indicating an increase of bargaining power for workers, since they can hold the requests for longer (*Card & Olson, 1995*). Another suggestive aspect of higher power for workers is that the percentage of defeats decrease over time, while victories increase. The picture that these patterns describe is one of a labour movement that was becoming more frequent, more organised and more capable of sustaining conflict, even as individual disputes involved fewer workers.

Table 4 Main characteristics of industrial strikes by period (1878-1911).

	All	North	Center	South	Islands
1878–1889					
1. Number of strikes	648	71.6%	16.2%	10.0%	2.2%
2. Median strikers	100	100	90	80	200
3. Median duration (days)	3.0	3.0	3.0	1.0	2.0
4. Victory (%)	19.2	19.8	14.6	20.0	28.6
5. Compromise (%)	39.9	41.8	38.8	32.3	21.4
6. Defeat (%)	41.0	38.5	46.6	47.7	50.0
7. Union-organised (%)	0.6	0.9	0.0	0.0	0.0
1890–1900					
1. Number of strikes	1,632	77.1%	15.3%	5.6%	2.1%
2. Median strikers	77	80	75	60	54
3. Median duration (days)	3.0	3.0	2.0	3.0	4.0
4. Victory (%)	27.2	27.3	28.2	22.0	32.4
5. Compromise (%)	31.3	32.4	31.0	25.3	11.8
6. Defeat (%)	41.4	40.3	40.7	52.7	55.9
7. Union-organised (%)	0.2	0.2	0.0	0.0	0.0
1901–1911					
1. Number of strikes	6,295	69.7%	16.9%	9.6%	3.8%
2. Median strikers	60	65	52	50	62
3. Median duration (days)	5.0	5.0	4.0	5.0	4.0
4. Victory (%)	28.6	26.9	32.3	33.8	29.8
5. Compromise (%)	37.3	38.9	36.1	28.4	36.4
6. Defeat (%)	34.1	34.3	31.6	37.8	33.8
7. Union-organised (%)	24.9	24.5	25.3	25.7	26.9

Note: Sample restricted to manufacturing strikes (textile, construction, metalmaking, food, minerals, clothing, paper, wood, leather, chemical, tobacco, and other/unclassified manufacturing). Victories, compromises, and defeats percentages are computed among strikes with a recorded outcome. The North comprises the regions of Piemonte, Liguria, Lombardia, Veneto and Emilia; the Centre comprises Toscana, Marche, Umbria and Lazio; the South comprises Abruzzi e Molise, Campania, Puglie, Basilicata and Calabria; the Islands comprise Sicilia and Sardegna.

3. Literature Review

Electricity can be considered as a General Purpose Technology (GPT), meaning an innovation with broad applicability, significant transformative effects, and the capacity to drive long-term economic

change (Bresnahan & Trajtenberg, 1995; Helpman, 1998). The literature on GPTs highlights that their labour market consequences depend on the type of tasks they displace or complement: technological progress tends to be skill-biased, substituting for routine tasks while complementing non-routine ones requiring judgment or physical dexterity, a mechanism associated with job polarization and rising wage inequality (Acemoglu & Autor, 2011). The impact of any GPT is also mediated by the institutional context, since the distributional gains from productivity growth are not automatic and technological change can shift bargaining power between capital and labour in ways that prevent productivity from translating into wage improvements (Acemoglu & Johnson, 2023).

Whether electricity displaced or complemented labour depended on what it changed inside the workplace, and here the contrast between power sources is relevant. Devine (1983) focuses on the differences between steam-powered factories and electricity-powered ones, finding that in steam-powered factories many machines had to be connected to the same power source, while electricity allowed each machine to have its own power source, which encouraged efficiency gains and increased flexibility for the factory organization. Another important dimension related to this is the different cost structure of the two technologies: Reichardt (2025) shows that steam power was predominantly adopted by large establishments due to its steep costs, while purchased electric power was accessible to smaller firms, finding that steam increased average firm size while electricity reduced it. This finding is relevant because the distribution of establishment sizes shapes the number of employers competing for labour in a given locality, and thus the degree of employer power in the local labour market (Manning, 2003). The direction of the effect on conflict is not obvious, however, since larger workplaces also concentrate workers in ways that lower the cost of collective action, so a shift towards smaller establishments may improve workers' outside options while weakening their capacity to organise.

These workplace-level effects had a spatial counterpart, since a technology that changed how production was organised also influenced where it could profitably be located, and a growing literature treats access to power as a determinant of where industry located. Severnini (2023) shows that hydroelectric dams built in the United States before 1950 led to faster industrialization and higher population density in nearby areas, while Leknes and Modalsli (2020), studying Norway, find that early access to hydroelectric power influenced industrialization and that hydropower municipalities experienced local employment growth and structural transformation. Both studies concern hydroelectricity in particular, where the location of generation was fixed by the river network and the resulting pattern of industrial growth followed the geography of water more closely than the geography of existing demand. In the case of Italy, Basile and Ciccarelli (2018) examine industrial location by contrasting factor endowments with domestic market potential, identifying the latter,

together with literacy, as the main determinants, and after controlling for market potential and human capital they find water endowments to be a relevant factor for labour-intensive sectors. Missiaia (2019) assigns endowments a larger role, finding that energy and human capital were the main determinants of early industrialisation patterns, with market access mattering only in its domestic form. Xamo and Ricciuti (2025) find that electricity was an important determinant of industrial location, highlighting how its diffusion transformed the industrial map and surpassed factors such as literacy rates and market access. These results are difficult to interpret causally, because energy infrastructure was extended to the places where manufacturing already existed and demand was highest, which is why the identification strategies discussed previously rely on the geographic determinants of generation and transmission to isolate variation in access that is independent of local industrial demand.

The same expansion that reshaped the industrial map also changed the demand for labour in the places it reached. Jayes et al. (2024) find that electrification had a positive effect on labour outcomes in Sweden during its developmental phase, reducing income inequality, and Kitchens and Fishback (2015) show that electrification increased labour demand in rural areas of the United States.

If electricity increased labour demand and transformed workplace organization, as the literature indicates, it also had the potential to influence workers' bargaining power and patterns of labour unrest. Theoretical frameworks on labour conflict suggest that technological change interacts systematically with the ability of workers to organize and challenge managerial authority. Mandel (1995) argues that labour unrest tends to intensify at the end of expansionary long waves associated with technological revolutions, because the systemic decline in profit rates forces capital to go on the offensive, utilizing radical technological changes and new forms of labour organization to break the resistance of a strengthened working class and increase exploitation. Similarly, Silver (2003) emphasizes that the expansion of capitalist production initially provokes concessions by employers, which are subsequently withdrawn to restore profitability, generating crises of social legitimacy and heightened conflict. Cramton and Tracy (1992) model strike decisions as strategic signals of workers' bargaining leverage and find that striking activity increases during economic expansions, since firm profitability shifts upward while the current wage remains fixed under the expired contract, creating a greater incentive for workers to strike for higher wages. Likewise, Card and Olson (1995) interpret greater worker ability to sustain strikes as a reflection of relative bargaining power. Mokyr et al. (2015) show that technological anxiety leads to conflict, which can be due to higher substitutability between workers and machines and to falling wages, but also to the dehumanization and alienation of labour.

These mechanisms did not operate uniformly across time. Frey (2019) documents lower resistance to technological change in the early twentieth century compared to the violent reactions to mechanization observed in the nineteenth, and one explanation points to the growing role of labour unions around the turn of the century, which may have helped direct technological adoption in ways that benefited workers (Acemoglu & Johnson, 2023). In the specific case of electricity, Molinder, Karlsson and Enflo (2021) find that the adoption of electricity preceded an increase in labour strikes in Sweden, which were largely offensive in nature and concentrated in sectors experiencing rising labour demand, a pattern they read as evidence that electrification strengthened workers' bargaining power.

Evidence on earlier technologies points in a similar direction. Caprettini and Voth (2020) examine labour-saving technologies during the Captain Swing riots in 1830s England and find that such technologies increased the frequency and intensity of local unrest, especially in areas more distant from major industrial centres. While these studies trace effects running from technology to conflict, a parallel literature examines the reverse. Kotsadam et al. (2026) find that strike threats pushed firms away from capital-intensive methods in Norway, since labour-intensive technologies preserved cost flexibility during work stoppages. This reverse channel, where the anticipation of conflict shapes technological choice, cautions that the technology and conflict relationship is likely simultaneous.

Beyond the technology channel, the same logic of outside options applies on the workers' side, and its direction is contested. Hirschman (1970) treats exit and voice as substitutes, so that the availability of an exit option draws away those most likely to press for change and leaves a diminished capacity for reform. Karadja and Prawitz (2019) find higher labour movement membership and greater strike participation where workers' exit options were stronger, a result they attribute to the improved bargaining position of those who remained. The symmetry with the argument developed here is direct, since an employer's capacity to move production and a worker's capacity to leave operate on the same margin, and the balance of power in a locality depends on which of the two is more constrained. The analysis that follows holds the workers' side fixed and concentrates on the geography of capital, a restriction imposed by the data, since weighing the two against each other would require measures of workers' outside options varying by municipality and by year.

What this body of work leaves open is the role of the generating technology itself. The studies reviewed here treat electrification as a single phenomenon, but the source of generation determined whether power was produced on site or purchased from a supplier, and whether the location of production was fixed by the river network or chosen by the firm. That distinction matters for labour in two ways that the existing literature has not separated. It determines the credibility of an employer's

threat to move production, which is the mechanism Malm (2016) identifies in the transition from water to steam, and it determines how densely the workforce dependent on that power was distributed across space, which governs the cost of organising collectively. The distinction between hydroelectric and thermal electricity offers a way of tracing where within that variation the Italian case falls.

4. Data and Sources

The primary unit of analysis is the *comune* (municipality), the smallest administrative unit available. To address the issue of changing borders from the Unification to 1911, the method of pseudo-municipalities with time invariant borders is utilized, as developed by Buscemi and Insa-Sánchez (2024).

The data on electricity comes from three sources: archival materials from the *Ministero dell'Agricoltura, dell'Industria e del Commercio* (MAIC) provide detailed information on the location, capacity, and activation dates of electric plants. The first survey from MAIC is from 1898, resulting in a publication (MAIC, 1901) documenting the diffusion and use of electricity over Italian municipalities. Then, a second publication (MAIC, 1911) from the same source is used, covering the period from 1898 to 1908. Since the official publications extend only to 1908, the gap between 1908 and 1911 is filled using data from the *Associazione Esercenti Imprese Elettriche in Italia* (AEIE). These sources provide information on the municipality where the powerplants were located, which municipalities they covered, their installed kilowatt capacity and output, the construction year, the type of current⁴, and, crucially, the type of primary energy⁵ (water, fossil fuels, or mixed). Because some power plants reported power output in horsepower and others in kilowatts, the horsepower values were converted to kilowatts using a conversion factor of 0.7457 to ensure consistency across the dataset. The data for this section was manually collected and digitized, and each plant was assigned to a corresponding pseudo-municipality. Taken together, these sources document more than 1,500 power plants, including both self-producers and municipal facilities and they provide the basis for constructing the first map of electricity availability and diffusion across Italian municipalities during its early phase.

To analyse the impact of electrification on strikes, a new panel dataset covering the period 1878-1911 was constructed. This involved reviewing information from *Bollettino dell'Ufficio del Lavoro* (MAIC, 1878-1911), a series of publications that reported detailed accounts of strikes, which was then translated into a more structured dataset. The task was particularly demanding, as each entry was manually extracted and digitized from the printed reports and it required interpretation and simplification of detailed historical records to ensure consistency. The dataset covers roughly 12,000

⁴ The sources distinguish between monophase, biphas, triphase, direct, and alternating current. For simplicity, these are grouped as alternating current (AC) and direct current (DC), with monophase, biphas, and triphase classified as AC. This distinction is useful because, historically, AC was more practical for long-distance transmission, owing to the ease of transforming its voltage.

⁵ The sources generally specify whether power plants were hydroelectric (using water) or steam-powered (coal, wood, peat, lignite). For the purposes of this classification, steam-powered plants are treated as using transportable energy sources, while hydroelectric plants are treated as location-dependent, since their energy source cannot be transported to the plant.

strikes, and the information useful for this study are the municipality where the strike occurred, its type⁶ (offensive or defensive), its sector, number of participants, and the outcome (victory, defeat, or compromise). The recorded sectors include agricultural, extractive, industrial and services, but, for the purposes of this study, the analysis focuses on the following: foodstuffs, metalmaking, textiles, chemicals, non-metallic minerals, paper, wood, leather, clothing, tobacco, and sundry manufacturing.

Then, to examine patterns of industrial location, this study relies on the *Censimento degli Opifici e delle Imprese Industriali* of 1911 (MAIC, 1914), which was the first complete industrial census in Italy and reports the number of industrial establishments, workers and horsepower by sector and municipality. The usefulness of the data is constrained by underreporting in this period (Fenoaltea, 2015) and by the fact that information is not consistently available at the municipal level. Moreover, the source only provides data for 1911 and does not specify when firms began operating, making it difficult to identify time trends and causal relationships between electricity availability and industrial activity. This limitation is addressed in the methodology section.

To build the instrument for hydroelectric capacity, a municipal index of hydrological and topographic suitability is used. The index captures the physical conditions required for hydroelectric generation: proximity to a water source and sufficient elevation to produce the hydraulic head needed to drive a turbine. The suitability index is defined as the ratio of mean elevation to river distance, and enters the regressions in log form. Higher values indicate municipalities that are both elevated and close to a river, and therefore more suitable for hydroelectric plant construction. The index is time-invariant and determined purely by physical geography, satisfying the exogeneity requirement for a valid instrument.

For additional controls, I construct municipal coal prices replicating the method⁷ by Licio (2022), who created a dataset of provincial coal prices by combining import prices with port-specific shipping costs and inland railway transport costs. Other useful data comes from the 1890 boiler census data⁸,

⁶ Offensive strikes are the ones where workers seek improvements in wages or conditions; defensive strikes are those where workers resist changes to the workplace. Strikes motivated by solidarity or other uncategorizable causes form a separate, residual category.

⁷ Coal prices are constructed at the municipal level as the sum of the import price at the port and the cost of moving coal inland to the municipality, evaluated for 1890. The port price is taken from Licio's series and inland transport is priced using the railway fare schedule for the 1881-1890 decade, which combines a fixed terminal charge of 1.71 lire per ton with a variable rate per ton-kilometre declining across distance bands, from 0.0768 lire below 100 km to 0.0349 lire above 800 km. Municipalities without a railway connection by 1890 are assigned road transport at 0.59 lire per ton-kilometre over their distance to the nearest port, with no terminal charge. Railway access and distance to port come from the historical railway network data.

⁸ Statistica delle caldaie a vapore esistenti nel Regno (1890), data kindly provided by Gabriele Cappelli and Sara Pecchioli.

Population data are drawn from the censuses of 1871, 1881, 1901, and 1911, with intercensus values estimated by linear interpolation.

5. Empirical Strategy

The labour conflict analysis examines whether electrification affected both the frequency and the nature of manufacturing strikes, and whether these effects differed by type of electricity. Four outcomes are constructed at the municipality–year level from digitized strike records: (i) the number of offensive manufacturing strikes in municipality i in year t , (ii) the number of defensive strikes, (iii) the number of strikers, and (iv) the number of favourable outcomes, defined as the sum of strikes ending in either worker victories or negotiated compromises. All outcomes are expressed per 10,000 inhabitants.

The empirical strategy follows the staggered difference-in-differences framework of Callaway and Sant’Anna (2021), which is designed to handle variation in treatment timing across units. The baseline specification can be summarized as:

$$Y_{it} = \alpha_i + \alpha_t + \beta \cdot \text{Electrified}_{it} + \varepsilon_{it}$$

where Y_{it} denotes one of outcomes for municipality i in year t ; α_i and α_t are municipality and year fixed effects; Electrified_{it} is an indicator equal to one from the year in which municipality i first received a power plant of the relevant type; and ε_{it} is an error term clustered at the municipality level. Each municipality is assigned to a treatment cohort g defined by the first year it received a powerplant. The comparison group consists exclusively of not-yet-treated municipalities, which are those that eventually electrified but had not yet done so at time t .

To better exploit heterogeneity in the effects of electrification, three additional analyses using the same methods are conducted. First, to assess the role of transmission technology, we distinguish between plants employing AC (long-distance transmission) and DC (local distribution only), which differ in the spatial reach of electricity supply and in the geographic fixity of the underlying capital. Second, I compare municipalities in the South and the North separately, to absorb any broader regional trends that might confound the estimates. Third, we analyse whether the effect operated through the technology channel by classifying sectors into mechanization levels from the 1890 boiler census, according to each sector's share of total industrial steam horsepower. Manufacturing strike counts are then aggregated into high- and low-mechanisation groups and each is run through the same specification.

To rule out a more straightforward channel, which is that hydro municipalities exhibited different strike patterns simply because they industrialized differently, the analysis turns to the effect of electrification on industrial location. Hydro and fossil municipalities may have attracted different numbers of establishments or workers, mechanically changing industrial agglomeration and therefore strike intensity. Different energy sources may also have altered firm size (Reichardt, 2025), which matters because firm size has implications for employer monopsony power and hence for workers' bargaining position. Three outcomes from the 1911 Industrial Census are examined at the municipal level: manufacturing workers, manufacturing establishments, and workers per establishment. The first two capture the scale of manufacturing activity, and the third captures plant size.

Electricity is measured in two complementary ways. The first is the presence of a plant, using binary indicators for any hydro and any fossil-fuel plant; the second is installed capacity, utilizing the log of kilowatts for each source, written as $\log(\text{kW}+1)$ so that unelectrified municipalities stay in the sample. The baseline OLS specification is:

$$\ln Y_i = \alpha + \beta_1 \ln(\text{kW}_i^{\text{hydro}} + 1) + \beta_2 \ln(\text{kW}_i^{\text{fossil}} + 1) + \gamma X_i + \delta_c + \varepsilon_i$$

where the vector of municipal controls X_i includes log 1911 population, mean elevation, log coal price, log distance to the nearest port, latitude, distance to the industrial triangle, and an indicator for railway access by 1890; δ_c are circondario fixed effects, and standard errors are clustered at the circondario level. The extensive-margin specification replaces the capacity measures with the binary indicators.

The two coefficients are estimated jointly, so the relevant test is not whether each is individually significant but whether they differ from one another. If hydro and fossil municipalities produced statistically similar industrial outcomes, the differential pattern in labour conflict cannot be attributed to differences in industrial scale or firm size. This is tested formally with the restriction $\beta_1 = \beta_2$, reported alongside each specification.

6. Results

6.1 Effects of electrification on labour conflict

This section presents the results of the staggered difference-in-differences analysis of electrification and manufacturing strike activity. Figure 4 compares the evolution of the number of strikes in treated and in never-treated municipalities. Generally, the trend shows that the treated municipalities were characterized by a sizable increase in striking action for all types of energy source, without taking in consideration the characteristics of the strikes. The growth of striking activity in the treated

municipalities has accelerated since the mid-1890s, which was the period where powerplants, especially hydroelectricity plants, started to quickly spread.

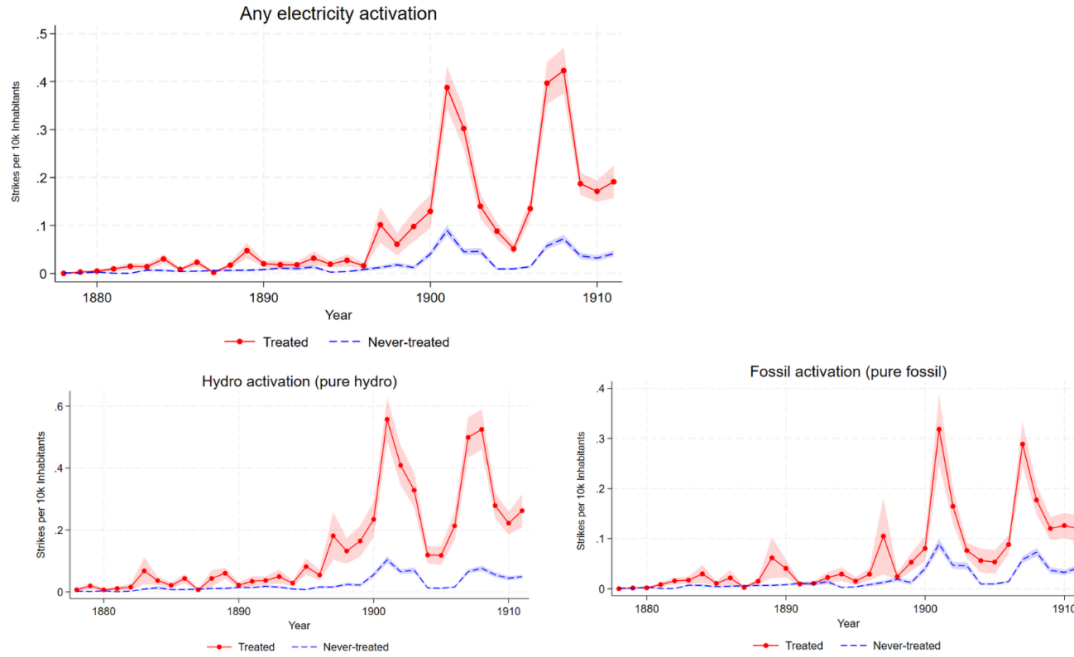


Figure 4 Impact of powerplant activations on total strikes (1878–1911).

Note: The ‘never treated’ group includes municipalities that will never be exposed to a powerplant.

Table 5 reports the main estimates of the effect of electrification on labour conflict outcomes.

Table 5 Effects of Electrification on Labour Conflict

	Hydro	Fossil	Any electricity
Total strikes	0.210*** (0.031)	0.044** (0.022)	0.143*** (0.021)
Offensive strikes	0.200*** (0.021)	0.032* (0.019)	0.131*** (0.016)
Defensive strikes	0.007 (0.020)	0.014** (0.007)	0.011 (0.012)
Strikers	33.491*** (5.535)	−1.707 (8.072)	20.317*** (4.133)
Favourable outcomes	0.131*** (0.023)	0.013** (0.013)	0.090*** (0.016)

Notes: Staggered difference-in-differences estimates following Callaway and Sant’Anna (2021), doubly robust with inverse probability weighting; the comparison group is not-yet-treated municipalities. The hydro and fossil columns use pure samples, excluding municipalities that received a plant of the other type. Outcomes are manufacturing strikes per

10,000 inhabitants; strikers is the number of workers involved per 10,000; favourable outcomes sum worker victories and negotiated compromises. Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

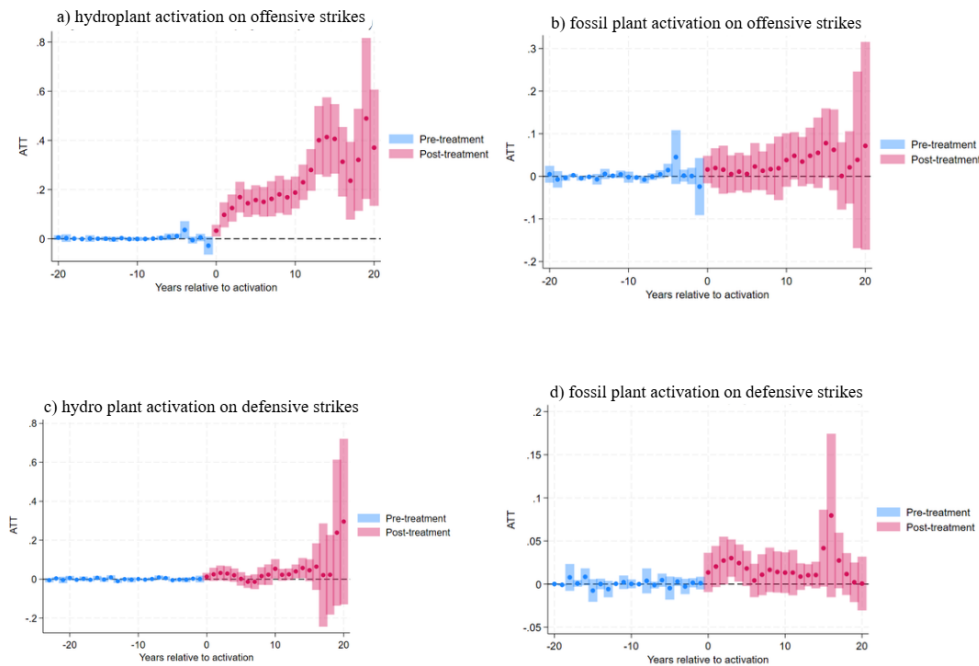


Figure 5 Impact of powerplants activations by source on offensive and defensive strikes

Notes: The dependent variable is the number of manufacturing strikes per 10,000 inhabitants, smoothed with a three-year backward moving average. The control group comprises not-yet-treated municipalities. Pure samples exclude municipalities that received plants of the other type during the period under analysis: the hydro specification excludes municipalities with any fossil-fuel plant, while the fossil specification excludes municipalities with any hydroelectric plant. The shaded areas represent 95% confidence intervals, with standard errors clustered at the municipality level.

The estimates in Table 5 show that electrification had a statistically meaningful association with manufacturing strikes. The activation of any plant raises offensive strikes, favourable outcomes, and the number of strikers, all significant at conventional levels. The null result for defensive strikes suggests that the diffusion of electric power did not, on average, generate a wave of defensive labour responses, but instead shifted workers towards offensive demands and broader mobilization.

When the analysis is disaggregated by the source of electricity the average effect of electrification shows an asymmetry between hydro and fossil municipalities. Offensive strikes and favourable outcomes rise in both sources, with hydro coefficients exceeding their fossil counterparts. The number of strikers seems to be impacted mostly by hydroelectricity activation and not by fossil-fuel-based. The contrast emerges most clearly on defensive strikes, where fossil municipalities show a small but significant positive effect, pointing to an active component of defensive worker mobilisation in places where coal-fired electric capacity was installed.

Before drawing any interpretive conclusion from this pattern, it is necessary to investigate whether the result reflects a feature of the technology itself or if it conceals other dynamics tied to where and how electrification unfolded.

The first concern is geographic. Hydroelectric plants in Liberal Italy were heavily concentrated in the North, where mountainous terrain and abundant water supply made hydropower technically viable, and the same Northern provinces had developed industrial structures and denser labour markets. It is therefore legitimate to ask whether the larger hydro coefficient documented in the main table simply captures the broader social and institutional context in which hydro plants operated, rather than something intrinsic to the technology. To address this, we re-estimate the main specification separately for all macro areas so that all comparisons take place between municipalities sharing similar institutional settings.

The second dimension concerns the transmission technology of the electric system, which provides a deeper test of the mechanism than the broad hydro/fossil distinction. Within hydroelectric municipalities themselves, the alternating-current systems introduced allowed power to be transmitted over considerable distances, decoupling the location of the plant from the location of the consuming industries. Direct-current systems, by contrast, required production and consumption to remain spatially proximate, anchoring industrial activity to the immediate surroundings of the plant. If the bargaining advantage of workers in hydro municipalities rests on the geographic fixity of the underlying capital, this advantage should be sharper in DC municipalities than in AC ones.

The third test asks whether the effect is valid for different levels of sectorial mechanization. If workers gained leverage because the plant employing them could not move, the effect should concentrate in industries that actually ran on mechanical power, and be weaker where work remained manual.

Sectors are split at the median of their share of manufacturing steam horsepower in the 1890 boiler census. The high group is textiles, food, metalmaking, chemicals and paper; the low group is minerals, wood, clothing, leather and tobacco. Strike counts are aggregated within each group and estimated separately, so treatment, timing and municipality are held fixed and only the sector varies.

Table 6 Effects of Electrification by Energy Source and macro-region

	North	Centre	South	Islands
<i>Panel A. Hydroelectric</i>				
Total strikes	0.147*** (0.028)	0.145*** (0.043)	0.245*** (0.051)	0.045*** (0.015)
Offensive strikes	0.120*** (0.024)	0.128*** (0.043)	0.244*** (0.034)	0.039*** (0.015)
Defensive strikes	0.032** (0.010)	0.016*** (0.005)	−0.005 (0.034)	0.008 (0.005)
Strikers	15.172*** (3.250)	12.822 (8.569)	46.110*** (9.076)	7.575* (3.983)
Favourable outcomes	0.092*** (0.019)	0.088** (0.037)	0.154*** (0.039)	0.026** (0.012)
<i>Panel B. Fossil fuel</i>				
Total strikes	0.059** (0.025)	0.029 (0.065)	0.034 (0.071)	0.028 (0.022)
Offensive strikes	0.059*** (0.017)	0.002 (0.061)	−0.005 (0.067)	0.034** (0.015)
Defensive strikes	−0.004 (0.016)	0.022 (0.015)	0.039* (0.022)	0.010* (0.006)
Strikers	−20.254 (23.016)	−9.388 (16.781)	22.531* (11.946)	2.831 (2.296)
Favourable outcomes	0.054*** (0.016)	0.051 (0.056)	0.039 (0.040)	0.022* (0.013)

Notes: The sample is split by geographic region and primary energy source. The North comprises the regions of Piemonte, Liguria, Lombardia, Veneto and Emilia; the Centre comprises Toscana, Marche, Umbria and Lazio; the South comprises Abruzzi e Molise, Campania, Puglia, Basilicata and Calabria; the Islands comprise Sicilia and Sardegna. Outcomes are per 10,000 inhabitants. Estimates are obtained by Callaway and Sant'Anna (2021) staggered difference-in-differences (not-yet-treated comparison group). Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7 Effects of electrification on strikes by transmission technology and source

	Hydroelectric		Fossil fuel	
	DC	AC	DC	AC
Total strikes	0.231*** (0.033)	0.148*** (0.053)	0.019 (0.028)	0.012* (0.015)
Offensive strikes	0.190*** (0.026)	0.181*** (0.033)	0.009 (0.025)	0.006 (0.031)
Defensive strikes	0.043 (0.013)	−0.040 (0.040)	0.015** (0.007)	0.019* (0.021)
Strikers	34.784*** (8.886)	23.695*** (6.558)	−9.801 (10.927)	14.846 (10.025)
Favourable outcomes	0.155*** (0.024)	0.085** (0.041)	0.029** (0.014)	0.068 (0.028)

Notes: The sample is split by transmission technology: DC (Direct Current) plants transmit electricity only over short distances, anchoring industrial activity to the immediate vicinity of the generating plant; AC (Alternating Current) plants allow long-distance transmission, weakening the spatial link between power generation and consumption. Not-yet-treated municipalities serve as the comparison group. All outcomes are counts per 10,000 inhabitants.

Table 8 Effects of electrification by sectoral mechanisation

	Hydroelectric		Fossil fuel	
	High	Low	High	Low
Total strikes	0.115*** (0.025)	0.039*** (0.007)	0.017 (0.015)	0.014 (0.010)
Offensive strikes	0.109*** (0.013)	0.040*** (0.006)	0.013 (0.014)	0.006 (0.009)
Defensive strikes	0.005 (0.019)	-0.003 (0.005)	0.002 (0.004)	0.007** (0.003)
Strikers	19.263*** (4.173)	4.335*** (1.261)	5.661** (2.446)	-9.901 (7.385)
Favourable outcomes	0.070*** (0.018)	0.030*** (0.005)	0.016* (0.009)	0.012*** (0.004)

Notes: Sectors are divided at the median of their share of total manufacturing steam horsepower in 1890. The high mechanisation group comprises textiles, food, metalmaking, chemicals and paper; the low-mechanisation group minerals, wood, clothing, leather and tobacco.

As demonstrated in Table 6, the significant effect of hydroelectricity on labour conflict persists across all macroregions, which suggests that the findings are not simply an effect of the differences between the north and the south. Interestingly, the activation of hydroelectric plants exerts a comparatively larger effect on offensive strike frequency and the number of strikers in the South than in the North. One explanation is that in the South, hydroelectric sites were significantly scarcer and the water sources more geographically constrained than in the North, so the geographic immobility of a hydro plant in the South represented a more absolute spatial anchor, and workers in these rare locations possessed a unique form of localized leverage that was difficult for capital relocate. A complementary explanation for the South's higher sensitivity is the relative shock of the technology, since coal-based steam power had a more established presence in the North's industrial triangle, so hydroelectricity in the South often represented a more disruptive break from previous production modes.

The results in Table 7 regarding transmission technology mirror the dynamics observed in the energy-source analysis, providing another layer of evidence for the spatial mobility mechanism. The analysis reveals that Direct Current electrification, characterized by its technical inability to transmit power over long distances, exerts the strongest positive effect on all outcomes. The Hydro-DC category emerges as the most potent driver of labour conflict. This represents a double constraint: the power source is fixed by topography (Hydro) and the power itself is trapped by technology (DC), so workers in these municipalities were associated with the largest increases in strike activity. At the opposite end, Fossil-AC plants show a negligible effect on striking activity and outcomes, apart from the defensive strikes category. These plants have dual flexibility, as the fuel (coal) can be transported to any location, and the resulting power can be sent across a vast grid (because it is AC). This "double

mobility" for capital neutralizes the geographic bargaining power that workers utilized in the Hydro-DC era.

Table 8 reports the estimates of the mechanization division. Hydroelectrification raises offensive strikes, strikers and favourable outcomes in both groups, and the coefficient is larger among mechanised sectors. Interestingly, fossil-fuel electrification effects seem to be concentrated in the least mechanised sectors, the only exception being the number of strikers, which rises in the high-mechanisation group; this isolated result is not sufficient to establish that the effects of fossil-fuel electrification were concentrated in the more mechanised sectors.

6.2 Industrial Location

Having established that proactive and successful labour conflict increased mostly in municipalities served by hydroelectricity and that this pattern differed in character from the conflict associated with fossil-fuel electrification, we now examine whether hydroelectric adoption triggered a simultaneous shift in the location of firms and workers to ensure the results on labour conflict are not confounded by changes in industrial density. If hydroelectricity drew a distinct pattern of manufacturing concentration relative to fossil-fuel electricity, then the labour conflict differential could simply reflect underlying differences in the industrial base rather than anything specific to the technology of electrification itself. We test this in two ways: the presence of a plant of each type, and the installed capacity of each source.

Table 9 Electricity and industrial location, 1911

	Log workers (1)	Log establishments (2)	Log workers/estab. (3)
<i>Panel A: Installed capacity, log(kW + 1)</i>			
Log kW hydro	0.100*** (0.018)	0.045*** (0.011)	0.036*** (0.009)
Log kW fossil	0.072*** (0.025)	0.066*** (0.019)	0.016 (0.011)
Equality test (<i>p</i>)	0.338	0.298	0.139
Observations	5,765	5,765	4,422
<i>Panel B: Plant presence (binary)</i>			
Any hydro plant	0.529*** (0.082)	0.247*** (0.050)	0.182*** (0.042)
Any fossil plant	0.415*** (0.114)	0.366*** (0.082)	0.063 (0.047)
Equality test (<i>p</i>)	0.399	0.189	0.034
Observations	5,765	5,765	4,422
Controls	Yes	Yes	Yes
Circondario FE	Yes	Yes	Yes

Notes: OLS estimates. Panel A measures electrification by the log of installed capacity, log(kW + 1), separately for hydroelectric and fossil-fuel plants; Panel B replaces capacity with binary indicators for the presence of any plant of each type. Controls are log 1911 population, mean municipal elevation, latitude, log delivered coal price, log distance to the

nearest port, log distance to the Milan–Turin–Genoa industrial triangle, and an indicator for railway access by 1890. Samples are outcome-specific: workers per establishment is undefined for municipalities with no recorded establishments, which accounts for the smaller number of observations in column (3). The equality test reports the p-value of the restriction $\beta_{\text{hydro}} = \beta_{\text{fossil}}$. Standard errors clustered at the *circondario* level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The question this exercise answers is whether hydro and fossil municipalities end up with different kinds of industry. If they did, the divergent strike patterns documented above might have nothing to do with the geography of energy and everything to do with the kind of manufacturing that grew up around each technology; the answer is that they did not.

Electrification of either kind is positively associated with manufacturing activity, and the association is of comparable magnitude whichever source supplied the power. By 1911 a municipality that had received a hydroelectric plant and one that had received a coal-fired plant were, in terms of the number of workers employed, the number of establishments operating, and the scale at which production was organised, substantially alike. The confidence intervals around the hydro–fossil difference are sufficiently narrow to exclude magnitudes approaching those that would be required to generate the observed gap in labour conflict, so the finding is not simply a consequence of imprecise estimation.

A partial exception concerns establishment size. Municipalities hosting hydroelectric plants display somewhat larger establishments than fossil-fuel municipalities, and this difference emerges when electrification is measured by the presence of a plant rather than by installed capacity. A plausible interpretation is that a generating station tied to a particular fall of water draws production towards itself, concentrating employment around a fixed point in a manner that a coal-fired plant, which could be sited wherever demand happened to be, did not require. The result is consistent with the interpretation advanced in this paper rather than in tension with it, in that spatial fixity would be expected to shape the physical organisation of production as well as the balance of bargaining power. It should nonetheless be treated with caution, as it appears on one margin only and is descriptive rather than causally identified.

These results close off the most direct alternative explanation for the labour conflict findings. Had hydroelectrification systematically produced denser industrial agglomerations, or larger firms exercising greater monopsony power, or a manufacturing base concentrated in sectors with a higher propensity to strike, the differential in strike activity would follow without recourse to any argument about capital mobility. The industrial geography recorded in the 1911 census provides no basis for such an explanation. The distinction between hydroelectric and fossil-fuel municipalities in their patterns of labour conflict cannot therefore be attributed to the scale or the composition of local manufacturing, and must operate through some other channel.

Conclusion

This paper has investigated whether the adoption of electric power altered workers' bargaining power and the character of industrial conflict in Liberal Italy, and whether the primary energy source used to generate that power mattered for the outcome. The central finding is that the effect of electrification on labour relations was not uniform across generation technologies. Municipalities that adopted hydroelectric power experienced a substantial increase in offensive strikes, in striker participation and in favourable settlements, with no corresponding rise in defensive mobilisation. Municipalities that relied on fossil-fuel electricity saw a smaller increase in offensive conflict together with a modest rise in defensive strikes, in which workers reacted to changes imposed by employers. The same technological category, in other words, carried different implications for labour depending on the form it took.

The most plausible interpretation of this pattern is that it reflects differences in the spatial mobility of the underlying capital, working through two channels that the data do not separate. Hydroelectric generation was tied to specific watercourses and, before long-distance transmission became routine, had to be consumed close to the point where it was produced, which limited the credibility of an employer's threat to move production away from workers who made demands. The same constraint drew the firms that depended on that power into a small number of sites and concentrated the workforce more densely than would have been the case had production been free to disperse, which lowered the cost of organising and sustaining collective action. Fossil-fuel plants imposed neither constraint, since coal could be carried to wherever demand and labour conditions were most favourable, so employers retained an outside option and the workforce remained more dispersed. Both channels follow from the same physical property of the technology and both predict more assertive conflict where that property binds, so the estimates should be read as their combined effect.

Several pieces of evidence are consistent with this reading. The asymmetry holds within each macro-region, so it does not simply reproduce the North-South divide, and the effect of hydroelectric adoption is if anything larger in the South, where suitable sites were scarcer and the anchoring of capital correspondingly more absolute. Direct-current systems, which confined the use of electricity to the immediate surroundings of the plant, are associated with the strongest effects, while alternating-current systems, which allowed power to travel, are associated with weaker ones. The analysis of industrial location, finally, shows that hydro and fossil municipalities did not differ systematically in the number of manufacturing workers or establishments they contained, which means the strike differential cannot be explained by one group having simply industrialised more than the other. What that analysis cannot settle is whether the two groups differed in how their manufacturing was

internally organised, since municipalities with comparable aggregate employment may still distribute it across workplaces of very different size, and the one margin on which the two technologies do part company is plant size, where hydroelectric municipalities show more workers per establishment. The channel that remains open is therefore the spatial organisation of local manufacturing, which is the second of the two mechanisms set out above and which follows from the same immobility of the energy source as the first.

The concept of bargaining power is central to interpreting these findings. In standard models of wage determination, the terms on which a bargain is struck depend on what each side can do if agreement fails, and when capital is geographically immobile the employer's fallback position weakens, since production cannot credibly be moved to a place with cheaper or less organised labour. The pattern of conflict documented here, in which workers in hydroelectric municipalities initiated disputes and secured favourable settlements more often than their counterparts elsewhere, is what that account would lead one to expect, while the concentration of fossil-fuel effects in defensive disputes fits a setting in which workers were responding to employer initiative from a weaker position.

The relationship between geographic fixity and monopsony power in the local labour market is more ambiguous and cannot be resolved with these data. Immobile capital may strengthen an employer's wage-setting power, since workers tied to a single site have fewer alternative employers within reach, while at the same time weakening the employer's capacity to exit the local labour market altogether. The two effects push in opposite directions, and the evidence assembled here speaks to the observed balance of conflict without identifying which of them dominated. Establishing that would require wage data at the municipal level and information on the number of employers competing for labour, neither of which is available for this period.

These results connect to several strands of literature. They build on Molinder, Karlsson and Enflo (2021), who identify a general positive relationship between electrification and offensive strikes in Sweden, by showing that the relationship is contingent on the technology through which power was generated and delivered. They are also consistent with the premise underlying Malm's (2016) account of the transition from water to steam, namely that the mobility conferred by fossil fuels had value to employers in their dealings with labour, though the evidence presented here concerns the consequences of that mobility for industrial conflict and not the motives behind the historical choice of one technology over another, which would require evidence on how firms selected their power source. More broadly, the findings contribute to work on technology and labour by showing that technological change can strengthen workers' position when the technology in question ties capital to particular places.

The conventional narrative in which the adoption of new technology inherently degrades labour's position is therefore too coarse. Whether a technology strengthens or weakens workers' bargaining power depends on what it concretely requires, on where it must be located and on what kinds of investment it ties down, and in the Italian case the technologies that fixed capital in place, hydroelectric generation and direct-current transmission, shifted leverage towards labour, while those that preserved mobility did not. This does not imply that technology alone determines labour outcomes, since unionisation, state policy and the regulation of the labour market all shaped the capacity of Italian workers to act, but it does suggest that the material properties of a technology have consequences for the balance of power between capital and labour that deserve more attention than they have received, both in economic history and in current debates on automation. What the Italian case suggests is that the relationship between technology and labour is not settled in advance by the technology itself, and that the same broad innovation can produce different distributional outcomes depending on the particular form it takes and on the spatial constraints that form imposes on employers and workers.

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