Colluding Against Workers

Vincent Delabastita[*] Michael Rubens[†]

This version: January 9, 2023
First version: November 15, 2021

Abstract

Empirical models of labor market competition usually assume that employers set wages non-cooperatively, despite ample evidence of collusive wage-setting agreements. We propose an identification approach for labor market collusion that relies on production and cost data, and use it to study how employer collusion affected wage markdowns of 227 Belgian coal firms between 1845 and 1913. We are able to detect collusion through the 1897 coal cartel, an observable shock to collusion, without ex-ante knowledge of its timing, and find that it explains the fast growth in markdowns after 1900.

JEL classification codes: N33, J42, L40

Keywords: Collusion, Industrial Revolution, Labor Markets, Monopsony

[*]Radboud University Nijmegen, Department of Economics and Business Economics.
E-mail: vincent.delabastita@ru.nl

[†]University of California, Los Angeles, Department of Economics.
E-mail: rubens@econ.ucla.edu.

Acknowledgements: We thank Frans Buelens, Erik Buyst, Jan De Loecker, Marc Deloof, Sebastian Fleitas, Maarten Goos, Joel Mokyr, Mohamed Saleh, Jo Van Biesebroeck, Gertjan Verdickt, Frederic Vermeulen, Hillary Vipond, Patrick Wallis and Noam Yuchtman for helpful comments and suggestions. Vincent Delabastita and Michael Rubens both benefited from a PhD Fellowship (Aspirant) of the Research Foundation - Flanders (FWO), grant numbers 11F8619N and 11A4618N respectively. Rubens gratefully acknowledges support from the ERC Consolidator grant 816638 MPOWER. We are grateful to Filip Strubbe from the Belgian National Archives for help with the data sources. This paper circulated previously circulated under the titles "Monopsony and Industrialization" and "Colluding Against Workers: Evidence from Belgium, 1845-1913".

1 Introduction

There are growing concerns about increasing levels of labor market power held by firms.[1] Whereas empirical labor market models have focused on many sources of imperfect competition, such as labor market frictions, concentration, or employer differentiation, they have usually assumed non-cooperative wage-setting by employers.[2] However, there is ample evidence of wage-fixing and anti-poaching agreements, for instance between high-tech firms, fast-food chains, oil companies, and universities (Gibson, 2021, Krueger & Ashenfelter, 2022, Naidu, Posner, & Weyl, 2018, 597-598).[3] The extent to which collusive wage-setting drives the wage markdown, which is the wedge between the marginal product of labor and wages, remains an open question.[4] The answer to this question is crucial when designing policies to constrain 'monopsony' or 'oligopsony' power.[5] For instance, antitrust policy has a key role in addressing oligopsony power if this oligopsony power is derived from collusion between employers, but not if it arises from non-cooperative sources, such as search frictions or employer differentiation.

In this paper, we close this gap in the literature by developing an empirical approach to detect and quantify employer collusion in labor markets using firm-level production, cost, and wage data. Our approach consists of estimating wage markdowns using a production-cost model that does not impose conduct assumptions upstream, and comparing these to markdown bounds that employers would charge if they would not collude and if they would perfectly collude. Knowledge of these markdown bounds requires imposing a model of labor supply, in addition to the labor demand conditions derived from the production model. A similar comparison was done for goods price markups by De Loecker and Scott (2016), but without inferring conduct, and assuming

[1]See, for instance, Krueger (2018) and surveys in Manning (2021) and Sokolova and Sorensen (2021).

[2]Recent examples include Caldwell and Harmon (2019) for oligopsony power due to search frictions, Card, Cardoso, Heining, and Kline (2018) for heterogeneous worker tastes over firm-specific (dis)amenities, and Schubert, Stansbury, and Taska (2021) for labor market concentration.

[3]See also U.S. Department of Justice (2019) for no-poaching agreement cases in higher education, the fast-food industry, and the rail industry. For now, we consider both non-poaching and wage agreements as forms of collusion against workers. Our model in Section 3.1 will be more specific about this. We also refer to Shi (forthcoming) for an analysis of the welfare implications of non-compete clauses.

[4]In his well-known literature review, Manning (2011, 979) already considered the potential role of collusion on labor markets an "open question".

[5]For the remainder of the paper, we use the terms 'monopsony' and 'oligopsony' for labor market power intermittently. However, we note that actual monopsonies are scarce.

perfectly competitive factor markets.

Given that employer collusion in current-day settings is illegal and hence usually unobserved, this paper takes a historical turn. More specifically, we apply our method to examine the extent to which wage markdowns of 227 Belgian coal firms between 1845 and 1913 were due to collusion, or to other sources of imperfect competition. This is possible, thanks to observable historical examples of collusion, both upstream and downstream. By examining imperfect labor market competition during the industrialization process of Belgium, we also touch upon an 'old' question in economics: were workers exploited during the industrial revolution, and to which extent was this due to collusion between employers?[6]

The Belgian coal setting is thus uniquely fit for our research question because of three reasons. First, cartels were legal throughout the 19th century, which allows us to observe collusion. In the Belgian coal setting, a cartel was formed in 1897, and we also observe information about collusive wage-setting through the membership of 'employers' associations', professional organizations at which firm executives met weekly to discuss current industry developments and wage-setting. This allows us to compare our wage collusion estimates, which do not require observing collusion, to observed collusive behavior. Second, the coal industry offers a rare case in which rich micro-data can be retrieved over a uniquely long period that covers most of the industrialization of Belgium, the first country on the European continent to participate in the Industrial Revolution. Third, the coal industry features limited product differentiation, which facilitates the empirical analysis. Despite these 'special' characteristics of the historical Belgian coal setting, our method can be applied in any other industry for which production, cost, and wage data are available, and can be extended to settings with differentiated goods and/or multi-product firms.

Our findings can be summarized as follows. During a first period, up to the 1870s, wage markdowns were stable, with workers being paid around two thirds of

[6]The relationship between workers' living standards and industrialization is a core question in economic history (for a notable example, see Feinstein, 1998). The roles of distorted labor markets and collusion are, however, rarely considered. This is remarkable, given that Friedrich Engels (1892, 241-260), whose work *The Condition of the Working Class in England* is a large source of inspiration for this literature on workers' well-being, himself already dedicated a chapter to lament the "cheating" and "plundering" by the "coal kings". The case of Belgium is particularly interesting, because Karl Marx, in a letter exchange with Engels, called the country "the snug, well-hedged, little paradise" of the capitalist (1985, 47).

their marginal product at the median firm. During the 1880s and 1890s, markdowns increased, leaving workers with around 60% of their marginal product. Finally, after 1900, markdowns increased even further, leaving workers less than 50% of their marginal product.

By comparing our markdown levels to non-collusive and fully collusive markdown bounds, we can unpack this markdown increase into collusive and other sources. We find that prior to 1900, the rise in wage markdowns was mostly due to non-collusive sources. Median markdowns were between 25 and 50% in between the non-collusive lower bound and the fully collusive upper bound, which indicates imperfect collusion. This degree of collusion was roughly constant throughout this time period, and hence does not explain markdown growth prior to 1900.

Contrary to this, the sharp increase in wage markdowns after 1900 was entirely due to collusion. Wage markdowns jumped to the fully collusive level right after the emergence of the Liège coal cartel in 1897. As 75% of the market was controlled by this cartel, markdowns rose not only at the cartel participants, but also at the other firms in the same market. Our test for labor market collusion cannot reject the null hypothesis of zero collusion from 1901 onwards. Crucially, our empirical approach would have been able to detect the increased collusion after the introduction of the cartel without observing this cartel. This increase in employer collusion had important implications for workers. Miner wages would have grown 40% faster after 1898 in the absence of the cartel, and 84% faster in the absence of any collusion on the labor market. Downstream, we find evidence for low markups, which suggests that firms were faced with competitive coal markets. The main source of market power of coal firms was hence the labor market, rather than the coal market.

We think that these results have external relevance beyond the 19$^{\text{th}}$-century coal setting, for two reasons. First, in terms of our findings about the role played by collusion in driving markdowns in the industrial era, we judge that these bear some external validity for other industries because Belgian coal mines were located within commuting distances of industrial cities, and shared many labor market characteristics with these other industries.[7] The introduction of cartels was not specific to coal, but happened in many industries both in Europe and the U.S.A., and we have anecdotal

[7] This is very different from earlier historical studies on labor market power power of U.S. coal mining firms, which are usually geographically isolated (for appraisals, see Fishback, 1992; Boal, 1995).

information that collusion was not unique to coal firms but was also present in, for instance, the steel industry.

Second, our results are not just relevant from a historical perspective, but also help understanding the upstream effects of cartels today. Given that output is more easily observed than inputs, firms might be more inclined to collude on output quantities or prices, even if the possible goal is to exert market power upstream, rather than downstream. We show that in settings with imperfect labor market competition, output-restricting cartels can lead to substantial wage markdown growth and the exertion of monopsony power, even if firms are faced with relatively competitive product markets downstream.

This paper contributes to three strands of literature. First, we contribute to the large literature on imperfectly competitive labor markets. Empirical models of imperfect labor market competition usually impose untested assumptions about firm conduct and competition, such as monopsonistic competition (Card et al., 2018; Lamadon, Mogstad, & Setzler, 2022) or oligopsonistic competition (Berger, Herkenhoff, & Mongey, 2019; Azar, Berry, & Marinescu, 2019). We contribute to this literature by allowing for collusive wage-setting, and by examining how labor market conduct changes when cartels are formed downstream.

Second, we build on a literature on conduct identification in the industrial organization literature. Most empirical work on collusion follows a 'demand-side' approach in the tradition of Bresnahan (1987), with the key challenge that both marginal costs and conduct are latent. Possible solutions are to identify shifts in collusion, rather than its level (Ciliberto & Williams, 2014), to rely on in-sample variation in ownership (Miller & Weinberg, 2017), or to find instruments that are orthogonal to affect only marginal costs but not conduct, or vice-versa (C. Michel & Weiergraeber, 2018; Backus, Conlon, & Sinkinson, 2021). If one has production-cost data, however, a production model like in De Loecker and Warzynski (2012) can be used to identify markups without making explicit conduct assumptions, which has been extended to the factor markets side by Morlacco (2020); Brooks, Kaboski, Li, and Qian (2021); Mertens (2020); Rubens (2021, 2022); Yeh, Macaluso, and Hershbein (2022).[8] We rely on a combination of

[8] Using production function estimation to categorize labor market competition goes back to the work of Dobbelaere and Mairesse (2013).

both approaches, as in De Loecker and Scott (2016), to identify conduct.[9] Our results show that cartels on product markets can have very large effects on anti-competitive behavior on input markets. This calls for taking into account downstream competition when studying imperfectly competitive factor markets.[10]

Third, we contribute to the economic history of employer collusion and anti-competitive labor market institutions. The economic history literature contains ample evidence for employer collusion on labor markets. For instance, 14th-century England feudal landlords coordinated to keep labor costs low (Jedwab, Johnson, & Koyama, 2022).[11] Guilds were widely used to manipulate wages (Ogilvie, 2019, 190-191). Textile firms colluded when setting prices for domestic textile production, which remained an invaluable source of income for many until deep in the 19th century (Humphries & Schneider, 2019, 152). Throughout the 19th century, employers increasingly unionized in employers' associations, in which employers sought to defend common commercial interests, control their labor force and counter emerging trade unions.[12] We contribute by showing that employers' associations were crucial vehicles of wage collusion for most of the 19th century, but that they lost this function due to the emergence of cartels during the 1890s. We find that employer collusion remained relatively stable throughout most of the industrial revolutions, only to increase sharply at the turn of the century.[13] The surge of cartels after the turn of the century, in Europe and the U.S.A. alike, hence provided opportunities for collusion not only on the product market, but also on the labor market[14].

[9] Rubens (2021) also combines a factor supply model with a production model, but for a different purpose, recovering markups and markdowns in the presence of non-substitutable inputs.

[10] A similar point was made in Rubens (2021) for downstream ownership consolidation.

[11] Interestingly and relatedly, the case of feudalism is also a particular case of labor coercion. Similar to the case of employer collusion, the many historical examples of labor coercion have long had only a limited impact on economics (Acemoglu & Wolitzky, 2011). Recently, a range of historical empirical studies have proven coercion's prevalence in industrial labor markets (Naidu & Yuchtman, 2013) as well as its long-run effects (Dell, 2010).

[12] A prominent example can be found in British coal mining during the Victorian era, where multiple coal owners' associations actively coordinated to fix wages (Church, 1986, 651-674). Empirical research on the role of employers' organizations is scarce, however. Exceptions with a historical focus can be found in Yarmie (1980) for the UK and Vanthemsche (1995) for Belgium. A current-day analysis of employer unions is done by Martins (2020), who studies how firm performance measures differ between members of such unions and other firms.

[13] Whereas collusion between employers was usually legal, there were legal restrictions on striking and unionization. Naidu and Yuchtman (2018) present evidence of substantial firm-specific rents in 19th-century US labor markets, facilitated by legal restrictions on striking efficacy.

[14] For a concise overview on European coal cartels, see Murray & Silvestre, 2020, 679-680). Lamoreaux (2019) provides an historical overview of cartelization in the U.S.

The remainder of this paper is structured as follows. Section 2 describes the historical setting of Belgian coal mining and presents the data. In Section 3, we present the model and estimate firm-level wage markdowns between 1845 and 1913. In Section 4, we test for employer collusion, decompose wage markdowns into a collusive and non-collusive component, and use these estimates to examine the consequences of the 1897 coal cartel for miners' wage growth. Finally, Section 6 concludes.

2 Industry background and facts

2.1 Coal demand and production

The industrialization of Belgium

Belgium's Industrial Revolution, the first on the Continent, started when Walloon entrepreneurs imitated British technological innovations during the 18$^{\text{th}}$ century.[15] The macroeconomic effects of these innovations materialized during the following decades, with industrial production taking off primarily from the middle of the 19$^{\text{th}}$ century: during the 1850s and 1860s, Belgium became an economic powerhouse (Gadisseur, 1979; Pluymers, 1992). This growth trend continued into the age of globalization when technologically advanced firms fuelled strong export performance in coal-based sectors, such as metal and steel production (Huberman, Meissner, & Oosterlinck, 2017).

Coal industry

The presence of rich and easily accessible coal deposits in the south played an important role in Belgium's industrialization (Allen, 2009, 104).[16] As a result, the coal mining industry became a major industrial employer, with its share of industrial employment surpassing 10% at the turn of the 19$^{\text{th}}$ century (Buyst, forthcoming).[17] This large

[15]This can be clearly illustrated by the case of the first Newcomen machine on the Continent, which was constructed in in Tilleur, near Liège, only eight years from its inception in 1712 (Lebrun, Bruwier, Dhont, & Hansotte, 1981, 263, 313).

[16]The discussion on the causes of the Belgian Industrial Revolution mirrors the international debate on whether coal was a crucial determinant in industrialization. Recent research has reappraised the crucial role of coal (Fernihough & O'Rourke, 2021).

[17]See Figure A1 in Appendix A.1 for an overview of the strong importance of coal mining in Belgian industry throughout the 19$^{\text{th}}$ century from an employment perspective. Figure A2 in Appendix A.1 underlines how wage developments in coal mining are indicative of the evolution in the industry overall.

labor force was distributed among three provinces in Belgium's industrial belt, from east to west, being Hainaut, Namur and Liège.[18] In this paper, we focus on the coal mines in Liège and Namur: these provinces represented approximately 3 out of 10 coal workers in Belgium and 20 to 25% of Belgian coal production throughout the 19$^{\text{th}}$ century.[19] There were on average 60 coal firms per year in the Liège basin and 19 in the Namur basin. The main buyers of coal were households (22% of sales), steel mills (20%), railroads (13%), cokes producers (10%) and non-ferrous metal manufacturers (10%) (De Leener, 1908).

The Belgian economy's reliance on coal also meant that the local coal industry grew in tandem with its booming industrial manufacturing sector. During the economic downturn of the 1870s, it became increasingly clear that the first signs of exhaustion of Belgian mines meant that domestic coal producers could not meet local demand. Increasing imports from France and Germany, however, meant that coal prices remained relatively stable at around 10 Belgian Francs (BEF) per ton until 1900, with sharp price fluctuations that quickly reverted to the mean. Nonetheless, after 1900, a prolonged increase in coal prices took place. As we will see below, this coincides with the emergence of coal cartels.

While coal can be considered a relatively homogeneous product, there is some differentiation in its volatile matter content, which determines its usage. Four coal types are distinguished in the data set based on volatile content percentiles: $13-18\%$ (*houille maigre sans flamme*, anthracite coal), $18-26\%$ (*houille sèche courte flamme*), $26-32\%$ *(houille maigre longue flamme)*, and $> 32\%$ *(houille grasse longue flamme)*. The first type was mainly used by households for heating purposes, the second for powering steam engines, and the latter two types for railroad locomotives. Mines often extracted a combination of these coal types, which are a function of the geological characteristics of the mine's location.

[18] See the map in Figure A4 in Appendix A. A distinction is typically made between the coal basins of the *Borinage*, *Centre*, *Charleroi* (all three in the province of Hainaut), *Basse-Sambre* (in Namur) and *Liège*.

[19] These employment shares are based on the industrial censuses of 1846 and 1896, allowing for comparison through the adaptation by Delabastita and Goos (2022). Production shares are based on Statistique de la Belgique (1858) and the *Annales de Mines de Belgique* (Administration des Mines, 1896, 505).

Production process and technological change

Extracting coal required, roughly speaking, four steps. First, the underground coal vein had to be reached by digging a mine shaft. Second, the coal had to be extracted. This was done manually by the miners (*abatteurs* or *ouvriers à veine*) with a pickaxe. Third, the lumps were hauled to the surface in containers or minecarts by mules and laborers, *hiercheurs*, often young children and women.[20] Fourth, coal had to be sorted from stones, which was done at the surface.

Throughout the sample period, there was extensive capital accumulation and mechanization. First, coal haulage was already mechanized at the start of our sample period, as steam-powered underground mining locomotives were introduced around 1812. The ratio of locomotive horsepower per employee-day used remained fairly constant over the sample period, as shown in Figure 1a. Two other forms of mechanization were, however, increasingly adopted during the 19th century. First, mechanical pumps were introduced to extract water from the mines. These were initially steam-powered, but from 1893 onwards also electrically-powered (Gaier, 1988, 72). Figure 1a shows that the usage of water pumps mainly increased during the 1870s. Second, steam-powered ventilation fans were introduced from the 1870s onwards, to deal with sudden releases of firedamp. In contrast to the hauling process, coal cutting was mechanized very little in Liège and Namur throughout our sample period. Pneumatic coal cutting machines would only be implemented in Liège coal mining around 1908 and had little success because coal veins were too narrow to use cutting machines.[21] This contrasts with, for instance, the case of the U.S. where these cutting machines were readily adopted from 1882 onward (Rubens, 2022).

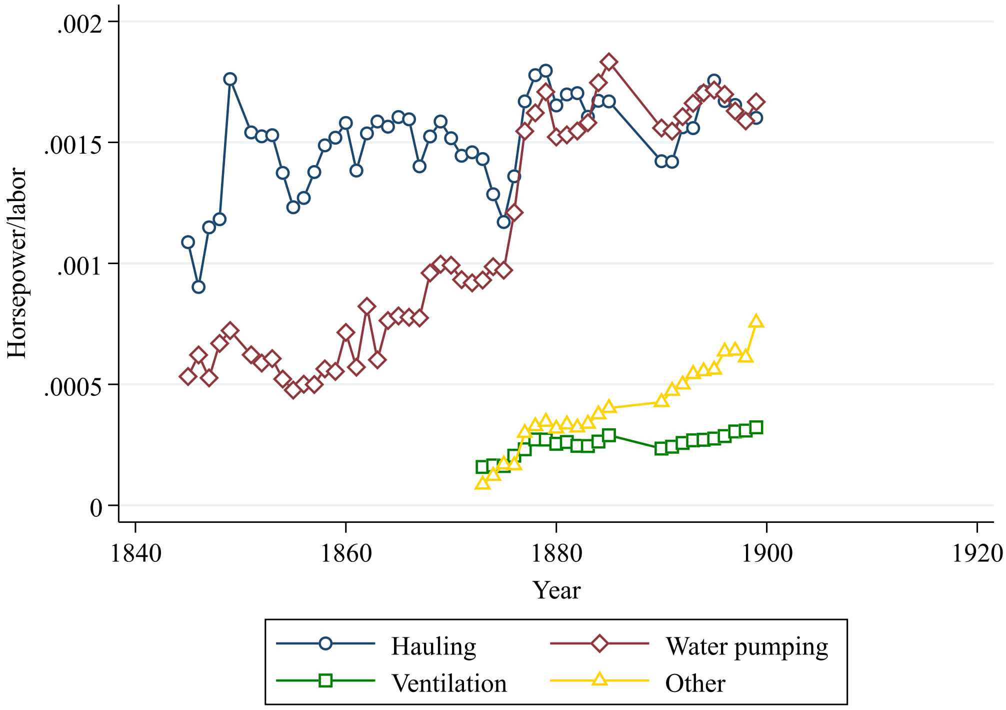
Figure 1b shows the evolution of total investment by Liège and Namur coal mines, in millions BEF. The main peak in investment happened in the late 1870s, and mainly resulted in the increased installations of water pumps and the adoption of mechanical mine ventilation fans which we described in Figure 1a.

[20] An important innovation lied in the successful combination of interior rails and horse-drawn carriages in the second decade of the 19th century (Gaier, 1988, 79). The tight nature of many Liège mines made the introduction of equine power challenging, however, and experimentation with new rail and mine cart systems would increase its applicability throughout the 19th century (Caulier-Mathy, 1971, 217-219).

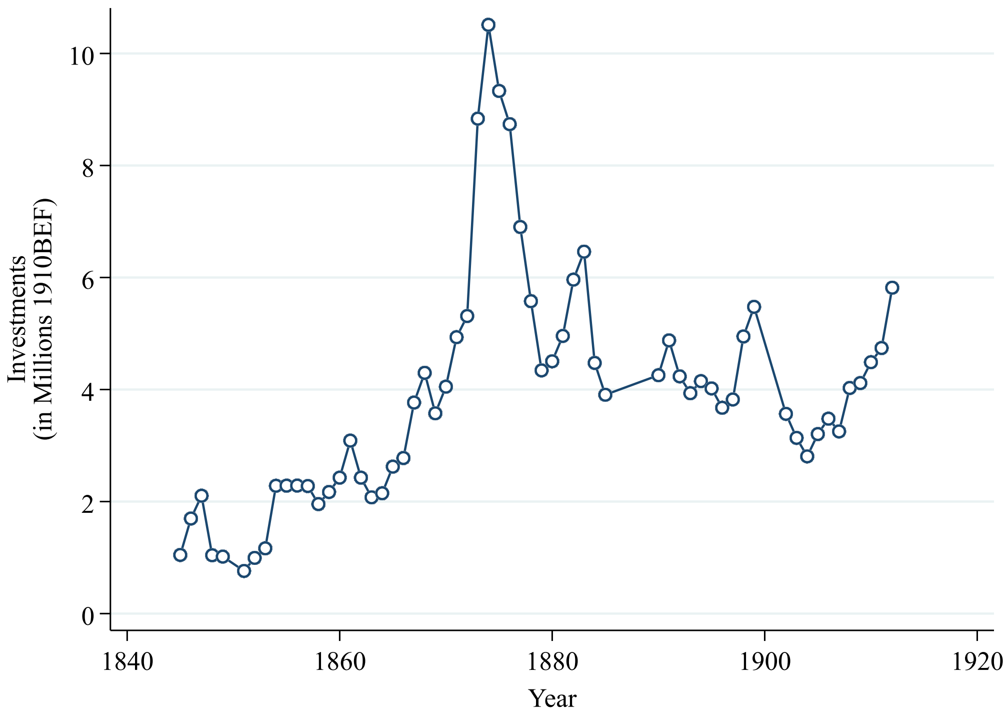
[21] At the 1905 world fair in Liège, organized to showcase the region's industrial leadership, local industrialists had to grudgingly admit that the introduction of mechanical cutting techniques was hampered by difficult geological conditions (Drèze, 1905, 816).

Figure 1: **Mechanization in Liège- and Namur-based coal mining**

(a) **Horsepower per worker-day, by technology, of Liège and Namur coal firms, 1845-1900**



(b) **Total investment by the Liège and Namur coal firms, 1845-1913**



2.2 Labor markets

Labor relations and wage-setting

Due to the high population density in Belgium, manufacturing and mining firms could easily tap into low-cost labor (Mokyr, 1976). Belgium was indeed labeled as a low-wage country by contemporaries, despite its industrial successes. Government intervention on labor markets remained all but nonexistent throughout the 19$^{\text{th}}$ century, as politicians held true to the liberal, *laissez-faire* principles on which Belgium was founded in 1830. Moreover, suffrage was conditional on wealth, with merely 1% of the population holding voting rights until 1893. This pushed questions on topics such as worker rights and living conditions to the political periphery.[22]

Labor legislation had been drafted under French rule in the beginning of 19$^{\text{th}}$ century and generally placed laborers in an unfavorable position by prohibiting collective bargaining for wages or working conditions.[23] Article 414 of the criminal code prohibited labor coalitions until 1866, when this article was replaced by stark limitations on strikes.[24] Large-scale labor movements consequently knew little to no development for the larger part of the 19$^{\text{th}}$ century. Belgian trade unions were only in the embryonic stages of their development in the 19$^{\text{th}}$ century, and employers did not recognize them as legitimate partners for collective bargaining until the First World War (Luyten, 1995, 16).[25]

Wage contracts were informal and primarily oral, and legal hiring and firing costs were virtually nonexistent (Van den Eeckhout, 2005). Salaries were determined using either time or piece rates, with the latter typically reserved for miners and other more skilled workers. The only source of government intervention in labor markets was

[22] Indeed, international comparisons of legislation with regards to child labor, working time and factory inspection, consistently rank 19$^{\text{th}}$-century Belgium amongst least regulated countries in Europe (Huberman & Lewchuk, 2003). We return to the issue of democratization in Section 5.

[23] Other than this feature and the aforementioned *livret*, most aspects of the labor relationship, such as working time, safety measures and method of wage payment, were largely agreed upon informally or orally (Van den Eeckhout, 2005).

[24] Strikes, the most important instrument of trade unions, remained illegal until 1921, when the article of 24 May 1921 was installed to warrant freedom of coalition.

[25] The few Belgian trade unions which did form were exclusive of nature and focused on limiting labor supply in urban craft industries. Trade unions that were able to successfully mobilize large parts of the labor force would only arise in the last two decades of the century, and would leave their mark on economic policy only during the 20$^{\text{th}}$ century (Vandaele, 2004, 270-271). In his overview work, Chlepner (1972, 27) aptly describes regarding Belgian trade unions in the 19$^{\text{th}}$ century: "it is not necessary to describe at length what does not exist".

the worker *livret*, a sort of worker's passport, which was abolished in 1883. These livrets could in theory be withheld from workers by employers to prevent workers from switching jobs. In practice, however, micro-evidence shows that this requirement did not stop coal workers from being highly mobile among employers. Coal workers were highly mobile: on average, more than half of the Liège-based coal workers changed workplaces 10 to 24 times within their careers (Leboutte, 1988, 49). Furthermore, Belgium's expansive transport network meant that transport costs were low and that the average Belgian worker was also mobile in a geographical sense (Huberman, 2008).

Output per worker and wages

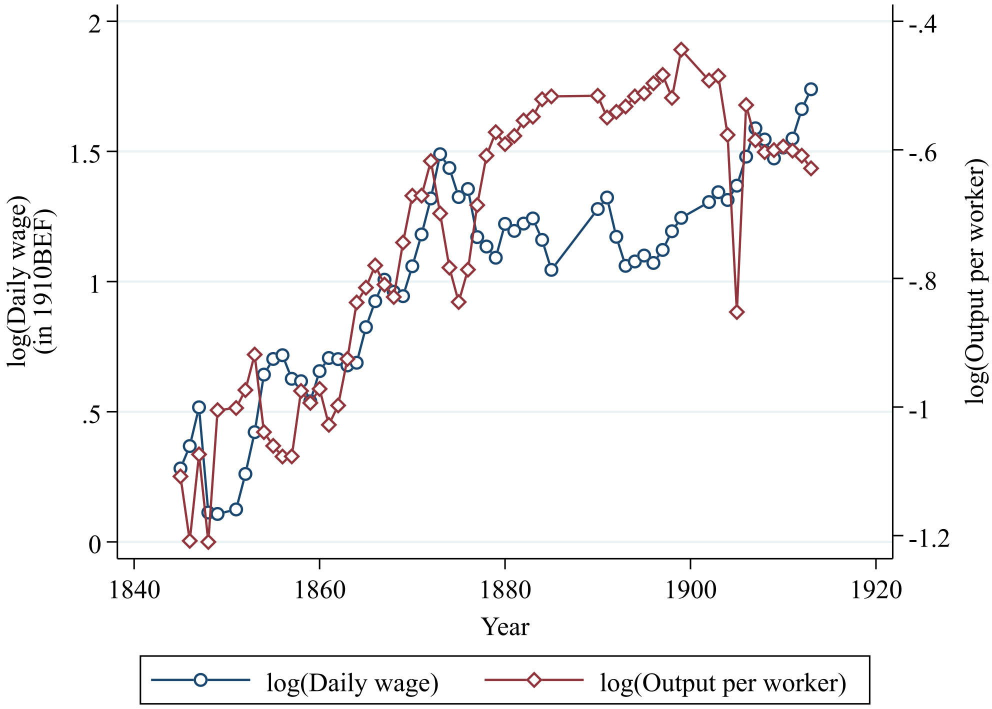
Figure 2a plots the evolution of output per worker and daily wages in the Liège and Namur coal basins during our sample period. From 1845 to 1875, both wages and output per worker grew proportionally. During the late 1870s and 1880s, wage growth stalled despite increasing output per worker. In the late 1890s, wages grew again while output per worker started to fall. These changes can be interpreted in many ways other than monopsony power. Output per worker is not equal to the marginal revenue product of workers because there are more inputs than labor and because product markets might be imperfectly competitive. For instance, capital investment seems important here. The increasing wedge between output per worker and wages during the 1870s coincides with increased capital investment and mechanization during those years, as shown in Figure 1b. Due to these issues, a production model is necessary to correctly identify the wedge between the marginal revenue product of labor and wages. We will lay out this model in Section 3.[26]

Figure 2b plots the median and weighted average cost share over time, defined as labor expenditure over total input expenditure. Until the 1890s, the median cost share of labor was relatively stable, whereas the weighted average cost share grew, indicating reallocation of inputs towards high labor cost share firms. After 1900, both the median and average labor cost share fell. This trend could either indicate technological change or a drop in the relative price of labor compared to the other inputs. We will examine this in the empirical model of Section 3.

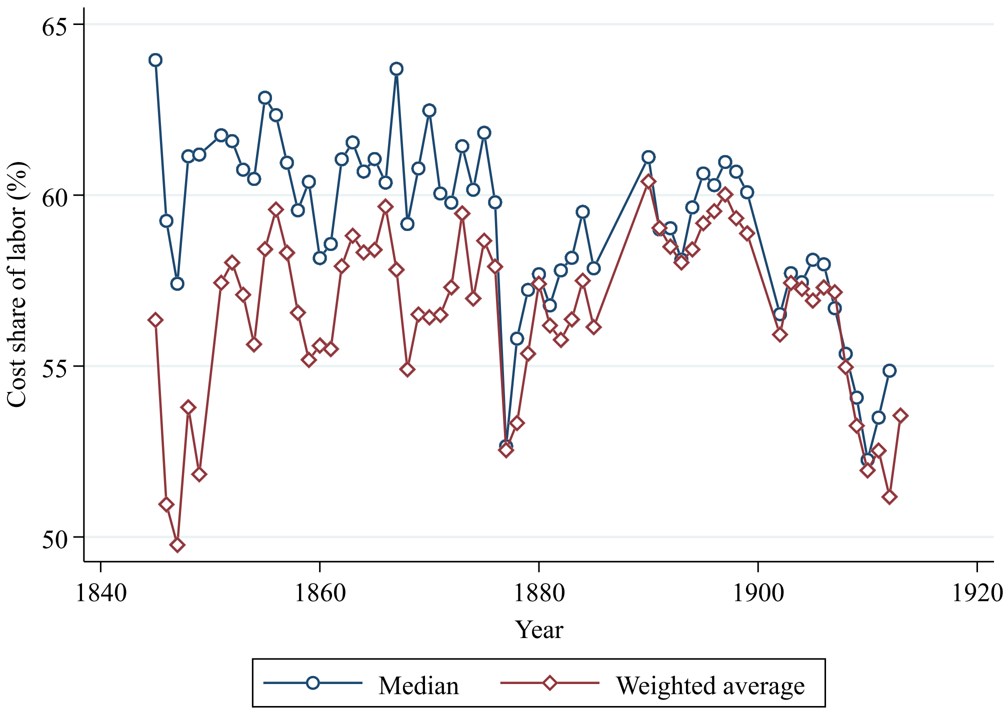
[26] Another reason for this changing wedge could be compensating differentials due to risk premia: we measure the actual wage, not the risk-adjusted wage. We argue that risk premia are not a crucial driver of wage markdowns in our setting in Appendix C.2.

Figure 2: **Output per worker, wages, and cost shares in Liège- and Namur-based coal mining, 1845-1913**

(a) **Output per worker and wages**



(b) **Cost share of labor**



2.3 Collusion

Two types of firm collusion are observed throughout the sample period. First, firms coordinated wages through employers' associations. Second, coal cartels were introduced during the late 1890s, which imposed output quota on cartel participants.

Employers' associations

Similar to worker collusion, employer collusion when setting wages was illegal. However, the law stipulated much harsher punishment for worker collusion, and included a vague and difficult-to-prove condition that employer collusion had to be "unjust" and "abusive" in order to be punishable (Stevens, 1998, 402). Wage collusion between employers was facilitated by employer unions or so-called 'employers' associations', a type of syndicate which was formed in many industries throughout the 19$^{\text{th}}$ century. In the Liège coal mining industry, several mines united in the form of the *Union des charbonnages Liégeois* in 1840, which was publicly registered in 1868 under the name of the *Union des charbonnages, mines et usines métallurgiques de la province de Liège*.[27] 33% of firms in our data set were members of an employers' association, but they produced 80% of output. Many small firms did not join these associations, likely because voting rights were granted based on the number of employees, causing employers' associations to be dominated by the large employers. The official objective of the *Union des charbonnages* was to defend the interests of the local coal and metal industries, and its annual reports reveal its role as a lobby group to fight government intervention in issues such as child labor, female labor, working conditions, and labor unionization (Union des charbonnages (...), 1869–1913).

The Union's committee convened on a monthly basis to discuss current industry developments and to coordinate all kinds of employment decisions (De Leener, 1909, 138). Importantly, the employers' association served to "coordinate salary fluctuations" (De Leener, 1904, 234). This aligns with the general perception of these early employers' associations in the 19$^{\text{th}}$ century as collusive devices (Dubois, 1960, 6-10). The collusion was of informal nature, as the Union did not impose formal quota or

[27]Similar initiatives surfaced in the other Belgian coal *bassins*. The other region in our data set, *Basse-Sambre*, was recognized by more small-scale, family-run firms, lacking formal cohesion. Charleroi's employers' association attempted to gain control over this area, but without widespread success in terms of membership (see Appendix B.2 for more details).

punish deviant behavior. In Mons, coal firm unions suspected that authorities would never bother to enforce the aforementioned regulation against labor coalitions, but stuck to oral agreements as to not warn authorities of their labor coalition violations (Lefèvre, 2004). Some clear-cut cases of collusive wage-setting in Belgian coal mining are known, however, as managers of Hainaut-based coal firms controlled by the universal bank *Société Générale de Belgique* openly compared the wages paid at their respective firms, and deviations from collusive wage levels were heavily frowned upon.[28] This anecdotal evidence indicates that multilateral wage agreements among 19$^{\text{th}}$-century employers were rife, and suggests that this collusive wage-setting behavior happened through employers' associations.

Coal cartels

As in many other industrializing countries, Belgian industries saw a strong increase in the number of cartels from the 1870s onwards. The number of official cartels in Belgium, which were legal and incorporated as firms, increased from 5 to 80 between 1880 and 1910. The coal industry was no exception: on July 1, 1897, 27 coal firms in Liège entered a cartel, the *Syndicat de Charbonnages Liégeois*. The *Syndicat* was set up as a *Société Anononyme* (SA), in which the partaking firms committed to waiving the vending rights of their production to the cartel. The directors of the coal firms assembled at least twelve times a year, and convened at the demand of a democratic majority; voting rights were determined according to each firm's output. The amount of coal sold was determined and constrained by a collectively decided quota in terms of tonnage. In practice, the individual coal firms remained responsible for their own customer relationships.[29] Cartel firms who sold more than the agreed upon quantity were fined 50 BEF per excess ton (compared to an average price of 9.7 BEF per ton in 1898), while other violations of the cartel statutes were fined 1000 BEF. In this framework, the cartel sold between 75 and 80% of total sales in the Liège *bassin*,

[28] The minutes of their monthly meetings can still be consulted (Mottequin, 1973). Comparative tables of the wages paid at the respective firms were presented and discussed. For instance, at the meeting of 23 February 1863, one of the managers had to defend the elevated wage levels at his firm by pointing to the difficult geological conditions of his exploitation (Mottequin, 1973, 367). It is important to emphasize that such inter-firm capital connections played a less important role in Liège and Namur (Kurgan-van Hentenryk & Puissant, 1990, 206-207). We return to this issue in Appendix B.1.

[29] This is in contrast to some other coal cartels from that era, where all sales activities were collectivized.

with the remainder being taken up by the dissenters. Although the *Syndicat* did not impose any quota on employment or other input expenditures, reduced output also led to reduced employment, as we will show later on. The cartel agreement was binding for a period of 5 years, and was renewed until 1935, when it was replaced by a national coal cartel, the *Office National des Charbons* (Vanthemsche, 1983).

The effect of this cartel can be clearly seen by comparing the Liège coal price to import price of coal in Belgium.[30] We plot this import price in Figure 3. Up to 1897, the Liège coal price was below the import price, as this import price includes transportation costs to the Belgian border. It was hence cheaper for Liège coal consumers, such as steel plants, to buy Liège coal over international coal. Following the cartel introduction in 1897, the Liège coal price increased up to the level of imported coal.[31] The cartel also seems to have had implications on the cost share of labor: as was shown in Figure 2b, the cost share of labor dropped after 1897, indicating that the cartel could have had labor market implications as well. We will examine this hypothesis in the empirical model.

2.4 Data

Annual inspection reports

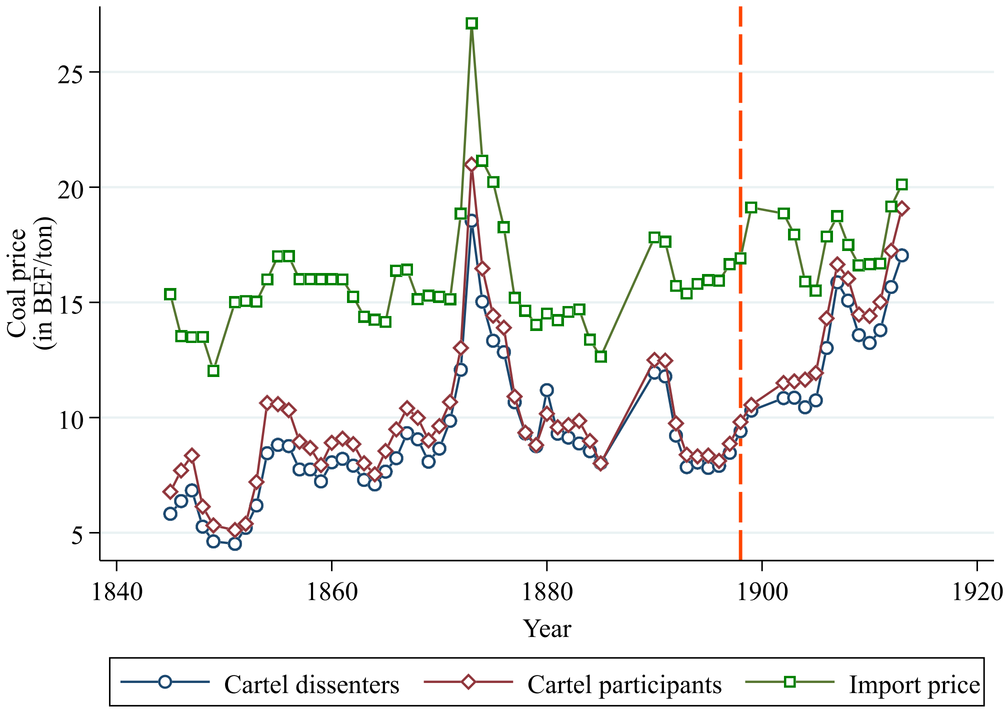
Our main data source is a novel data set which collects annual reports by the *Administration des Mines*, a state agency that employed engineers to annually inspect coal mines.[32] We refer to Appendix B for all details concerning the data collection and processing. The *Administration* data comes at the level of mining concessions, in which the state grants permission to a person or firm to mine its natural resources. Concessions can be composed of multiple mines (production units). In theory, the same individual or firm could operate multiple concessions simultaneously, but in practice, however, this almost never happened in the Liège and Namur *bassins* as firms who owned multiple concessions immediately merged these into a single concession. Hence, we can assume that the concession-level unit of observation in the data corresponds

[30]This import price is computed as total value of imported coal at the border divided by imported quantity of coal; it hence includes transport costs from foreign mines to the border.

[31]A cartel would not price above this import price, as this would lead to massive substitution towards imported coal.

[32]More historical background on this agency and the reports is in Appendix B.1.

Figure 3: **Prices and the Liège coal cartel, 1845-1913**



Notes: The dashed vertical line represent the start of the coal cartel, the *Syndicat de Charbonnages Liégeois.*

to mutually independent firms.[33]

For the 227 firms in our data set, we observe annual coal extraction in tons by type of coal, and coal prices at the mine gate. Employment is reported in numbers of workers and in days, with a distinction between underground and surface workers.[34] Gross and net wages by worker category are also recorded.[35] The data reports expenditure on, literally, 'non-labor ordinary expenses' and 'extraordinary expenses'. The latter category includes all expenses that involve 'mine construction, mine transformation and other expansion costs' (Wibail, 1934). Hence, we consider the former to be intermediate input expenditure and the latter to be fixed capital investment.[36] Besides capital investment, we also observe the total horsepower of the various machine types used per firm, up to 1899. We use these different capital measures to construct the capital stock using a perpetual inventory method, as explained in detail

[33]We motivate this assumption in depth in Appendix B.1.

[34]For some years, especially the earlier and later periods, the counts also differentiate workers based on their age and gender.

[35]For the earlier periods, the distinction between gross and net wages (typically due to participation in insurance schemes) was irrelevant.

[36]Further information on the construction of the cost variables can be found in Appendix B.1.

in Appendix B.3.

Additional data sets

We complement the inspection reports with various other data sources.[37] We obtain yearly information on each firm's membership of an employers' association by digitizing the monthly *Bulletin* of the *Union des Charbonnages, Mines et Usines Métallurgiques de la Province de Liège*, for the Liège basin, and of the *Association Charbonnière et l'industrie houillière des bassins de Charleroi et de la Basse-Sambre*, for the Namur basin. We also observe membership in coal cartels using the cartel lists from De Leener (1904). Furthermore, we link the municipalities in which the firms are located to data on opening dates of railroad and tramway stations. Hence, we know for every firm in every year whether it was connected to the railroad and tramway networks, or not. Finally, we use the Consumer Price Index (CPI) of Segers (2003) and the extension thereof to 1845 using Scholliers' index (1995) to deflate all monetary variables in the data set.

3 Quantifying wage markdowns

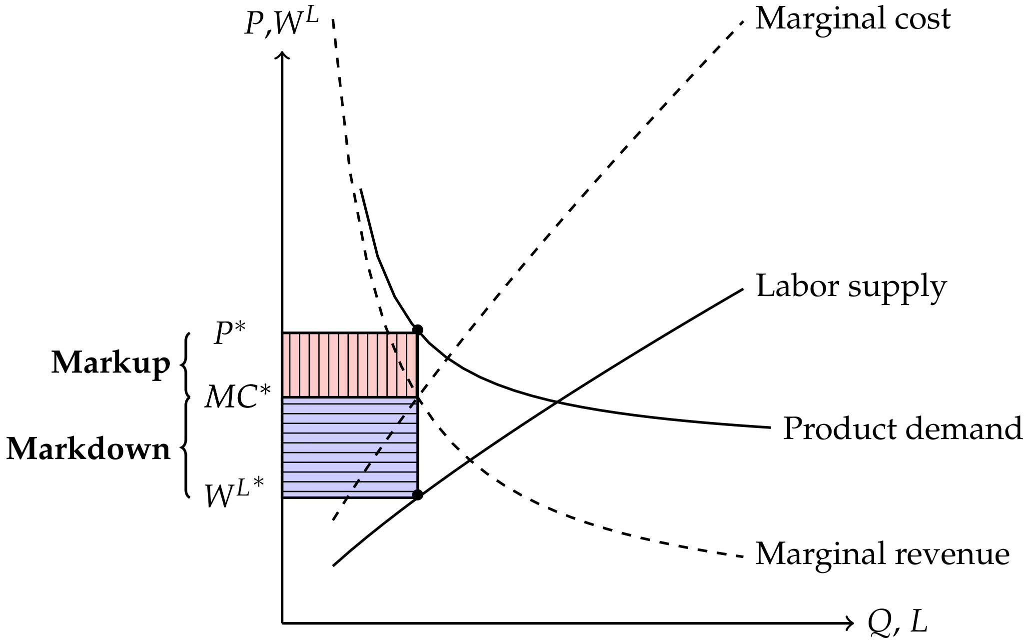
In this section, we estimate the wedge between the marginal revenue product of labor and their wage, the 'wage markdown'. If a firm possesses monopsony power over workers, this should result in a markdown wedge. In the next section, we will examine the extent to which collusive-wage setting contributed to the level and evolution of this wage markdown. The empirical challenge of estimating input markdowns is illustrated in Figure 4. Just like the remainder of this paper, our exposition will focus on labor input and wage markdowns, but we emphasize that our empirical approach can be applied to other inputs and markdowns as well.

Consider a firm that faces an upward-sloping labor supply curve and a downward-sloping product demand curve. If the firm is profit-maximizing, or cost-minimizing, it will choose its labor quantity, and all other input quantities, in order to equate the marginal cost and revenue of each input. This results in the product price P to be marked up above marginal costs, and the wage W^L to be marked down below the

[37] More information on the construction of these variables is provided in Appendix B.2.

marginal revenue product of labor. The key empirical challenge is that even if output and input prices may be observed, marginal revenue products are latent. Simply comparing the revenue per worker to the wage per worker does not uncover the wage markdown because first, there are usually multiple inputs, and second, output prices are endogenous to firm size if there is imperfect competition downstream.

Figure 4: **Markups, markdowns and market power**



3.1 Model

Production model

Output Q_{ft} indicates the tonnage of coal extracted during a given year by firm f, and P_{ft} is the mine-gate coal price per ton. Given that there is limited differentiation in coal quality, we assume coal to be a homogeneous product. Although there is some differentiation in terms of coal quality, we sum the output of coal across qualities, because quality depends on exogenous geological conditions, and does not affect the production function.[38] To verify this assertion, we regress the estimated TFP residual on the share of high-quality coal, and obtain an R^2 below 10^{-5}.

[38]Quality differences are mainly due to variation in caloric content. We observe the breakdown of coal output into three quality categories but aggregate to a single product by summing physical output.

Firms use two variable inputs: labor L_{ft}, which is measured as the average number of miners employed throughout the year, and the amount of intermediate inputs purchased, M_{ft}. The capital stock consists of steam engines used for water pumping, coal hauling, and ventilation. The value of total capital used at each mine is denoted K_{ft}. Logarithms of variables are denoted in lowercases. As our baseline specification, we assume a Cobb-Douglas production function in materials, labor, and capital, as given by Equation (1).

$$q_{ft} = \beta^l l_{ft} + \beta^m m_{ft} + \beta^k k_{ft} + \omega_{ft} \tag{1}$$

The Cobb-Douglas specification implies that it is possible to substitute between the different inputs. In case of the materials and labor inputs, this can be straightforwardly illustrated with the example of mine tunnel excavation, an important activity in 19$^{\text{th}}$-century coal production. One can choose to use manual labor to dig these tunnels; an alternative, however, is to use explosives to open up new areas for coal extraction. We define the output elasticities of labor and materials as $\theta^l_{ft} \equiv \frac{\partial Q_{ft}}{\partial L_{ft}} \frac{L_{ft}}{Q_{ft}}$ and $\theta^m_{ft} \equiv \frac{\partial Q_{ft}}{\partial M_{ft}} \frac{M_{ft}}{Q_{ft}}$. In the baseline Cobb-Douglas model of Equation (1), the output elasticities are constant, $\theta^l_{ft} = \beta^l$. In Appendix C.1, we extend to a more flexible functional form by estimating a translog production function.

Total factor productivity is denoted ω_{ft}. We assume that the total factor productivity transition is given by the first-order Markov process in Equation (2), with an unexpected productivity shock υ_{ft}.

$$\omega_{ft} = h(\omega_{ft-1}) + \upsilon_{ft} \tag{2}$$

The main benefits of this Markov process relate to the identification of the production function, as will be explained later. Of course, there are also costs to this approach: we rule out richer productivity processes that arise due to cost dynamics. We defend this assumption in Appendix C.1. Second, by specifying a Hicks-neutral production function, we rule out factor-biased technological change. We defend this assumption in our setting using detailed technology data in Section 5.

We assume that both labor and intermediate inputs are variable and static inputs, meaning that they are not subject to adjustment frictions and only affect current profits. Capital is, in contrast, assumed to be a dynamic and fixed input: we assume capital investment is chosen one period in advance, and affects both current and future profits, as capital does not depreciate immediately. We defend these timing assumptions in Section 5, by looking at the impulse-response functions of the different inputs after the coal demand shock of 1871.

Labor and intermediate input supply

Firms face a labor supply function with an inverse firm-level elasticity of $\psi^l_{ft} \equiv \frac{\partial W^l_{ft}}{\partial L_{ft}} \frac{L_{ft}}{W^l_{ft}}$. If firms are wage takers on the labor market, this implies that $\psi^l_{ft} = 0$, whereas labor market power implies $\psi^l_{ft} > 0$. We assume that firms are price-takers on their intermediate input markets, meaning that $\psi^m_{ft} \equiv \frac{\partial W^m_{ft}}{\partial M_{ft}} \frac{M_{ft}}{W^m_{ft}} = 0$. The Belgian coal industry was well integrated in the manufacturing sector and had to compete with other industrial sectors for material inputs such as tools, explosives and black powder, so it seems reasonable to assume that these input markets were indeed competitive. To corroborate this assumption, we collected monthly prices for *pétroleum* (lamp oil), an important intermediate input in underground coal mining. Lamp oil was chosen because of data availability reasons, as well as its homogeneity allowing for straightforward regional comparison. This exercise resulted in a panel data set, which covers all major urban and industrial centers in Belgium for the period 1896 to 1913.[39] As shown in Figure A5 in Appendix A.1, we find little regional variation in the prices of this input, both within mining areas (such as between Mons, in the west, and Liège, in the east), and across mining and non-mining centers (such as Bruges, Brussels and Ghent). This underlines that Belgian markets for industrial inputs were well integrated and supports our assumption of exogenous intermediate input prices.

Firm behavior

The 'production approach' to markups of De Loecker and Warzynski (2012) assumes that firms choose variable inputs to minimize their own current variable costs. However, collusion between firms implies cooperative input decisions. To allow for the

[39]This database is built on retail prices, collected by the Belgian labor inspection services. Few wholesale prices survived for 19$^{\text{th}}$-century Belgium, and reconstructions are mostly based on nationally aggregated trade statistics (such as in Loots, 1936). Regional prices for earlier periods are even more scarcely available. For more information on the source, we refer to Figure A5.

possibility of collusion, we formulate the cost minimization problem in Equation (3). Firms choose variable inputs in order to minimize a joint cost function, with collusion weights λ_{fgt} between firm f and each other firm g within the same input market $i(f)$, with the set of firms in market i being denoted $\mathcal{F}_{i(f)t}$. This is the cost minimization equivalent of the objective functions in empirical collusion models such as Bresnahan (1987). The shadow value parameter κ_{ft} captures the marginal cost of increasing output by one unit at firm f.

$$\min_{L_{ft},M_{ft}} \Big(\sum_{g\in\mathcal{F}_{i(f)t}} \big(\lambda_{fgt}(L_{gt}W^L_{gt} + M_{gt}W^M_{gt})\big) - \kappa_{ft}\big(Q_{ft} - Q(L_{ft}, M_{ft}, K_{ft}, \Omega_{ft}; \boldsymbol{\beta})\big)\Big) \quad (3)$$

with $\lambda_{fgt} = 1$ if $f = g$, and $0 \leq \lambda_{fgt} \leq 1$ if $f \neq g$. The collusion weights λ_{fgt} indicate the extent to which firms internalize only their own costs when choosing inputs, or also the costs of their competitors. If firms choose variable inputs to minimize only their own costs, this implies that the matrix of λ_{fgt} weights, Λ_t is the identity matrix, in which case our model collapses to the one in De Loecker and Warzynski (2012). If firms are perfectly colluding, they are choosing inputs to minimize joint costs, as if they would be a single firm, and Λ_t becomes a matrix of ones. This general formulation nests different kinds of collusive practices. Both if firms would agree to a non-poaching agreement, and if they would outright collude on their employment quantities (or wages), this is captured by the collusion parameter λ_{fgt}. Note that collusion on output quantities or prices is also picked up in terms of the collusion parameter λ_{fgt}: firms do not internalize each other's revenues and costs differently.[40]

Timing of choices

In accordance with the assumptions made above, the timing of choices is as follows. At time $t-1$, prior to observing productivity shocks ν_{ft}, firms choose their capital investment and their collusion weights λ_{fgt}.[41] At time t, after the productivity shock materializes, they choose labor and intermediate inputs.

[40] In theory, one could distinguish different collusion weights on competitor sales and costs, but in order to separately identify these, one would need to impose both a model of competition downstream and upstream, whereas we only do the latter.

[41] We do not formally model the underlying collusion decisions, which must be a dynamic optimization problem.

Price markups and wage markdowns

As in De Loecker and Warzynski (2012), the markup μ_{ft} is the ratio of the output price P_{ft} over marginal costs κ_{ft}: $\mu_{ft} \equiv \frac{P_{ft}}{\kappa_{ft}}$. We denote the revenue share of labor as $\alpha^l_{ft} \equiv \frac{L_{ft}W^l_{ft}}{P_{ft}Q_{ft}}$, and similarly the revenue share of materials as α^m_{ft}. The first-order conditions for labor and materials imply the following system of markup equations:

$$\mu_{ft} = \frac{\theta^m_{ft}}{\alpha^m_{ft}} \tag{4a}$$

$$\mu_{ft} = \frac{\theta^l_{ft}}{\alpha^l_{ft}(1+\psi^l_{ft}+\sum_{g\in\mathcal{F}_{i(f)t}\setminus f}\lambda_{fgt}(\psi^l_{fgt}\frac{L_{gt}W^l_{gt}}{L_{ft}W^l_{ft}}))} \tag{4b}$$

with the cross-wage elasticities being $\psi^l_{fgt} \equiv \frac{\partial W^l_{gt}}{\partial L_{ft}}\frac{L_{ft}}{W^l_{gt}}$.

Similarly to Mertens (2020); Morlacco (2020); Brooks et al. (2021), but now allowing for collusion, we divide the markup derived from labor by the markup derived from intermediate inputs to obtain the wage *markdown* expression in Equation (5):

$$\mu^l_{ft} \equiv \frac{\theta^l_{ft}W^m_{ft}M_{ft}}{\theta^m_{ft}W^l_{ft}L_{ft}} = 1+\psi^l_{ft}+\sum_{g\in\mathcal{F}_{i(f)t}\setminus f}(\lambda_{fgt}\psi^l_{fgt}\frac{L_{gt}W^l_{gt}}{L_{ft}W^l_{ft}}) \tag{5}$$

The left-hand side of Equation (5), μ^l_{ft} is known up to the production function parameters. It can be intepreted as a 'wage markdown'. As shown in Appendix D, this variable is equal to the ratio of the marginal (joint) revenue product of labor at firm f, $MRPL_{ft}$, over the wage at firm f:

$$\mu^l_{ft} = \frac{MRPL_{ft}}{W^l_{ft}}$$

As motivated at the start of this section, the markdown variable μ^l_{ft} will be the main object of interest in the empirical analysis: in perfect competition, wages are equal to marginal revenue products, so $\mu^l_{ft} = 1$. In the absence of collusion, the wage markdown is equal to one plus the inverse *firm*-level elasticity of labor supply: $\mu^l_{ft} = 1+\psi^l_{ft}$. In case of full collusion, the wage markdown is equal to one plus the inverse *market*-level elasticity of labor supply: $\mu^l_{ft} = 1+\psi^l_{ft}+\sum_{g\in\mathcal{F}_{i(f)t}\setminus f}\psi^l_{fgt}\frac{L_{gt}W^l_{gt}}{L_{ft}W^l_{ft}}$.

In the remainder of this section, we will estimate the wage markdowns μ^l_{ft} under the observed conduct Λ_t. In the next section, we will infer the underlying conduct parameters Λ_t by comparing the observed wage markdowns to the firm- and market-level labor supply elasticities.

3.2 Identification and estimation

Identification

In order to identify the production function, we combine timing assumptions on firms' input choices, as proposed by Olley and Pakes (1996), with a labor supply shifter. As labor and materials were assumed to be static and variable inputs, they are chosen after the productivity shock υ_{ft} is observed by the firm, at time t, while capital is fixed and dynamic, so investment is chosen before the productivity shock is observed, at time $t-1$. Second, we rely on agricultural wage shocks as an additional instrument. It is a well-established fact in Belgian economic history that the Walloon coal belt attracted a large surplus of agricultural labor, predominantly from Flanders, the northern area of Belgium (Segers, 2003, 334; Buyst, forthcoming, 23). Negative shocks to agricultural wages hence should have acted as positive labor supply shocks to coal mines. We include lagged agricultural wages in Belgium, as measured by Segers (2003, 622-623), in the instruments vector. The assumption here is that changes in agricultural wages in the previous year, w_{t-1}^{agri} affected labor supply to the mines, but did not affect coal mining productivity directly. In Appendix Table A1 in Appendix A.2, we provide evidence on the first stage by regressing the annual change in log total mining employment in the Liège and Namur coal basin on the annual change in log agricultural wages in Belgium. Negative agricultural wage shocks indeed increase the growth of coal mining employment.[42]

Following these assumptions, we can now write the moment conditions to estimate the mining production function as:

$$\mathbb{E}\Big[\upsilon_{ft}|(l_{fr-1}, m_{fr-1}, k_{fr}, w_{r-1}^{agri}\Big]_{r\in[2,\ldots,t]} = 0 \tag{6}$$

The usual approach in the literature is to invert the intermediate input demand

[42] We include lagged agricultural wages, rather than current wages, because current agricultural wages could be influenced by current mining employment choices through general equilibrium, which would violate the timing assumptions imposed on the input choice problem.

function to recover the latent productivity level ω_{ft}, which can be used to construct the productivity shock υ_{ft} using the productivity law of motion (Olley & Pakes, 1996; Levinsohn & Petrin, 2003; Ackerberg, Caves, & Frazer, 2015). This approach hinges on productivity being the only latent, serially correlated input demand shifter. However, input demand varies due to markup and markdown variation as well. The approach with input inversion can still be used when making additional parametric assumptions about the distribution of markups and markdowns. Another possibility is to impose more structure on the productivity transition process. Following Blundell and Bond (2000), the productivity transition (2) can be rewritten as an AR(1) process with serial correlation ρ, Equation (7). By taking ρ differences of Equation (7), one can express the productivity shock υ_{ft} as a function of estimable coefficients without having to invert the input demand function.

$$\omega_{ft} = \rho\omega_{ft-1} + \upsilon_{ft} \tag{7}$$

We pursue this approach as it allows us not to impose additional structure on the distribution of markups and markdowns across firms and over time. This comes at the cost of not allowing entry and exit of mines to be endogenous to their productivity level, contrary to Olley and Pakes (1996). However, as is often noted in the literature, our use of an unbalanced panel, in which we do not select negatively on market exit, already alleviates most concerns of selection bias.[43]

Estimation

Rewriting the moment conditions from Equation (6), and only using the lags up to one year, the moment conditions are given by Equation (8).[44]

$$\mathbb{E}\Big[q_{ft} - \rho q_{ft-1} - \beta^0(1-\rho) - \beta^l(l_{ft} - \rho l_{ft-1}) - \beta^m(m_{ft} - \rho m_{ft-1}) - \beta^k(k_{ft} - \rho k_{ft-1}) \\ |(l_{ft-1}, m_{ft-1}, k_{ft}, k_{ft-1}, w_t^{agri})\Big] = 0 \tag{8}$$

As the estimation procedure requires lagged variables to be observed, we can estimate the model only on years for which the prior year is included in the data

[43]See Olley and Pakes (1996) and De Loecker, Goldberg, Khandelwal, and Pavcnik (2016).

[44]In theory, one could use more lags, but this further reduces the data set, which is already small.

set as well, which reduces the sample size to 4003 observations. This also excludes firms that do not use capital or intermediate inputs, as logarithms are taken. Labor is measured as the number of workers times the number of days worked. Materials are measured using the 'ordinary expenses' variable, which is reported in the data. Capital is constructed by using the perpetual inventory method on the 'extraordinary expenses' category, which we describe more in detail in Appendix B.3. We block-bootstrap the estimation procedure, taking draws by replacement within mines over time. We use 200 bootstrap draws. We sequentially estimate (i) the production function, (ii) markdowns and markups, and (iii) regressions of markdowns and/or markups on other variables within the same bootstrap iteration, in all the regressions that follow.

3.3 Wage markdowns: level and evolution

Production function estimates

The production function estimates are in Table 1a. The first column reports the OLS estimates, as a comparison, whereas the second column reports the GMM estimates, which are used in the remainder of the paper. The output elasticity of labor is estimated to be 0.697, whereas the output elasticity of materials is estimated at 0.225. These estimates confirm the historical record that Belgian coal mining was indeed very labor-intensive. The capital coefficient is 0.151. As is usually the case, OLS overestimates the output elasticity of labor but underestimates the output elasticity of capital. As was explained in Section 2, capital investment in Liège mines was mainly limited to mining locomotives and lifts, ventilation fans, and water pumps. Ventilation fans and water pumps are safety investments, which can be seen as a sunk cost to operate the mine, but do not affect labor productivity. Mining locomotives, however, increased productivity, as documented for U.S. mines in Rubens (forthcoming). Finally, cutting machines, which were unskill-biased and TFP-augmenting,[45] were barely adopted in the mines in our dataset due to too narrow coal veins, as was explained earlier.

[45]This is documented for U.S. coal mines in Rubens (2022)

Table 1: **Production model estimates**

(a) Production function		OLS		GMM	
		Est.	SE	Est.	SE
log(Labor)	β^l	0.795	0.034	0.697	0.330
log(Materials)	β^m	0.275	0.029	0.225	0.137
log(Capital)	β^k	-0.008	0.140	0.151	0.074
R-squared		.941		.938	
Observations		4476		3999	

(b) Markdowns/markups	Wage markdown		Price markup	
	Est.	SE	Est.	SE
Median	1.651	0.448	0.724	0.492
Average	1.796	0.487	0.775	0.530
Weighted average	1.771	0.581	0.736	0.541

Notes: Block-bootstrapped standard errors (SE), 200 iterations.

Wage markdown and price markup levels

Using the production function coefficients, we estimate coal price markups and wage markdowns following Equations (4) and (5). The estimated moments are in Table 1b. At the median firm, the wage markdown is 1.651, which implies that worker wages are 40% below their marginal revenue product. The average markdown is 1.771 when weighting by employment usage, and 1.796 when taking the unweighted average. Although the median, average, and weighted average wage markdown was not significantly different from one over the entire time period, there is an important fraction of firms and time periods for which markdowns are significantly above one, which implies the exertion of oligopsony power. We will assess drivers of this markdown heterogeneity across firms and time further below.

In contrast to wage markdowns, the coal price markup was low and close to one: the price markup was at the median firm 0.724, on average 0.775, and weighted by employment usage 0.736. Hence, coal prices lay below marginal costs, which does not imply that firms were loss-making, as the total profit margin is the combined wage markdown and price markup. The markup being close to one implies that coal mines had little market power downstream. This is no surprise, given that the relevant coal market size was much larger than Liège and Namur. Figure 3 showed that the coal price in Liège and Namur followed the international coal price up to 1897, which indicates that the firms in our data set were price takers on the coal market. Our markup estimates are also in line with recent historical research that has highlighted the increasingly integrated nature of the European coal market throughout the 19$^{\text{th}}$ century (Murray & Silvestre, 2020).

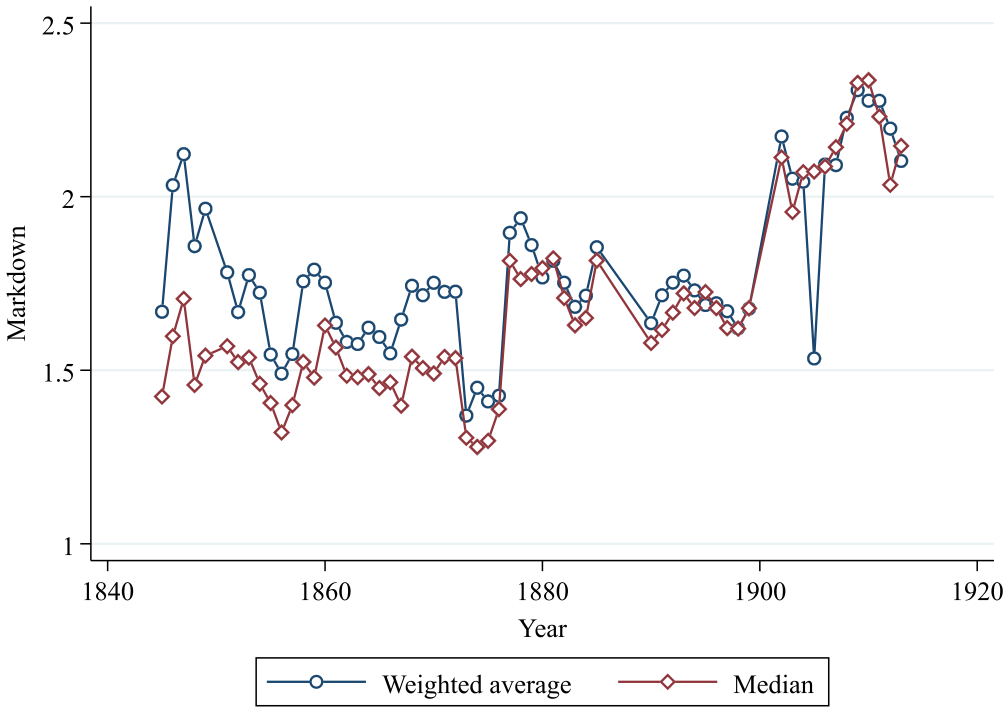
These results suggest that coal firms mainly derived profits from market power on their labor markets, rather than on the coal market. Still, equilibrium markdowns above one do not necessarily imply collusion: they could be due to non-collusive oligopsony power or to other labor market imperfections. We will unpack the effects of collusion on wage markdowns in the next section.

Wage markdown evolution

Figure 5 plots the evolution of wage markdowns in all coal mines in Namur and Liège provinces between 1845 and 1913. Up to the 1870s, the median firm had a wage markdown of around 1.5, which implies that workers received around two thirds of their marginal revenue product. This markdown was relatively stable throughout the 1840s, 1850s, and 1860s. The weighted average markdown was higher, around 1.75, which means that larger firms could charge higher wage markdowns. During the late 1870s and 1880s, a long period of recession, median wage markdowns jumped to around 1.7. Despite short-run fluctuations, markdowns usually reverted to their long-term means within 4 to 5 years.

Around 1900, there was a sharp increase in wage markdowns, both on average and at the median firm. The average markdown after 1897 was around 2.2, meaning that workers received less than 50% of their marginal revenue product. This markdown increase was persistent: there was no reversion to the pre-1897 steady-state level. The estimates in Table 2 show that the increase in the wage markdown after 1897 was statistically significant. The markdown increase after 1897 does not reflect reallocation between firms but was the result of within-firm markdown growth. Figure A6 in Appendix A.2 compared the unweighted average wage markdown to the weighted

Figure 5: **Evolution of the average and median wage markdown, 1845-1913**



Notes: This graph shows the evolution of the weighted average (by employment) and median wage markdown in Liège and Namur coal mines from 1845-1913.

average wage markdown, by employment usage. The unweighted average markdown grew by even more after 1897, which indicates that there was some reallocation away from the highest-markdown firms after 1897.

What could explain the variation in markdowns across firms? Section 2.3 highlighted two key drivers. First, there was the pervasive nature of employers' associations throughout the 19$^{\text{th}}$ century. Based on internal communication by the *Union*, we created a time-invariant variable indicating the *Union* membership of each firm. A second big shift in the competitive environment of both coal and labor markets happened in 1897, when the coal cartel *Syndicat des Charbonnages Liégeois* was set up. The cartel statutes reveal which firms were part of said cartel.[46]

When comparing markdowns across firms, the estimates in the first column of Table 2 show that markdowns were 11% higher among employers' association members. This confirms anecdotal evidence of wage-fixing through these employers' associations. Markdowns were also around 8% higher for members of the coal cartel, but given that the membership of the cartel and the employers' associations overlap, there is a

[46]For more information on the firm-level membership data, we refer to Appendix B.2.

concern of multicollinearity here. Also, comparing markdowns at cartel and non-cartel members does not reveal the true effect of the cartel on wage markdowns, for reasons we will explain in Section 4.

Table 2: **Markdowns: correlations and evolution**

(a) Markdown correlations	log(Markdown)		log(Markdown)	
	Est.	SE	Est.	SE
1(Employers' Association)	0.106	0.053		
1(Cartel)	0.078	0.040		
1(1855<Year<1865)			-0.021	0.038
1(1865<Year<1875)			-0.020	0.038
1(1875<Year<1885)			0.058	0.044
1(1885<Year<1895)			0.107	0.046
1(1895<Year<1905)			0.196	0.042
1(1905<Year<1915)			0.421	0.044
Year FE	Yes		No	
R-squared	.146		.076	
Observations	4156		4699	

(b) Employers' assoc.: pre- vs. post-cartel	log(Markdown)		log(Markdown)	
	Est.	SE	Est.	SE
1(Employers' Association)	0.111	0.041	-0.039	0.092
Time period	1845-1897		1898-1913	
R-squared	.087		.140	
Observations	3464		708	

Notes: Reference category is the period between 1845-1859. Block-bootstrapped standard errors (SE), 200 iterations.

In Table 2b, we compare the correlation between wage markdowns and employers' association membership between two time periods: the pre- and the post-cartel period. The difference in wage markdowns between employers' association members and non-members that existed prior to 1897 entirely disappears after the introduction of the cartel in 1897. This suggests that the informal wage collusion that took place in employers' associations, which was not legally binding, was replaced as a driver of wage markdowns by the formal collusion through the coal cartel. Although the cartel restricted output, whereas employers' associations targeted wages, reducing output results in a negative labor demand shift, which also leads to a wage reduction. We will formalize this intuition in the collusion model of the next section.

4 Employer collusion

The previous section documented an increase in wage markdowns in the Belgian coal industry, especially after the turn of the century. In this section, we quantify the degree of collusion between mining firms, and examine the extent to which this affected wage markdowns.

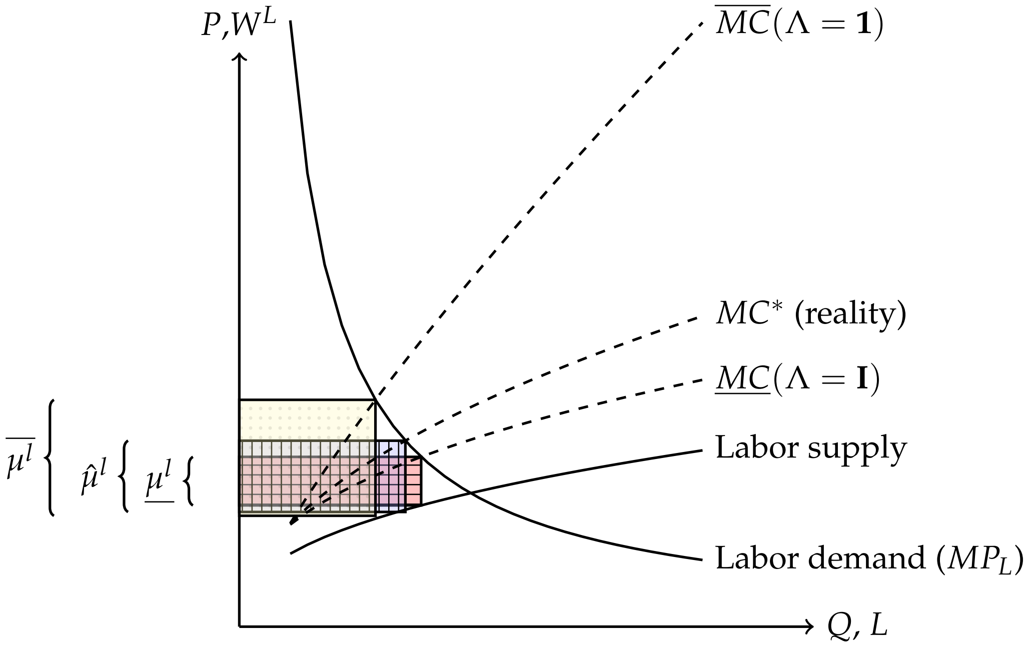
4.1 Identifying employer collusion

Intuition

Figure 4 graphically showed the distinction between input price markdowns and product price markups. The markdown estimates from the previous section recovered the actual wage markdowns charged in the market, without imposing conduct assumptions on the labor market. The objective of this section is to examine the extent to which wage markdowns are driven by collusive behavior.

Figure 6 visually explains the intuition for our conduct identification approach. As becomes clear from Equation (3), different collusion weights imply different marginal cost curves. Under no collusion, the marginal cost curve of a firm only contains its own wage, whereas under collusion it also includes the wages paid by its competitors. The estimated markdown under the production-cost model is $\hat{\mu}^l$. In order to quantify the extent of labor market collusion, we need to benchmark this markdown against the lower bound of the markdown under zero collusion, $\underline{\mu}^l$, and the upper bound under full collusion $\overline{\mu}^l$. The upper bound implies that the collusion matrix Λ is a matrix of ones, $\Lambda = \mathbf{1}$: $\lambda_{fgt} = 1, \forall g \neq f$. The lower bound corresponds to a unity matrix $\Lambda = \boldsymbol{I}$: $\lambda_{fgt} = 0, \forall g \neq f$.

Figure 6: **Markdowns and labor market conduct**



Labor supply model

In order to identify the non-collusive and fully collusive markdown bounds, we need to impose a labor supply model. We rely on a static homogeneous firms Cournot model to benchmark our estimated markdowns against. The main reason to model firms as not being differentiated is that there is very limited wage variation across firms within towns. Firm and year fixed effects together explain 93% of wage variation, whereas municipality and year fixed effects explain 92% of wage variation. If firms would be differentiated in terms of non-wage amenities, this should translate into within-market wage differences.[47] That being said, we want to emphasize that this does not reduce the broader applicability of our approach: for labor markets in which employer differentiation is important, the benchmark model against which the markdown estimates from the production model are compared should just be adapted to allow for such

[47]Although a model of monopsonistic competition with amenities, such as a CES model, could result in homogeneous markdowns even with differentiation, this would still lead to wage heterogeneity due to differences in marginal labor products across firms.

differentiation.[48] Similarly, other sources of imperfect labor market competition, such as search costs, could be incorporated in the benchmark model.

We assume a log-linear labor supply curve with inverse market-level elasticity Ψ^l, as shown in Equation (9). Wages W^l_{it} are the same for all firms within a labor market i in each year t. Market-level employment is denoted L_{it}, and a market-specific residual ν_{it} reflects variation in the relative attractiveness of different labor markets, for instance due to variation in outside options available to workers. The upward slope of the market-level labor supply curve can have different sources. Even if local labor markets would be non-frictional, heterogeneity in reservation wages across workers, for instance due to different outside options, would lead to an upward-sloping aggregate labor supply curve.

$$W^l_{it} = L_{it}^{\Psi^l} \nu_{it} \tag{9}$$

In the absence of collusion, each firm chooses the employment level that minimizes its own current variable costs. Working out the first order conditions of this problem delivers the following markdown expression. The wage markdown under no collusion, $\underline{\mu}^l_{ft}$, is equal to the inverse labor supply elasticity at the market level, $\Psi^l \equiv \frac{\partial W^l_{it}}{\partial L_{it}} \frac{L_{it}}{W^l_{it}}$ multiplied by the labor market share s^l_{ft}, plus one. This mirrors the Cournot markup in imperfectly competitive homogeneous goods markets. The firm-level residual labor supply curve is still upward-sloping because firms partly internalize the upward slope of the market-level labor supply curve.

$$\underline{\mu}^l_{ft} = 1 + \Psi^l s^l_{ft}$$

In the other extreme, denote the markdown level in the presence of full wage collusion as $\overline{\mu}^l_{ft}$. In a fully collusive market, firms behave as joint cost minimizers, which implies that their labor market share becomes one. Accordingly, the upper bound for the markdown under full collusion in the Cournot model becomes:

$$\overline{\mu}^l_{ft} = 1 + \Psi^l$$

We estimate Equation (9) in logs, defining labor markets at the municipality-year level. As mentioned above, there is barely any within-municipality wage variation.

[48] For instance, a static Bertrand-Nash model of wage-setting with differentiated employers.

Moreover, 90% of the workers did not commute more than 10km from their home, as shown in Figure A8 in Appendix A.2. This shows that most workers worked within the boundaries of the village where they lived.[49] In order to identify the labor supply curve, we need labor demand shifters, as firms choose employment levels with knowledge of the latent market-level labor supply shifters $\nu_{\ell t}$. We rely on two labor demand shifters.

First, we construct an indicator variable for the coal demand shock between 1871 and 1874 due to the aftermath of the Franco-Prussian war, which was shown in Figure 3 as a peak in the international coal price.[50] Second, we include cartel membership during the cartel period as a demand shifter, given that the cartel decreased coal supply, and hence labor demand, for the cartel participants. The estimates are in Table 3. The market-level inverse elasticity of labor supply is estimated at 1.013. This implies that at a monopsonistic firm, the marginal revenue product of labor is twice the wage, whereas it would be 10% above the wage at a firm with a labor market share of 10%.

Table 3: **Labor supply**

	log(Wage)	
	Est.	S.E.
log(Employment)	1.013	0.248
First-stage F-statistic	456	
R-squared	.096	
Observations	1990	

Notes: Block-bootstrapped standard errors (SE), 200 iterations.

Testing for collusion

Combining the labor supply estimates above with the markdown estimates from the previous section permits the identification of the degree of wage-setting collusion in

[49] We examine different labor market definitions in Appendix C.4.

[50] After the Franco-Prussian war of 1870, the French coal basin in Lorraine was annexed by Germany, which resulted in a sharp increase in the international coal price, and hence in demand for coal in the Liège and Namur coal basin. Other contributions to the 'coal famine' of the early 1870s were the Boer War, cold winters and other reasons for rapid increases in consumption (Murray & Silvestre, 2020, 688).

the labor market. We define a collusion index $\hat{\lambda}_{ft} \in [0,1]$ as:

$$\hat{\lambda}_{ft} \equiv \frac{\hat{\mu}^{l}_{ft} - \underline{\mu}^{l}_{ft}}{\overline{\mu}^{l}_{ft} - \underline{\mu}^{l}_{ft}}$$

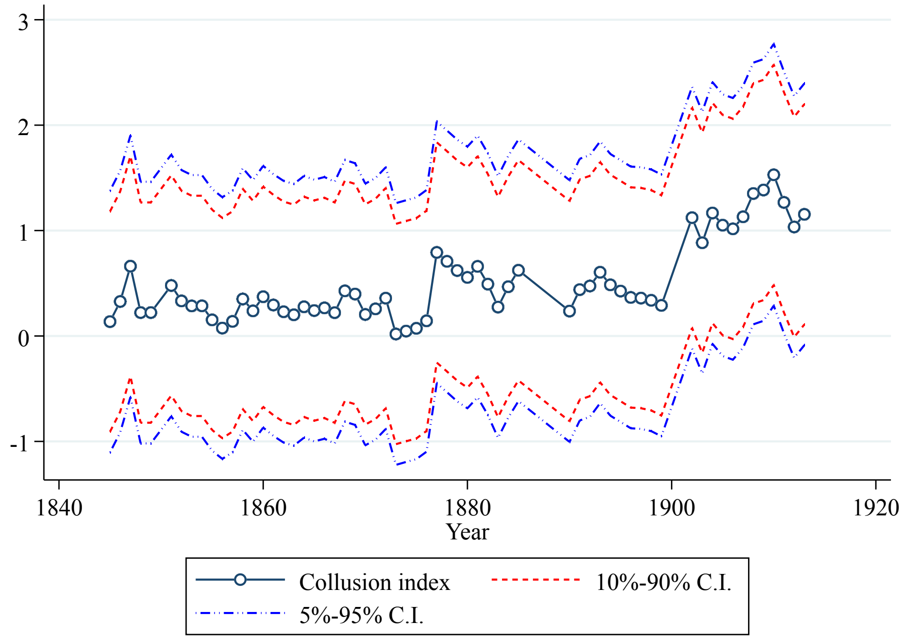
In the absence of collusion, $\hat{\lambda}_{ft} = 0$, whereas in a fully collusive market, $\hat{\lambda}_{ft} = 1$. Using the production and labor supply estimates, we estimate the collusion indicator $\hat{\lambda}_{ft}$.

Can we pick up wage collusion during the coal cartel without ex-ante knowledge of this cartel? Figure 7a plots the evolution of median collusion by year, along with confidence intervals. We find that the median markdown fluctuated around 50% of the collusive markdown level up to 1900, but cannot reject the null hypothesis of no wage collusion for any year up to 1900. From 1901 onwards, we can reject the null of no collusion for every year except 1903 at the 10% confidence level. At the 5% confidence level, we can reject the absence of collusion for 1904 and in between 1906 and 1910. The price data in Figure 3 suggests that the collusive behavior within the cartel took off from 1904 onwards, as this is the year in which Liège coal mine prices start moving towards the international coal price. The collusion estimates hence seem to be able to detect collusion due to the cartel, without requiring any a priori information about the cartel.[51]

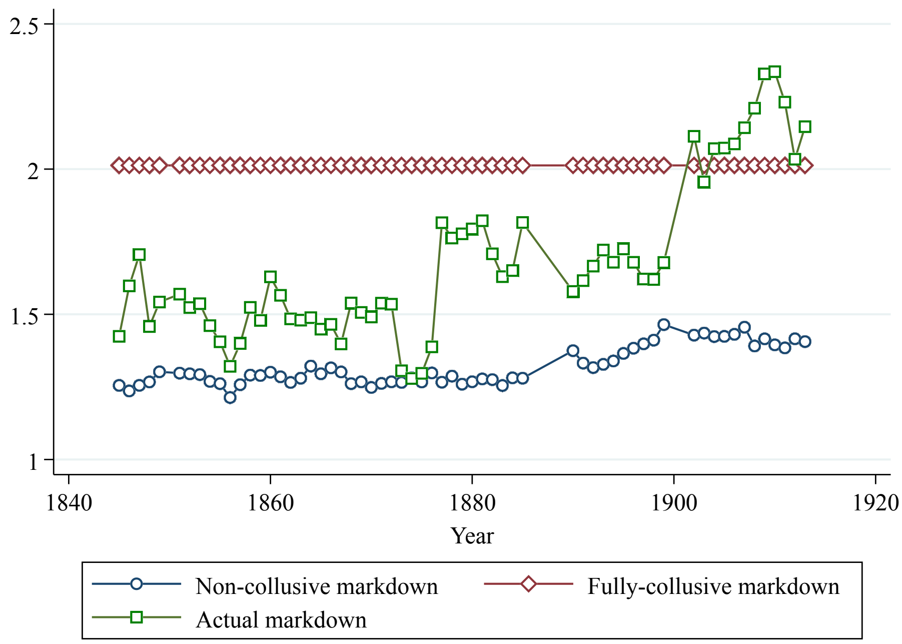
[51] Admittedly, we did rely on cartel information as a demand shifter to estimate labor supply, but this is not strictly necessary. With the availability of demand shifters, one could identify collusion using our approach without requiring information about which firms are colluding, or when.

Figure 7: **Employer collusion**

(a) **Median employer collusion index**



(b) **Collusive vs. non-collusive markdowns (median)**



Notes: The upper graph plots the evolution of median wage collusion, by year, together with block-bootstrapped confidence intervals between 1845-1913 (200 iterations).

4.2 Consequences of employer collusion

Markdown decomposition

First, we examine the extent to which the markdown increase documented in Section 3 was due to collusion. To answer this question, we decompose our estimated markdowns into a collusive and a non-collusive component. Figure 7b plots the evolution of three markdown series. The blue circles are the evolution of the median lower bound for markdowns in the absence of collusion. The red diamonds are the upper bound of markdowns under full wage collusion - this is the inverse market-level elasticity of labor supply. The green squares are the estimated median markdowns. Prior to the introduction of the cartel in 1897, the actual markdown lies above the non-collusive lower bound. This difference could be due to imperfect wage collusion devices such as the employers' associations.[52] After the introduction of the cartel in 1897, the estimated markdown level goes up the fully collusive upper bound.

From 1870 to 1900, there was an increase in the median markdown level, but there was equally an increase in the non-collusive lower markdown bound. The growth in markdowns prior to 1900 hence seems not to be related to wage collusion. However, around 1900, markdowns jump to the fully collusive upper-bound for the wage markdown. Given that the non-collusive markdown does not grow after 1900, the growth in markdowns after the introduction of the coal cartel appears to have been entirely driven by wage collusion.

The effects of the 1897 cartel

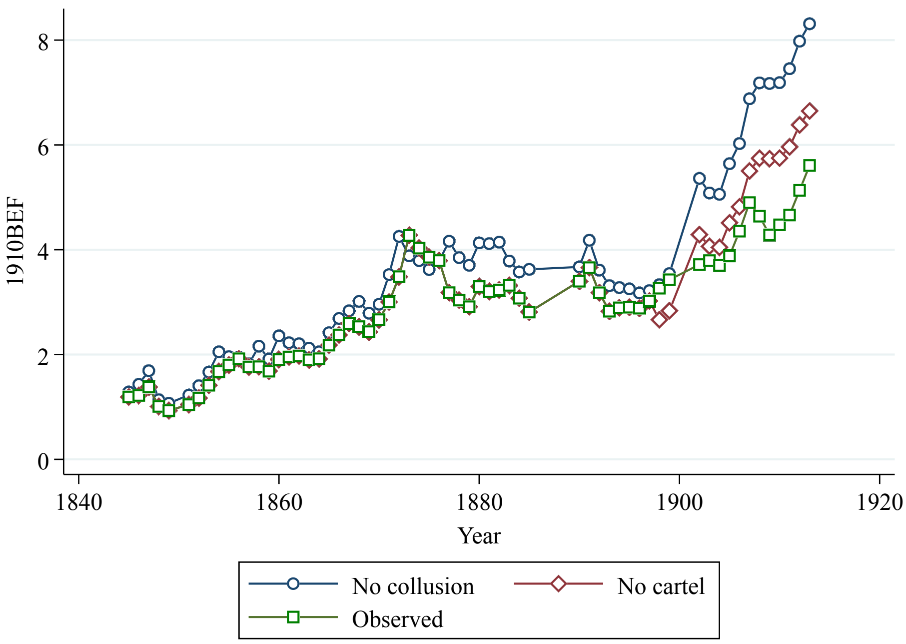
Next, we investigate the effects of the 1897 coal cartel on markdowns and wages. The across-firms markdown comparison in Section 3.3 did not measure the true effect of the cartel on markdowns because the reduction of employment by the cartel firms did not just decrease wages at the cartel firms, but also at the non-cartel firms: in the absence of employer differentiation, there is a single market-level wage. To quantify the effect of the cartel on markdowns and wages, we compute two counterfactual wage series. As a first counterfactual, we compute wages if there would be no wage collusion, meaning

[52] This difference could also be due to any other deviation from the baseline Cournot model, such as search or adjustment frictions, firm differentiation, or dynamic labor supply. We examine these possible sources of misspecification of our labor supply model in the next section.

that $\lambda_{ft} = 0, \forall g \neq f$, holding the marginal revenue product of workers fixed. This first counterfactual wage is equal to $\frac{MRPL_{ft}}{\underline{\mu}^l_{ft}}$. In a second counterfactual, we compute wages if the cartel would not have been introduced, by fixing the level of collusion at its median level over the period 1845-1898. Denoting the observed median markdown prior to the cartel as $\tilde{\mu}$, we compute this second counterfactual wage as $\frac{MRPL_{ft}}{\tilde{\mu}^l}$

The evolution of the corresponding median wage levels are plotted in Figure 8. In reality, daily wages increased from 3.02 to 5.61 BEF between 1897 and 1913, an increase of 86%. Without the cartel, the estimated wage increase was from 3.02 to 6.65 BEF, an increase of 120%. Without collusion, wages were higher to begin with, at 3.22 BEF, and increased to 8.31 BEF, an increase of 158%. Hence, wages would have grown 40% faster after 1897 without the cartel, and 84% faster in the absence of any collusion. Despite that the cartel was a downstream cartel, restricting coal output, it hence also led to decreased wage growth, by decreasing labor usage in the presence of upward-sloping labor supply curves.

Figure 8: **Wage consequences of collusion**



Notes: This graph plots the evolution of median wage collusion, by year, together with block-bootstrapped confidence intervals between 1845-1913 (200 iterations).

5 Sensitivity analysis

We conclude the empirical analysis by discussing three potentially confounding variables of our markdown estimates, and hence of our collusion measure: adjustment frictions, factor-biased technological change, and the emergence of collective bargaining and unionization.

5.1 Input adjustment costs

Although labor markets were characterized by little firing and hiring costs from the employer side, as documented in Section 2.2, there could still be adjustment frictions that explain wedges between the marginal revenue product of inputs and input prices. Such frictions would be reflected in our our markdown estimates: they are additional reasons for a wedge between the marginal revenue product of labor and wages. Also, inventories of intermediate inputs would invalidate our static input demand model and could explain short-run fluctuations in cost shares. Both these deviations from the static input demand model would threaten the identification of labor collusion: they would lead to wedges between the observed markdown and the labor supply elasticities unrelated to collusion. However, given that adjustment costs are by definition temporary, they should mainly affect cross-sectional variation in markdowns, and cannot explain the longer-term trends of our wage markdown and collusion estimates, nor their correlation with the employer unions and cartels. Moreover, we have direct evidence of the lack of adjustment frictions on labor and materials by looking at the impulse-response function of the aforementioned large coal demand shock in 1871. We plot labor and intermediate input expenditure and capital investment in the median mine around the 1871 demand shock in Figure A9 in Appendix A.2. Labor and intermediate input expenditure increase immediately as the import price of coal increases, but capital investment lags by approximately one year. This evidence for the lack of adjustment costs on labor and intermediate inputs, but for the existence of adjustment costs on capital, confirms the timing assumptions made for identifying the production function. The lack of adjustment costs on the variable inputs also shows that it is unlikely that our markdown estimates pick up input adjustment costs rather than monopsony power, which is important for the identification of collusion, as was explained above.

5.2 Factor-biased technical change

Our markdown identification strategy relies on a Hicks-neutral production function. In the presence of directed technological change, factor-augmenting productivity levels are not separately identified from wage markdowns (Rubens, 2021). That would be problematic for our identification approach of collusion: the difference between the labor supply elasticities and the markdown estimates could then be due to directed technological change, rather than to collusion. Rubens (2021) finds that, in the context of 19^{th}-century U.S. coal mining, coal cutting machines were a directed technology, which changed the output elasticity of miners. However, as mentioned before, these machines were not adopted in Liège until 1908 and were not used a lot afterward either due to coal veins being too narrow. Moreover, we have two facts in defense of the Hicks-neutrality assumption made in the paper. First, as was shown in Figure 2b, the labor cost share did not persistently change between 1870 and 1890, despite the large upshoot in capital investment during the 1870s. If technological change was capital- or materials-biased, we should see a falling cost share of labor throughout this investment peak. Conversely, the decrease in the labor cost share after 1897 did not coincide with a large increase in capital investment. Second, the correlation between our markdown estimate and the amount of horsepower for each of the three technology variables we observe is low: -0.012 for ventilation machines, 0.015 for water pumps, and 0.003 for locomotives. If these technologies would be factor-biased, they should correlate with our markdown estimates, as they should affect variable input cost shares. Third, we note that an alternative production function specification that allow for interaction effects between capital and the variable inputs, in Appendix C.1, confirms the finding that wage markdowns increased in 1897.

5.3 Unionization and democratization

In this paper, we have focused on labor market collusion between employers. However, workers could also collude, for instance through trade unions. Our focus on employer rather than employee collusion is due to the fact that trade unions struggled to make a significant impact in Belgium throughout the 19th and early 20th century, as worker collectives were heavily restrained by the legal framework (see Section 2.2). In the social movements of the 1880s and onward, coal mine workers were prominent participants, but they largely failed to materialize their demands.[53] A reason for this can be found in the lack of centralized syndical actions, as the Belgian federation is considered to have been the "weak link in the international chain of mining syndicalism" (J. Michel, 1977, 467).[54] If trade unions would have been successful during the time period studied, this would violate the labor supply model imposed, which assumes that employers unilaterally choose employment, and hence wages, without bargaining with the workers. However, changes in workers' bargaining power should be reflected in our cost-side markdown estimate, which does not impose a conduct assumption on the worker side. Given that higher bargaining power of unionized workers would lead to higher wages, this would negatively affect the cost-side markdown estimate, and hence also the employer collusion estimate.

One dimension in which the social movements of the final decades of the 19$^{\text{th}}$ century were successful, was the demand for increased political participation. In Appendix C.3, we examine the extent to which increased democratization and the rise of the Belgian Socialist Party affects our results. Overall, we find little support for the hypothesis that the socialists' emergence on the political scene decreased employer market power and the scope of collusion in the short run, aligning with the historical record of the welfare state gaining traction in the later stages of the 20$^{\text{th}}$ century.

6 Conclusions

In this paper, we examine the role of employer collusion in the exertion of labor market power. Building on prior 'cost-side approaches' to markup and markdown identification, we propose a novel method to identify employer collusion on the labor market using production and cost data. We use this approach examine the extent to which wage markdown levels and growth during the Belgian industrial revolution was driven by collusion between employers. We estimate wage markdowns set by 227 firms between

[53]Indeed, the coal sector was by far the biggest social battleground in terms of numbers of strikes and employees involved at the turn of the 19$^{\text{th}}$ century. The share of successful strikes from the perspective of the labor force, however, was notably lower than the industry average, indicating a strong position of the employer (see Figure A3 in Appendix A.1).

[54]This was especially the case in the Liège coal basin, where the scattered and heterogeneous nature of local mining companies hindered the formation of collective action (J. Michel, 1977, 470).

1845-1913, and hence provide the first long-run view of how labor market competition evolved during the industrialization process. Our findings reveal that markdown levels were relatively stable throughout the 19th century, but increased sharply around the turn of the century. We decompose these markdowns into a collusive and non-collusive component, and use this to show that the rise of markdowns around 1900 was entirely driven by collusive behavior. This confirms observed collusion through the introduction of the Belgian coal cartel in 1897, which we are able to identify without requiring to observe it.

Our findings have two important implications. First, we find that collusive behavior can play an important role in shaping labor market power and wage growth, which calls for the incorporation of cooperative wage-setting in empirical models of imperfectly competitive labor markets. Second, we find that downstream cartels can have adverse effects on workers, besides the usual focus on consumers, by affecting collusive behavior upstream. This underlines the importance of effective antitrust policies, both on downstream and upstream markets. In settings with frictional or localized input markets, antitrust policy should not just be concerned with policing collusion on product markets, but also on labor and other factor markets, as also argued by Naidu et al. (2018). As an avenue for future research, we see much potential in more research on specific types of collusive labor market practices besides overt wage fixing, such as tacit wage collusion, information sharing, and 'no-poaching' agreements: practices that can be observed in both historical and current-day labor markets.

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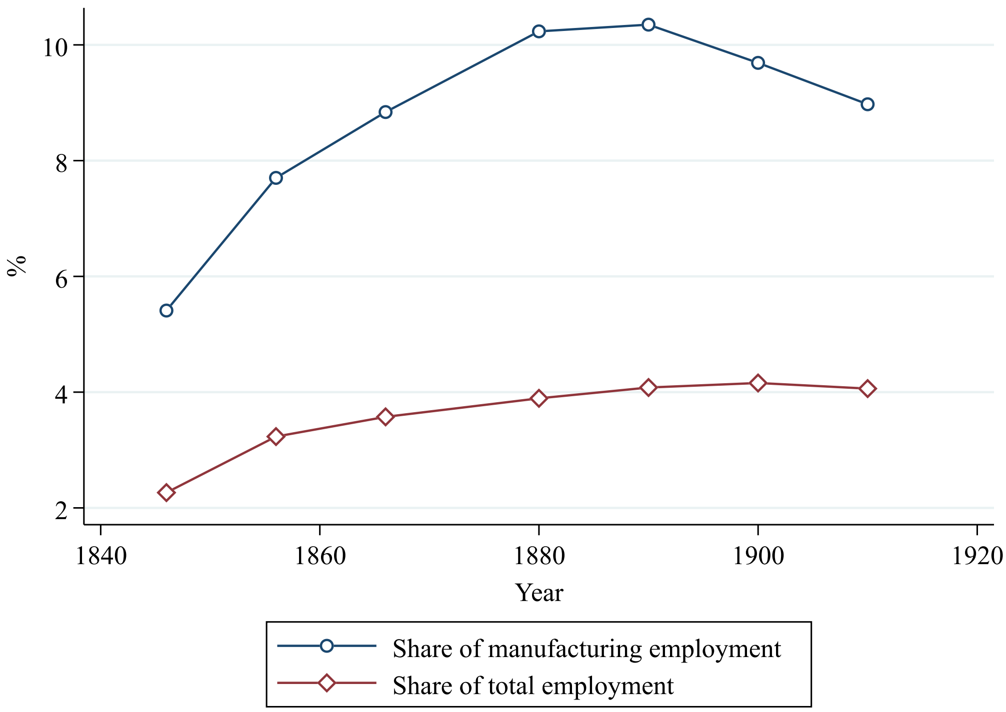
Appendices

A Background data

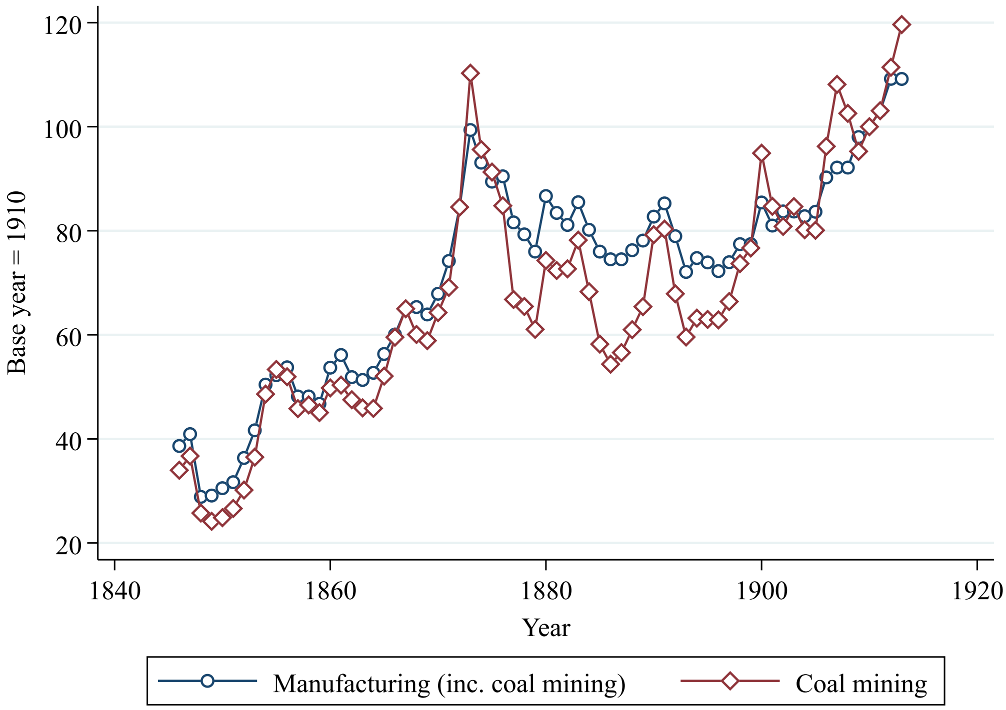
A.1 The Belgian coal industry in the long 19$^{\text{th}}$ century

Figure A1: **Share of coal mining activities in Belgian manufacturing and total employment, 1846-1910**



Source: Coal mining employment is from the published accounts of the *Administration des Mines*, as cited in Gadisseur (1979). Manufacturing and total employment are based on Buyst (forthcoming).

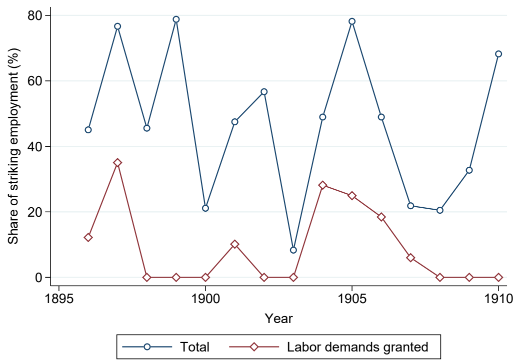
Figure A2: **Real wage index in Belgian coal mining and the entire Belgian manufacturing and mining sector, 1846-1913**



Source: Coal mining wages are from the published accounts of the *Administration des Mines*, as cited in Scholliers (1995). Manufacturing wages and the Consumer Price Index are based on Segers (2003).

Figure A3: **Share of coal mining employees involved in Belgian strikes, 1896-1910**

(a) Number of strikes

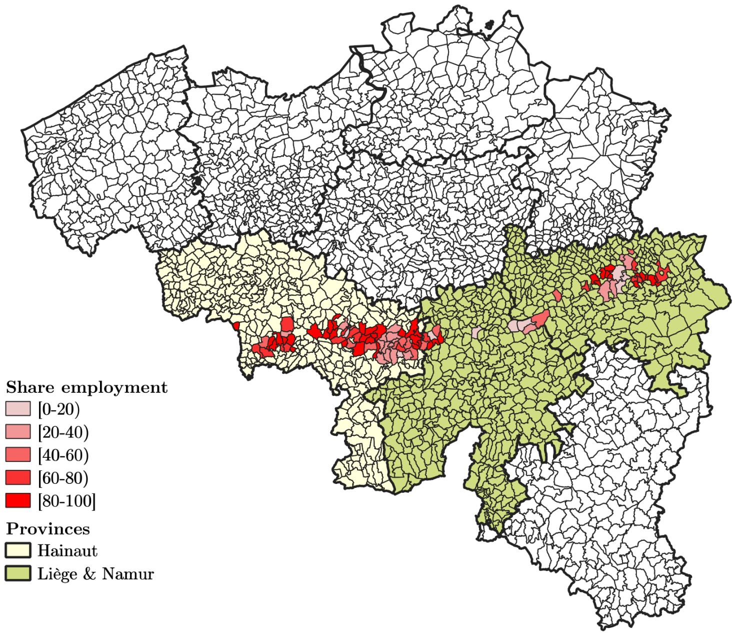


(b) Number of strikers involved

Notes: The registration of strike action might be biased towards the coal industry, due to the high government supervision of this sector. However, the lack of success from the perspective of the employees indicates that there were rents to be fought over, and that employers had a particularly strong bargaining position in the decade before the First World War.

Source: Data are adapted from Office du Travail (1903, 1907, 1911).

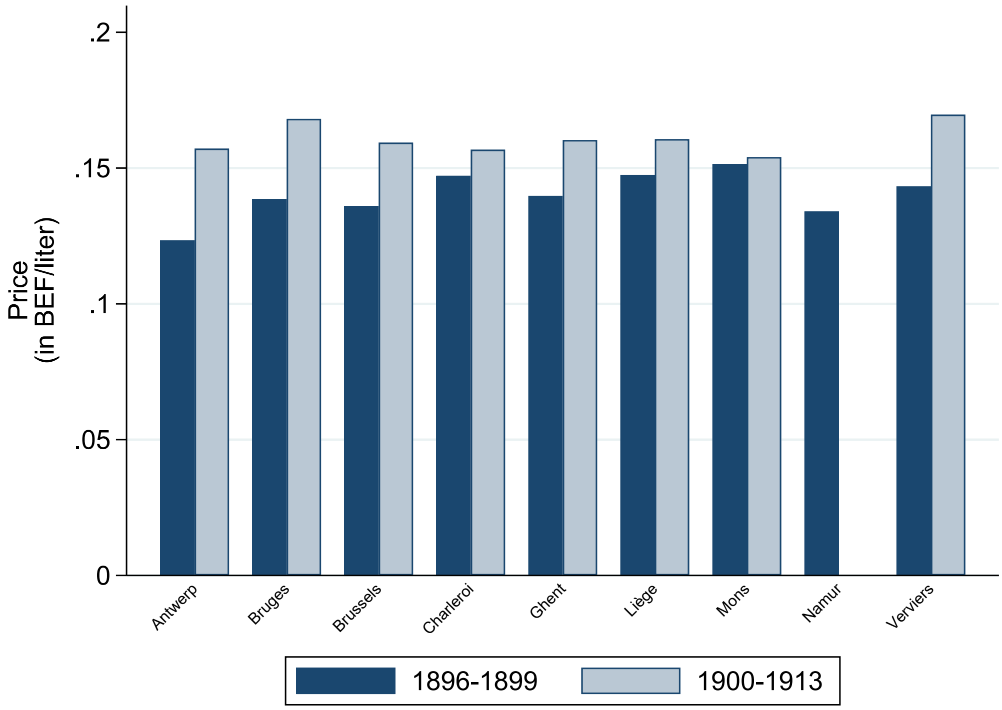
Figure A4: **Map of share of coal employment of total industrial manual employment, 1896**



Notes: Historical community borders of 1890.

Source: Data are adapted from the industrial census of 1896 (Office du Travail, 1896a, 1896b). This source was digitized by the *Quetelet Center for Quantitative Historical Research* (Ghent University).

Figure A5: **Average retail price for petroleum in major urban centers, 1896-1913**

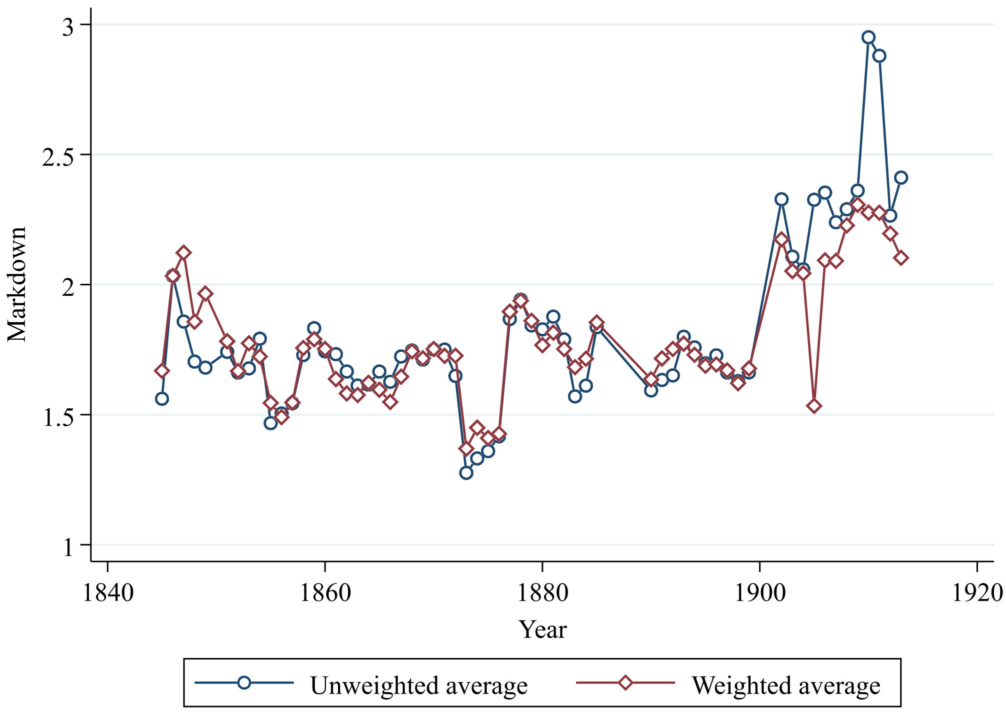


Notes: Based on monthly prices for the period 1896-1899 and on quarterly prices for the period 1900-1913.

Source: Data are adapted from the monthly publications by the Belgian *Office du Travail* (1896–1913), who collected monthly (quarterly from 1903) updates on the retail prices in Belgian urban centers.

A.2 The Liège and Namur-based coal industry in the long 19^{th} century

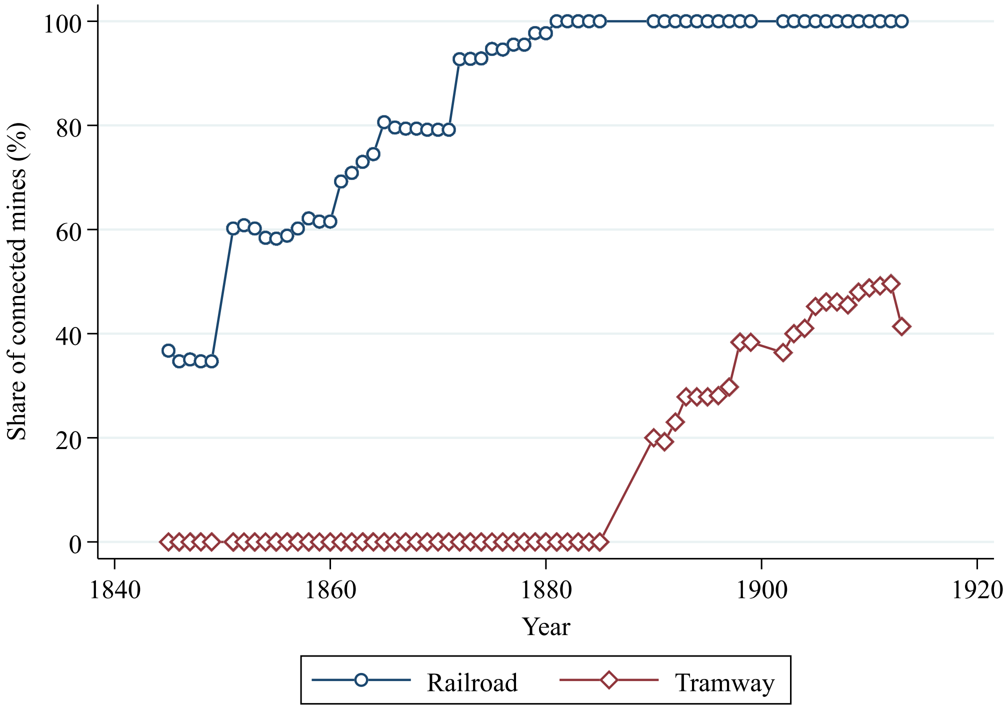
Figure A6: **Markdown reallocation**



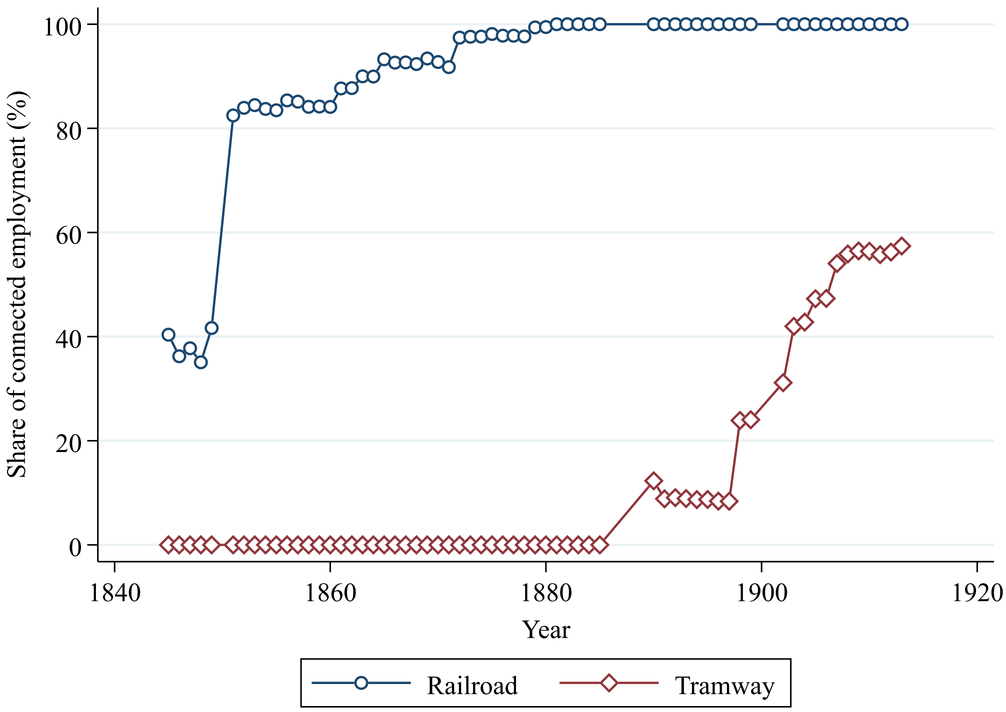
Notes: This graph shows compares the evolution fo the unweighted and weighted average (by employment) of the wage markdown in Liège and Namur coal mines from 1845-1913.

Figure A7: **Expansion of the railroad and tramway networks, connection to Liège and Namur mines, 1845-1913**

(a) **Share of connected mines (firms)**

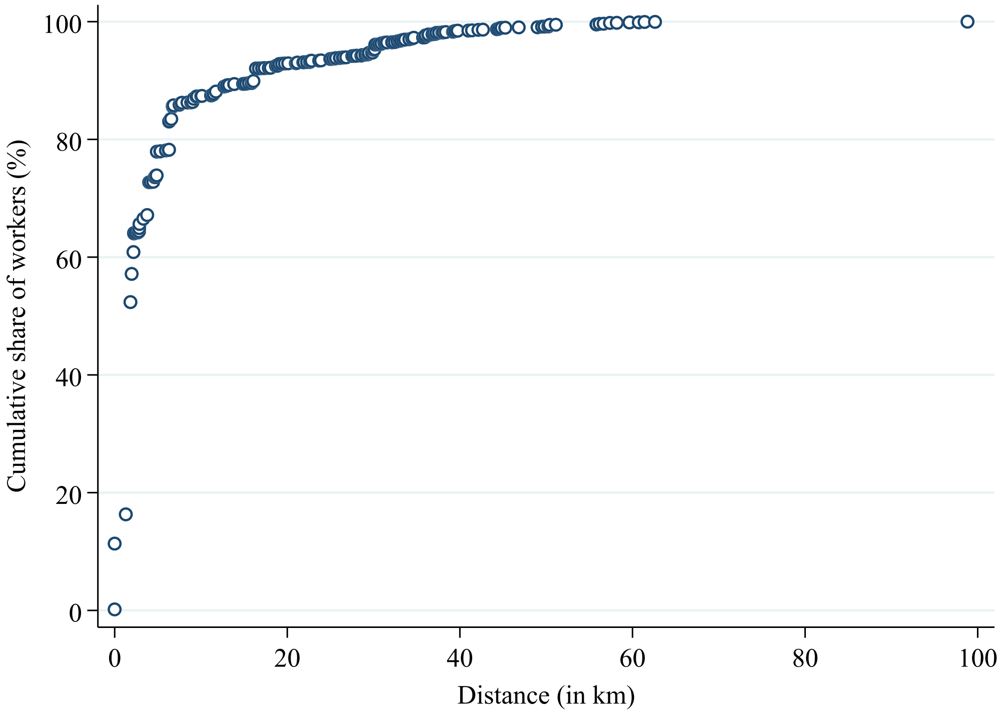


(b) **Share of connected employment**



Source: Authors' database. Opening dates of Belgian train stations are provided by the *Quetelet Center for Quantitative Historical Research* (Ghent University). For more information, see Section B.2.

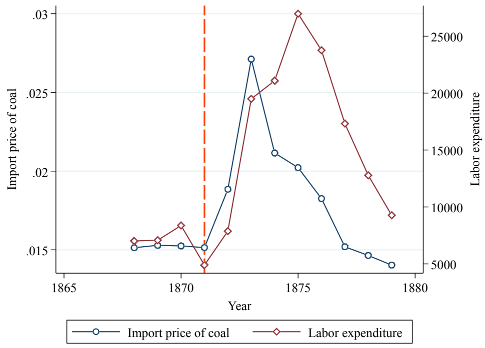
Figure A8: **Commuting distances in 1905**



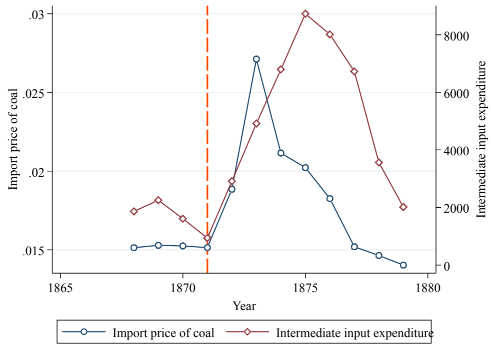
Source: Own calculations based on the survey by Mahaim (1911) at the Liège-based firms *Ougrée-Marihaye* and *Espérance-Bonne-Fortune*.

Figure A9: **Impulse-response function of input usage**

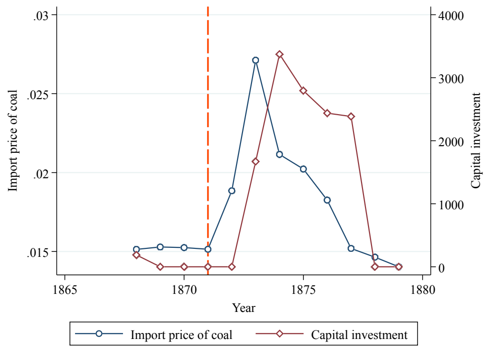
(a) **Labor expenditure**



(b) **Intermediate input expenditure**



(c) **Capital investment**



Notes: The dashed vertical lines represent the coal demand shock.

Table A1: **Agricultural wages and mining labor supply**

	Δ log(Coal mining employment)	
	Est.	S.E.
Δ log(Agricultural wage)	-0.445	0.129
R-squared	.137	
Observations	58	

Notes: This table reports the estimates of a regression of the yearly change in the log total number of workers in the Liège and Namur coal basin on the yearly change in log agricultural wages in Belgium, between 1845 and 1913.

B Data

B.1 *Administration des Mines* archives

Historical background

The institutional framework of Belgian coal mining was installed by the French state, which governed the region from 1794 to 1814. By law of 28 July 1791, all mineral resources belonged to the state, and could only be exploited under concession and surveillance of the state. Accordingly, the *Conseil des Mines* was founded: this government institute dispatched inspectors and mining engineers to all mining concessions on a yearly basis. While these visits were initially of a rather advisory nature, the role of the mine inspection would gradually be expanded towards an effective supervision unit in terms of "vices, dangers or abuses" by the end of the French period (Caulier-Mathy, 1971, 117).[55] The fall of the French empire, and Belgium's annexation to the Netherlands, would not have a major impact on the French mining legislation in place, (Leboutte, 1991, 707).[56] In fact, the new Belgian government would call to life the *Conseil des Mines de Belgique* by the law of 2 May 1837, which would fill the institutional gap left behind by its French counterpart (Geerkens, Leboutte, & Péters, 2020, 293).

Due to its French roots, the close supervision of the mining industry presents us with a valuable exception on the aforementioned *laissez-faire* principles of the Belgian state. Crucially, this translated into a vast body of statistical inquiries and visit reports. We leverage this archival information to construct a micro-level panel data set, covering all coal mining activities in Liège and Namur on a yearly basis. The oldest consistent data we could retrieve, traces back to 1845, allowing us to build a comprehensive data set from 1845 to 1913. This endeavour was facilitated by the consistent nature of reporting by the engineers of the *Administration des Mines*, allowing for the

[55] Important was the law of 21 April 1810, which imposed a set of requirements (*cahier de charges*) on mine exploitations to guarantee their competencies. Official engineers were tasked to verify and enforce these regulations under the banner of the *Administration des Mines*, established on 3 January 1813.

[56] From a governance perspective, some changes were implemented as most state engineers quit Belgium after the retreat of the imperial army in 1814. The French engineer Boüesnel would, however, stay and be appointed Chief Engineer under Dutch rule. He would subsequently also enter Belgian service, providing continuity and knowledge transfers to the mining department (Delrée & Linard de Guertechin, 1963, 54-55).

straightforward integration of the yearly accounts into a uniform data structure.[57]

Construction of the variables

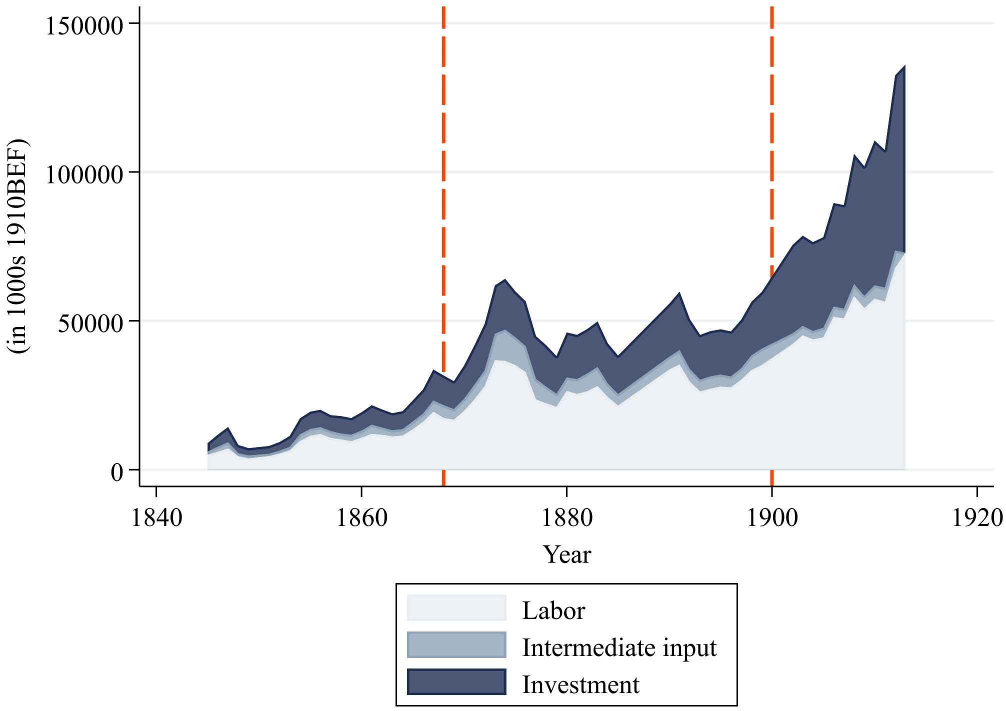
In this section, we provide a structural overview of how we constructed the variables for our empirical analysis. As outlined above, the data collected by the mining engineers are remarkably consistent over the almost-70-year period. In the case of the expenditure statistics, however, some changes in terminology were implemented throughout the years:

- ⚒ Up to 1868:
  - Labor = Labor expenditure
  - Intermediate inputs = Other current expenditure
  - Investment = Preparatory investment (*Depenses préparatoires*)
- ⚒ 1869-1899:
  - Labor = Current labor expenditure
  - Intermediate inputs = Other current expenditure
  - Investment = Extraordinary expenditure (*Depenses extraordinaires*)
- ⚒ 1900-1913:
  - Labor = Current labor expenditure
  - Intermediate inputs = Other current expenditure
  - Investment = Extraordinary expenditure (*Dépenses extraordinaires*) + 'Expenses for first use' (*Dépenses premier ...*).

The class of extra-ordinary expenses, which changes in terminology throughout the years, includes all costs related to major expansion, transformation and preparation works within the mines (Wibail, 1934, 13). Using these aggregations, we were able to create consistent measures of input expenditures and capital investments. In Figure B.1, we plot the cost shares according to our database. The dashed vertical lines indicate the years in which possible discontinuities in the variable definitions occur. The great continuity in the cost structure around these structural breaks alleviates any concerns regarding inconsistent definitions of the variables.

[57]This consistency was already exploited at the macro-level using the aggregated published statistics in Wibail (1934). The hand-written mine-level files were, however, largely left untouched by historical research.

Figure B.1: **Structural composition of the expenses, 1845-1913**



Notes: The dashed vertical lines represent the changes in terminology of the variables.

Source: Authors' database.

Concession and firm composition

As outlined in Section B.2, Belgium's coal mining sector was organized around concessions, in which firms conditionally received mining rights to the state's mineral resources. The general regulation was thus generally organized according to these concessions. Such concessions were typically independent and separate production units, with their own respective *directeurs des travaux* (managers). In the main analysis, we consequently considered these concessions to be independent firms.

Nevertheless, it is important to emphasize that this assumption potentially discards certain firm dynamics regarding the acquisition and merger of mining concessions. Firms were legally allowed to own multiple concessions[58], and this implies that our findings of monopsony and employer collusion are potentially biased upwards by within-firm coordination. We argue, however, that this is not a likely driver behind our conclusions on the ubiquity of employer collusion. For the period 1896-1913, we do have access to comprehensive accounts of active mining concessions and their respective *sociétés exploitantes* (exploiting firms), in the form of the *Tableaux des mines de houille en activité* (Administration des Mines, 1896–1913). Table B.1 reveals that, for the *bassins* of Liège and Namur, all but one firm exploited a single concession in 1896. By 1913 (see Table B.2), there were still only two exceptions to this rule.[59] This confirms that our empirical evidence on employer collusion for this period is not driven merely by labor market coordination across concessions within single firms.

Going back in time, however, our view on the firm-concession relationship becomes somewhat more obscure. Fortunately, we were able to reconstruct the histories of most Liège- and Namur-based *Sociétés Anonymes* (or S.A., an equivalent to public companies). This type of enterprise was very popular among the biggest coal companies, as it facilitated funds acquisition the in the capital-intensive business of mining. In other words, the biggest holdings - which are arguably the most likely to have exploited multiple concessions - are covered by our manually collected database of

[58]Article 31 in the law of 21 April 1810 reads:

> *Several concessions may be brought together in the hands of the same concessionaire, either as an individual or as a representative of a company, but at the expense of maintaining the operation of each concession.*

[59]Multiple-concession firms appear to have been located primarily in the *Bassin du Couchant de Mons*, not surprisingly the area in which universal banks had the strongest hold on the coal industry: we return to this issue of inter-firm ownership below.

19th-century public coal companies.

In general, it appears that firms preferred to unite concessions under their supervision, as "their reunion and a single concession can only be advantageous to the good development and economic exploitation of the mine".[60] Specific reasons include the removal of fences (for example, see Demeur, 1878, 672), the ability to mine veins under concession borders (for example, see Recueil Financier, 1893, 159), as well as administrative simplicity in terms of government supervision. As a consequence, most firm mergers or acquisitions were followed by the unification of the firms' concessions as well.[61]

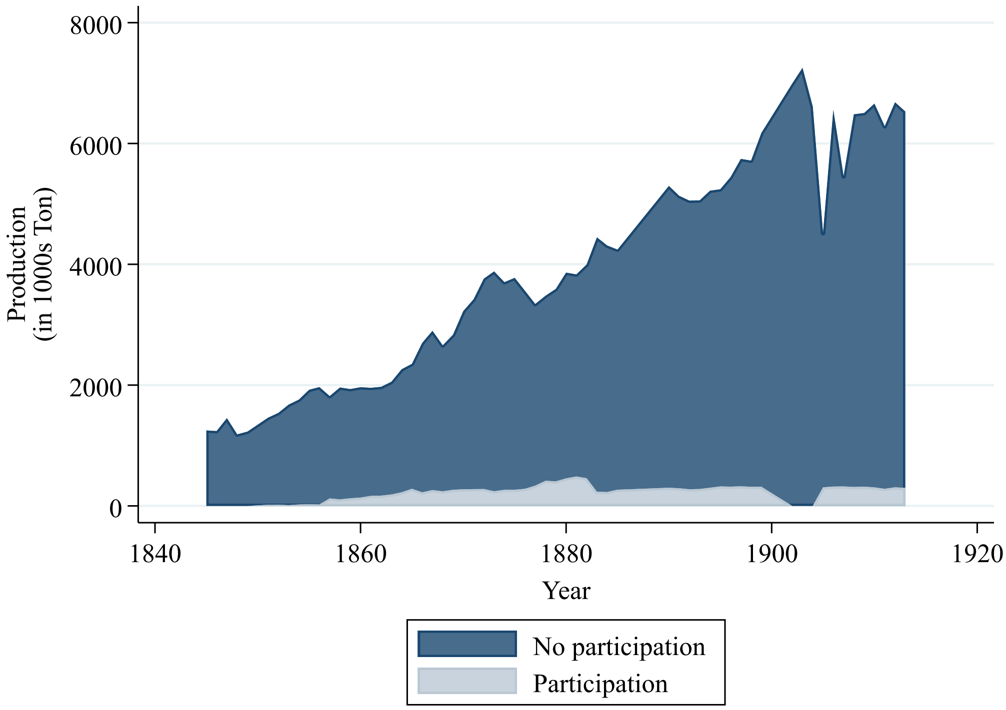
A more prevalent connection between the concessions in our database appeared to have in been the form of *common* and, more importantly, *inter-firm ownership.* Collusion due to *common ownership* is probable if powerful investment banks had a strong hand in multiple exploitations. As discussed in Section 2.2, Hainaut-based coal firms with their mutual ties to the *Société Générale de Belgique* were indeed openly colluding in wage setting. In the case of Liège- and Namur-based coal mining, however, this appears to have been less apparent. Our analysis of the portfolio of the *Société Générale*, by far the most powerful and omnipresent universal bank in 19th-century Belgium (Van Overfelt, Annaert, De Ceuster, & Deloof, 2009), reveals that its involvement in coal mining was strongly confined to the aforementioned *bassins* in Hainaut.[62] In Figure B.2, we decompose coal production in Liège and Namur by whether a firm had some financial ties (in the form of stock ownership) with the *Société Générale.* This illustrates that the universal bank's control over this industry was limited and that its development over time does little to explain the observed monopsony and employer collusion surge after the turn of the century. This conclusion aligns with historical appraisals of the industrial relations in Liège during that era (Kurgan-van Hentenryk & Puissant, 1990).

[60] This is a quote from the royal decree regarding the unification of the concessions from the *SA des charbonnages de la Chartreuse et Violette* (Demeur, 1878, 680-681).

[61] For examples, see the aforementioned case of *SA des charbonnages de la Chartreuse et Violette*, as well as the *SA des charbonnages de Bonne-Fin*, who fully acquired the concession of Baneux in August 1863. Early next year, the concessions of Bonne-Fin and Baneux were accordingly united (Laureyssens, 1975, 139).

[62] We thank Gertjan Verdickt and the *StudieCentrum voor Onderneming en Beurs* or SCOB (University of Antwerp) for help with this data.

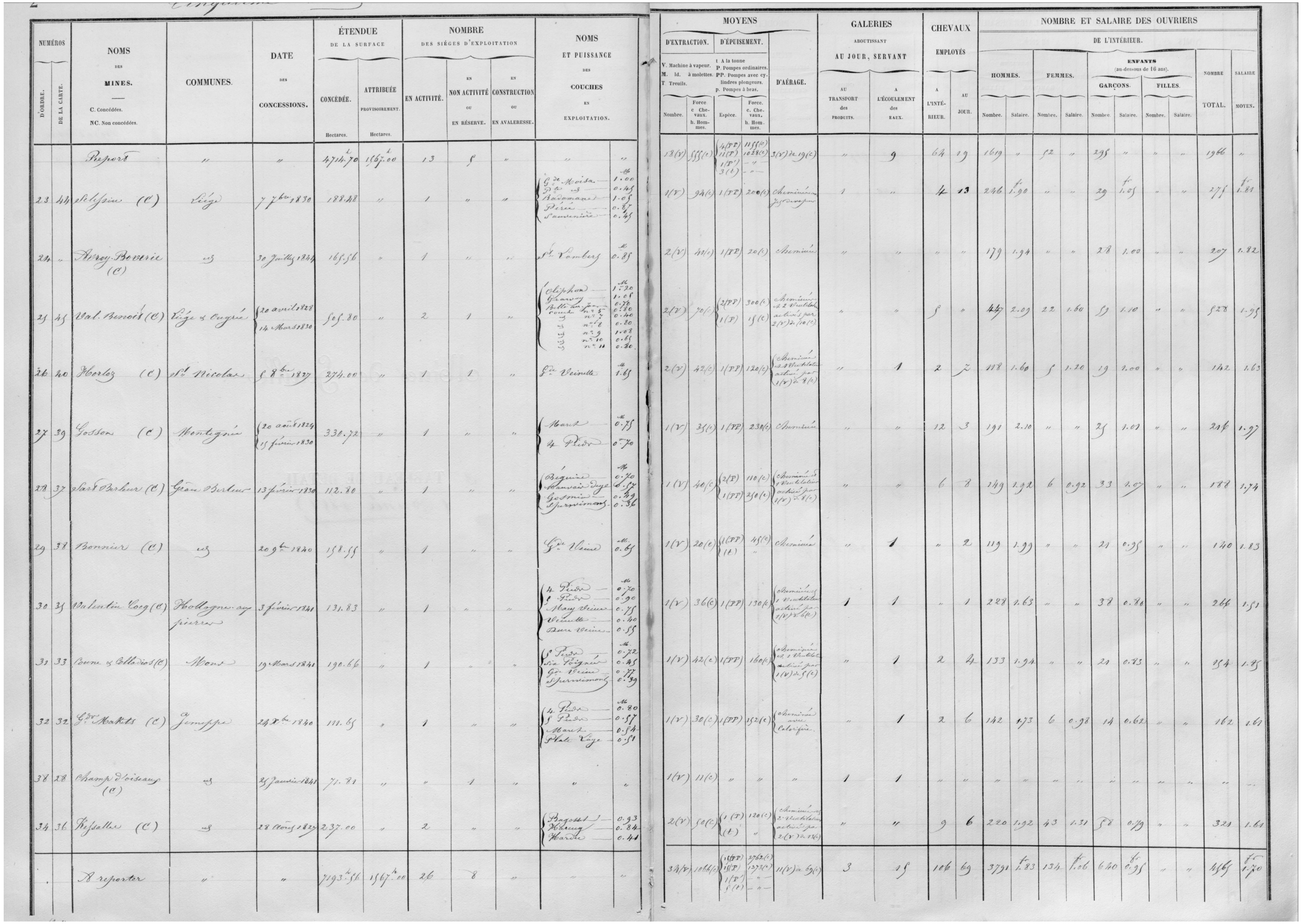
Figure B.2: **Involvement of the *Société Générale de Belgique* in Liège- and Namur-based coal mining, 1845-1913**



Source: Authors' database and the yearbooks of the *Société Générale de Belgique* (SCOB).

Inter-firm ownership, on the other hand, implies that industrial conglomerates had a hand in multiple, competing concessions other than their own exploitation, pressuring its managers into aligning their labor market strategies. We see this as a plausible source of employer-side collusion in industrial labor markets. A prime example is undoubtedly the influential Liège-based Orban family. Jean Michel Orban (1752-1833) was among the first to successfully implement innovations in mechanized water pumping and animal-powered coal transport. Hence, other firms asked him to participate in their coal mining ventures, expanding his involvement in the local coal industry. His son Henri Joseph Orban (1779-1846) and other relatives would continue to tighten the family's grip on the local industry (Kurgan-Van Hentenryk, Puissant, & Montens, 1996, 491). At Henri Joseph Orban's death in 1846, his inheritance listed financial ties with various firms in our sample, including the *Houillère de Nouvelle Bonnefin*, the *Houillère des Baneux* and the *Houillère du Bon Buveur* (Capitaine, 1858, 13). Comprehensively charting such financial ties over time for the Orban family, as well as for other industrial dynasties such as the Cockerill family, is beyond the scope of this paper (if not beyond the scope of the available historical sources as well). Nevertheless, we do see the connection between inter-firm ownership and labor market collusion as an exciting avenue for future research.

Figure B.3: **Example of one of the count sheets of the *Administration des Mines***



N° d'ordre	N° de la carte	Noms des mines (C. Concédées. NC. Non concédées.)	Communes	Date des concessions	Étendue de la surface: Concédée (Hectares)	Étendue de la surface: Attribuée provisoirement (Hectares)	Nombre des sièges d'exploitation: En activité	En non activité ou en réserve	En construction ou en avaleresse	Noms et puissance des couches en exploitation	
		Report	"	"	4714.70	1567.00	13	5	"	"	"
23	44	Sclessin (C)	Liège	7 7bre 1830	188.48	"	1	"	"	Gde Moisa Pte id Badamane Pérée Sauvenière	1.00 0.45 1.05 0.87 0.45
24	"	Avroy-Boverie (C)	id	30 Juillet 1844	165.56	"	1	"	"	Ste Lambert	0.85
25	45	Val-Benoit (C)	Liège & Ougrée	20 avril 1828 14 Mars 1830	505.80	"	2	1	"	Oliphon Dravay Belle au Jour couche n° 5 id n° 7 id n° 8 id n° 9 id n° 10 id n° 11	1.20 1.05 0.70 0.80 0.40 0.80 1.08 0.65 0.80
26	40	Horloz (C)	St Nicolas	5 8bre 1827	274.00	"	1	1	"	Gde Veinette	1.65
27	39	Gosson (C)	Montegnée	20 août 1824 15 février 1830	330.72	"	1	"	"	Marét 4 Pieds	0.75 0.70
28	37	Sart Berleur (C)	Gran Berleur	13 février 1830	112.80	"	1	"	"	Béguine Mauvais Deye Gosmia Spurvimont	0.70 0.57 0.49 0.36
29	38	Bonnier (C)	id	20 9bre 1840	158.55	"	1	"	"	Gde Veine	0.65
30	35	Valentin Cocq (C)	Hollogne-aux-pierres	3 février 1841	131.83	"	1	"	"	4 Pieds 5 Pieds Macy Veine Veinette Dure Veine	0.70 0.90 0.75 0.40 0.55
31	33	Burre & Colladios (C)	Mons	19 Mars 1841	190.66	"	1	"	"	5 Pieds Six Poignées Gde Veine Spurvimont	0.72 0.45 0.77 0.39
32	32	Gdes Makets (C)	Jemeppe	24 Xbre 1840	111.65	"	1	"	"	4 Pieds 5 Pieds Marét Plate Laye	0.80 0.57 0.54 0.51
38	28	Champ d'oiseaux (C)	id	25 Janvier 1841	71.81	"	"	1	"	"	"
34	36	Kessales (C)	id	28 Août 1827	237.00	"	2	"	"	Bagosset Harung Hardie	0.93 0.84 0.41
		A reporter	"	"	7193.56	1567.00	26	8	"	"	"

N° d'ordre	Moyens d'extraction: Nombre (V. Machine à vapeur. M. Id. à molettes. T. Treuils.)	D'extraction: Force (c. Chevaux. h. Hommes.)	D'épuisement: Espèce (t. A la tonne. P. Pompes ordinaires. PP. Pompes avec cylindres plongeurs. p. Pompes à bras.)	D'épuisement: Force (c. Chevaux. h. Hommes.)	D'aérage	Galeries aboutissant au jour, servant: Au transport des produits	A l'écoulement des eaux	Chevaux employés: A l'intérieur	Au jour	Hommes: Nombre	Hommes: Salaire	Femmes: Nombre	Femmes: Salaire	Garçons: Nombre	Garçons: Salaire	Filles: Nombre	Filles: Salaire	Nombre total	Salaire moyen
Report	18(V)	555(c)	4(PP) 11(P) 1(P') 3(t)	1155(c) 1028(c) —"— —"—	3(V) de 19(c)	"	9	64	19	1619	"	52	"	295	"	"	"	1966	"
23	1(V)	94(c)	1(PP)	200(c)	Cheminée à jet de vapeur	1	"	4	13	246	1.90	"	"	29	1.05	"	"	275	1.81
24	2(V)	41(c)	1(PP)	20(c)	Cheminée	"	"	"	"	179	1.94	"	"	28	1.00	"	"	207	1.82
25	2(V)	70(c)	2(PP) 1(P)	300(c) 15(c)	Cheminée et 2 Ventilateurs activés par 2(V) de 10(c)	"	"	5	"	447	2.09	22	1.60	59	1.10	"	"	528	1.95
26	2(V)	42(c)	1(PP)	120(c)	Cheminée et 1 Ventilateur activé par 1(V) de 8(c)	"	1	2	2	118	1.60	5	1.20	19	1.00	"	"	142	1.63
27	1(V)	35(c)	1(PP)	230(c)	Cheminée	"	"	12	3	191	2.10	"	"	25	1.01	"	"	216	1.97
28	1(V)	40(c)	2(P) 1(PP)	110(c) 250(c)	Cheminée et 1 Ventilateur activé par 1(V) de 8(c)	"	"	6	8	149	1.92	6	0.92	33	1.07	"	"	188	1.74
29	1(V)	20(c)	1(PP) (t)	45(c) "	Cheminée	"	1	"	2	119	1.99	"	"	21	0.95	"	"	140	1.83
30	1(V)	36(c)	1(PP)	130(c)	Cheminée et 1 Ventilateur activé par 1(V) de 6(c)	1	1	"	1	228	1.63	"	"	38	0.86	"	"	266	1.51
31	1(V)	42(c)	1(PP)	160(c)	Cheminée et 1 Ventilateur activé par 1(V) de 5(c)	"	1	2	4	133	1.94	"	"	21	0.83	"	"	154	1.85
32	1(V)	30(c)	1(PP)	152(c)	Cheminée avec Calorifère	"	1	2	6	142	1.73	6	0.98	14	0.62	"	"	162	1.61
38	1(V)	11(c)	"	"	"	1	1	"	"	"	"	"	"	"	"	"	"	"	—
34	2(V)	50(c)	1(P) (t)	120(c) "	Cheminée et 2 Ventilateurs activés par 2(V) de 13(c)	"	"	9	6	220	1.92	43	1.31	58	0.79	"	"	321	1.61
A reporter	34(V)	1066(c)	15(PP) 15(P) 1(P') 5(t)	2762(c) 1373(c) —"— —"—	11(V) de 69(c)	3	15	106	69	3791	1.83	134	1.06	640	0.95	"	"	4565	1.70

Source: Administration des Mines (1831–1933, Series 103).

Table B.1: **Concession and firm concordance in Liège and Namur, 1896**

Basin & District		**Concession**	**Firm**
Bassin de Namur	5	Hazard	SC du charbonnage du Hazard
	5	Auvelais Saint-Roch	SA des charbonnages de Saint-Roch-Auvelais
	5	Falisolle	SA du charbonnage de Falisolle
	5	Arsimont	SA du charbonnage d'Arsimont
	5	Ham-sur-Sambre	SA des charbonnages de Ham-sur-Sambre et Moustier
	5	Malonne	SA des charbonnages de Malonne et Floreffe
	5	Le Château	SC du charbonnage de Château
	5	Basse-Marlagne	SC du charbonnage de Basse-Marlagne
	5	Stud-Rouvroy	SC du charbonnage de Stud-Rouvroy
	5	Andenelle	SC du charbonnage d'Andenelle
	5	Groynne	SC du charbonnage de Groynne
Bassin de Liège	6	Bonnier	SA du charbonnage du Bonnier
	6	Sarts-au-Berleur	SA du charbonnage du Corbeau-au-Berleur
	6	Gosson-Lagasse	SA des charbonnages de Gosson Lagasse
	6	Horloz	SA des charbonnages du Horloz
	6	Kessales-Artistes	SA des charbonnages des Kessales
	6	Concorde	SA des charbonnages réunis de la Concorde
	6	Nouvelle-Montagne	SA de Nouvelle-Montagne
	6	Halbosart	Famille Farcy
	6	Ben	Desoer et Compagnie
	6	Marihaye	SA des charbonnages de Marihaye
	6	Bois de Gives et Saint-Paul	SC des charbonnages de Gives et Saint-Paul
	7	Angleur	SA des charbonnages d'Angleur
	7	Sclessin-Val Benoit	SA des charbonnages du Bois d'Avroy
	7	Espérance et Bonne Fortune	SA des charbonnages d'Espérance et Bonne Fortune
	7	La Haye	SA des charbonnages de La Haye
	7	Patience-Beaujonc	SA des charbonnages de Patience-Beaujonc
	7	Bonne-Fin Bâneux	SA des charbonnages de Bonne-Fin
	7	Ans et Glain	SA des Mines de houile d'Ans
	7	Grande-Bacnure	SA de la Grande Bacnure
	7	Petite-Bacnure	SA des charbonnages de la Petite Bacnure
	7	Belle-Vue et Bien Venue	SA des charbonnages de Belle-Vue et Bien-Venue
	7	Espérance (Herstal)	SA de Bonne-Espérance et Batterie
	7	Batterie	SA de Bonne-Espérance et Batterie
	7	Abhooz et Bonne-Foi-Hareng	SA des charbonnages d'Abhooz et Bonne-Foi-Hareng
	7	Bicquet-Gorée	SA des charbonnages d'Oupeye
	8	Cockerill	SA John Cockerill
	8	Cowette-Rufin	SC de Cowette-Rufin, Grand-Henri
	8	Crahay	SA de Maireux et Bas-Bois
	8	Hasard-Melin	SA du Hasard
	8	Herman-Pixherotte	SC de Herman-Pixherotte
	8	Herve-Wergifosse	SA de Herve-Wergifosse
	8	Lonette	SA de Lonette
	8	Micheroux	SA dus Bois de Micheroux
	8	Minerie	SA de la Minerie
	8	Ougrée	SA d'Ougrée
	8	Près de Fléron	SC des Près de Fléron
	8	Quatre Jean	SA des Quatre Jean
	8	Six-Bonniers	Société charbonnière des Six-Bonniers
	8	Steppes	SC du canal de Fond-Piquette
	8	Trou-Souris-Houlleux-Homvent	Charbonnages réunis de l'Est de Liège
	8	Wandre	Suermondt, frères
	8	Wérister	SA de Wérister

Notes: *Sociétés Anonymes* and *Sociétés Civiles* are abbreviated as SA and SC respectively. Firms underlined and in blue are multiple-concession firms.

Source: Annales des Mines de Belgique (1896–1913, vol. I).

Table B.2: **Concession and firm concordance in Liège and Namur, 1913**

Basin & District		**Concession**	**Firm**
Bassin de Namur	5	Tamines	SA des charbonnages de Tamines
	5	Auvelais Saint-Roch	SA des charbonnages de Saint-Roch-Auvelais
	5	Falisolle	SA du charbonnage de Falisolle
	5	Ham-sur-Sambre, Arsimont et Mornimont, Franière et Diminche	SA des charbonnages de Ham-sur-Sambre et Moustier
	5	Jemeppe-sur-Sambre	SA du charbonnage de Jemeppe-Auvelais
	5	Soye, Floriffoux, Floreffe, Flawinne, La Lâche et extensions	SA des charbonnages réunis de la Basse Sambre
	5	Le Château	SC du charbonnage de Château
	5	Basse-Marlagne	SC du charbonnage de Basse-Marlagne
	5	Stud-Rouvroy	SC du charbonnage de Stud-Rouvroy
	5	Groynne	SC du charbonnage de Groynne
	5	Andenelle, Hautebise et Les Liégeois	SC du charbonnage de Hautebise
	5	Muache	Victor Massart
Bassin de Liège	6	Bois de Gives et Saint-Paul	SC des charbonnages de Gives et Saint-Paul
	6	Halbosart-Kivelterie	SA des charbonnages de Halbosart
	6	Sart d'Avette et Bois des Moines	SA des charbonnages du Pays de Liège
	6	Arbre Saint-Michel, Bois d'Otheit et Cowa	SA des charbonnages de l'Arbre Saint-Michel
	6	Nouvelle-Montagne	SA de Nouvelle-Montagne
	6	Marihaye	SA d'Ougrée-Marihaye: Division Marihaye
	6	Kessales-Artistes	SA des charbonnages des Kessales
	6	Concorde	SA des charbonnages réunis de la Concorde
	6	Sarts-au-Berleur	SA du charbonnage du Corbeau-au-Berleur
	6	Bonnier	SA du charbonnage du Bonnier
	6	Gosson-Lagasse	SA des charbonnages de Gosson Lagasse
	6	Horloz	SA des charbonnages du Horloz
	7	Espérance et Bonne Fortune	SA des charbonnages d'Espérance et Bonne Fortune
	7	Ans et Glain	SA des Mines de houile d'Ans et de Rocour
	7	Patience-Beaujonc	SA des charbonnages de Patience-Beaujonc
	7	La Haye	SA des charbonnages de La Haye
	7	Sclessin-Val Benoit	SA des charbonnages du Bois d'Avroy
	7	Bonne-Fin Bâneux	SA des charbonnages de Bonne-Fin
	7	Batterie	SA de Bonne-Espérance et Batterie
	7	Espérance et Violette	SA de Bonne-Espérance et Batterie
	7	Abhooz et Bonne-Foi-Hareng	SA des charbonnages d'Abhooz et Bonne-Foi-Hareng
	7	Petite-Bacnure	SA des charbonnages de la Petite Bacnure
	7	Grande-Bacnure	SA de la Grande Bacnure
	7	Belle-Vue et Bien Venue	SA des charbonnages de Belle-Vue et Bien-Venue
	7	Bicquet-Gorée	SA des charbonnages d'Oupeye
	8	Cockerill	SA John Cockerill
	8	Six-Bonniers	Société charbonnière des Six-Bonniers
	8	Ougrée	SA d'Ougrée-Marihaye
	8	Trou-Souris-Houlleux-Homvent	Charbonnages réunis de l'Est de Liège
	8	Steppes	SC du canal de Fond-Piquette
	8	Cowette-Rufin	SC de Cowette-Rufin, Grand-Henri
	8	Wérister	SA des charbonnages de Wérister
	8	Quatre Jean	SA des Quatre Jean
	8	Lonette	SA de Lonette
	8	Hasard-Fléron	SA des charbonnages de Hasard
	8	Crahay	SA des charbonnages de Maireux et Bas-Bois
	8	Micheroux	SA du charbonnage de Bois de Micheroux
	8	Herve-Wergifosse	SA de Herve-Wergifosse
	8	Minerie	SA des charbonnages réunis de la Minerie
	8	Wandre	Suermondt, frères
	8	Cheratte	SA des charbonnages de Cheratte
	8	Basse-Ransy	SA des charbonnages de la Basse-Ransy

Notes: *Sociétés Anonymes* and *Sociétés Civiles* are abbreviated as SA and SC respectively. Firms underlined and in blue are multiple-concession firms.

Source: Annales des Mines de Belgique (1896–1913, vol. XVIII).

B.2 Other sources

⚒ Membership of the *Union des charbonnages*

To quantify membership of the *l'Union des charbonnages, mines et usines métallurgiques de la province de Liège* throughout the years, we constructed a yearly binary membership variable for each firm in our data set. In their monthly *Bulletin* publications (1869–1913), the organization disseminated the minutes of its meetings, as well as noteworthy news in the local coal industry. On a yearly basis, a complete list of its members was also published. We used the latter as a source for our membership variable.

This variable does not cover the period before the *Union* was officially recovered, from 1840 to 1868. Based on the available member lists, there is no evidence of exit from the union, so we assume that all members who remained member from 1868 to 1913 were founding members and accordingly create a time invariant membership dummy.

⚒ Employers' associations in Namur

Most *bassins* in Belgium had their own respective employers' organizations, much like the *Union*. However, the smaller and diluted Namur coal industry - the other *bassin* in our data set next to Liège, Basse-Sambre - was an exception. The Charleroi-based *Association des charbonnages du bassin de Charleroi* did attempt to gain control over this area. In order to attract more Namur-based coal mines, the organization changed their name into *L'Association charbonnière et l'industrie houillière des bassins de Charleroi et de la Basse-Sambre* (Association charbonnière (...), 1931, 30). Membership lists of said organization reveal that the reach of these efforts was very limited in terms of membership, however.

⚒ Access to the railroad network

We assigned the coal mines' location to their respective communities. The transport database of the *Quetelet Center for Quantitative Historical Research* (Ghent University) gives us access to the opening years of all train and tramway stations in Belgium. By combining these two pieces of information, we were able to retrace all coal mines' approximate year of connection to the Belgian railroad network.

⚒ Cartel membership

The work of contemporary economist Georges De Leener is without a doubt considered to be the seminal source on Belgian cartels of that era (for example, see Vanthemsche, 1995, 18). We obtain the cartel membership list in 1905 from De Leener (1909). We trace this cartel membership data back to 1898 by taking into account name changes of mines, and assume that no firms entered or exited the cartel between 1898-1905. This results in 27 cartel firms in 1898, which is in line with anecdotal evidence in De Leener (1904). After 1905, we take into account the exit of the *Gosson-Lagasse* mine in 1907, mentioned by De Leener (1909), and for the remainder we assume that the cartel membership remained stable, as no mention of any other exiters or entrants was made in De Leener (1909).

B.3 Constructing the capital stock

In this section, we describe how we construct the capital stock K_{ft}. In every year between 1846 and 1912, we observe capital investment I_{ft}, from the variable *dépenses extraordinaires*. We specify the usual capital accumulation equation:

$$K_{ft} = K_{ft-1}(1-\delta) + I_{ft}$$

In order to determine the amount of of depreciation, we estimate the capital transition process for both machine horsepower and equine horsepower. The estimates are in Table B.3. If no investment has taken place in the previous year, machine horsepower decreases by 12.7%, and equine horsepower by 15.1%. If there has been investment in the previous year, machine horsepower increases by 1.7%, but equine horsepower remains stable: investments in horses were mainly replacement investments, not expanding the amount of horses used. Given that the depreciation rates lied around 13%, we set $d = 0.13$ in order to calculate the capital stock. For years in which investment data are missing, we linearly interpolate missing investments.

One problem is which capital stock to assume in the first year of the data set, 1845. This was most likely not zero. We proceed as follows to find the initial capital stock. We regress yearly investment on changes in the number of horsepower for excavation and extraction, K^1 and K^2, and the change in the number of horses K^h, in order to recover the price per horse and the price per unit of horsepower for each machine.

$$I_{ft} = W^1(K^1_{ft} - K^1_{ft-1}) + W^2(K^2_{ft} - K^2_{ft-1}) + W^h(K^h_{ft} - K^h_{ft-1}) + u_{ft}$$

Next, we compute the initial capital stock in 1845 as:

$$K_{f,1845} = W^1 K^1_{f,1845} + W^2 K^2_{f,1845} + W^h K^h_{f,1845}$$

We assume the deflated prices per horse and horsepower are constant across firms and years. This assumption could be violated if machine technologies became cheaper over time. However, we only need the price per horsepower and horse in 1845 to construct the initial capital stock, not the price per horsepower and horse in every year.

Table B.3: **Estimates of depreciation**

(a) Machine horsepower	Not invested		Invested	
	Est.	SE	Est.	SE
$1-\delta$	0.873	0.008	1.017	0.003
R-squared	.782		.974	
Observations	3550		3277	
(b) Equine horsepower	Not invested		Invested	
	Est.	SE	Est.	SE
$1-\delta$	0.849	0.009	0.993	0.005
R-squared	.721		.934	
Observations	3550		3277	

Notes: We estimate depreciation by regressing horsepower on lagged horsepower for both machines and horses, both if firms invested in the previous period and if they did not invest.

C Robustness checks

C.1 Production function: extensions

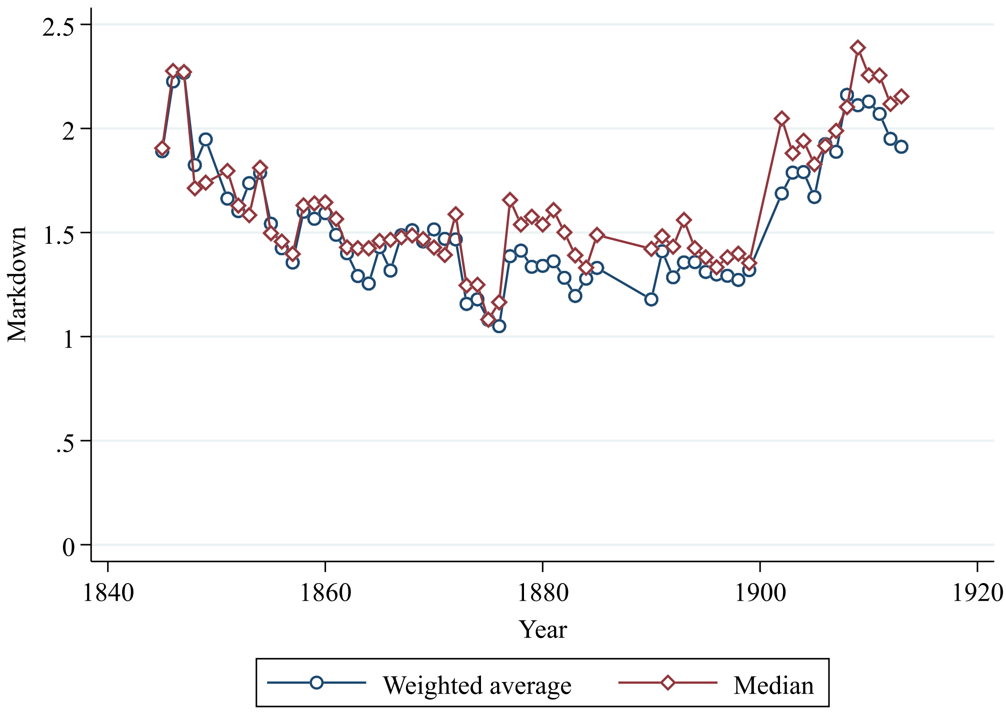
Translog production function

In order to allow for more flexibility in the production function, we estimate a translog production function, which allows both for interaction terms between all inputs and for nonlinearities in the output elasticities. We rely on the same moment conditions as in the main text to estimate this equation, but add the transformations of the instruments as additional instrumental variables.

$$q_{ft} = \beta^l l_{ft} + \beta^m m_{ft} + \beta^k k_{ft} + \beta^{kl} k_{ft} l_{ft} + \beta^{km} k_{ft} m_{ft} + \beta^{lm} l_{ft} m_{ft} + \beta^{ll} l_{ft}^2 + \beta^{kk} k_{ft}^2 + \beta^{mm} m_{ft}^2 + \omega_{ft} \tag{C.1}$$

The resulting markdown series is in Figure C.1. The markdown is still estimated to be roughly constant before 1898, and to increase sharply after 1897. The pre-1897 markdown level is estimated to be higher, between 2 and 3, indicating substantial wage markdowns even before the cartel. However, none of the interaction terms is statistically significant, which is why we stick to the Cobb-Douglas function in our baseline analysis.

Figure C.1: **Translog production function**

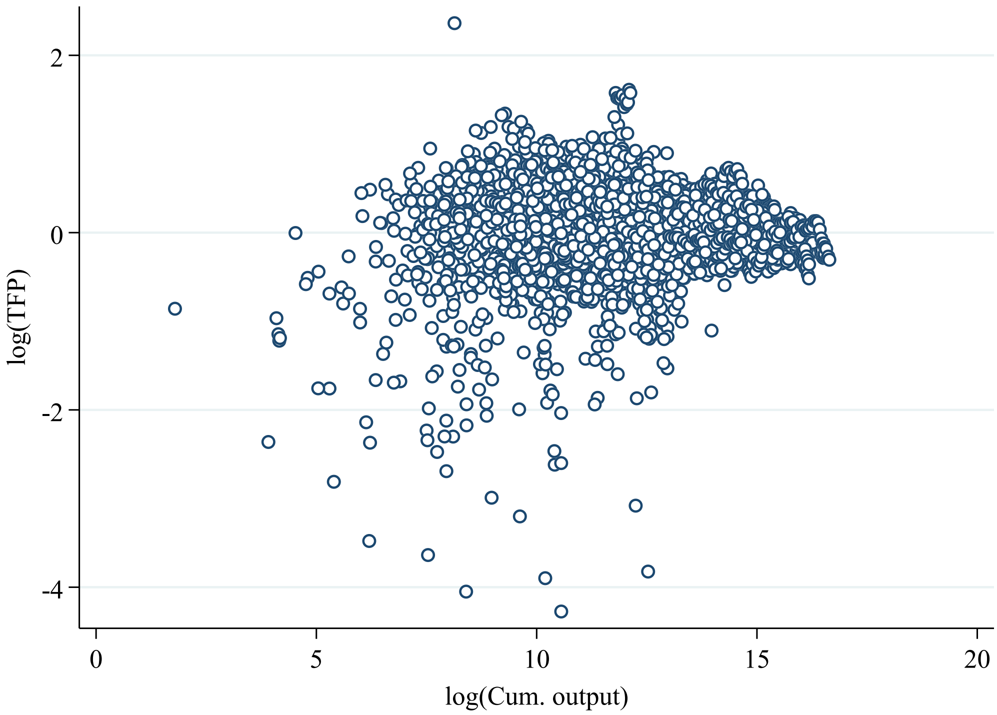


Notes: We estimate markdowns using the translog production function specified in Equation (C.1).

Cost dynamics

Next, we test for cost dynamics that would violate the AR(1) TFP transition assumed in the main text. In Figure C.2, we plot log(TFP) against log cumulative past output. No positive relationship emerges, in contrast to what would be expected if cost dynamics matter, as in the model of Benkard (2000). Furthermore, the coefficient on the ratio of surface to underground workers, which is an indicator of mine depth, in the production function is close to zero and insignificant, which seems in contrast to a TFP transition model where TFP changes dynamically due to mine depth.

Figure C.2: **Scatter plot of log TFP and log cumulative past output**



C.2 Compensating differentials

Another possible driver of the long-run evolution of markdowns are changes in compensating differentials due to changes in mining risk. This can also be interpreted as a specific case of monopsonistic competition with firm differentiation (for instance, see Lamadon et al., 2022). The arguments against firm differentiation as a plausible driver of markdowns forwarded in the main text thus also hold here.

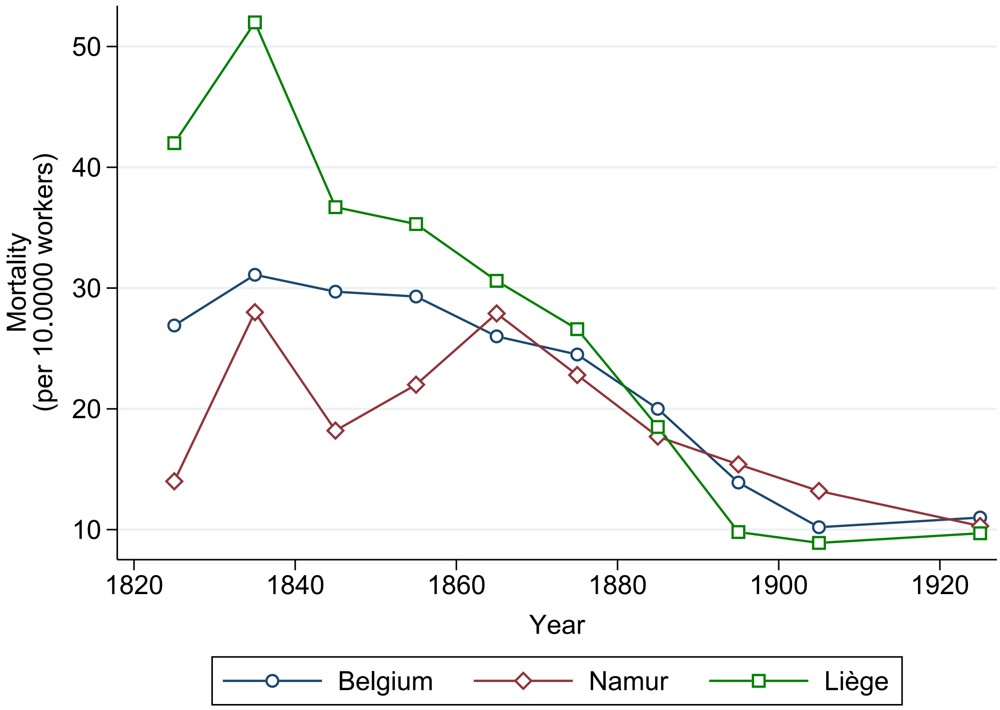
The nature of work changed substantially throughout 19th-century industrialization and it could be that the documented long-run pattern of markdowns reflects these changes: we rely on observed wages, but do not take into account an implicit risk premium. Changes in wages due to changes in the underlying risk premium would be interpreted as changes in markdowns in our model.[63] One specific dimension which merits attention in this context is the role of worker safety. Coal mining was a notoriously dangerous profession in that era, and coal firms have been found to provide some compensation to their workers for these professional hazards (Fishback, 1992, 125).

Could drastic changes in mine safety explain the markdown estimates as documented in this paper? In Figure C.3, we reconstruct the safety record of Liège-based coal mines in terms of fatal casualties for the long 19th century. From a Belgian perspective, mines in Liège were relatively dangerous because of their geological composition, with narrow coal veins. Throughout the second half of the century, however, working conditions improved substantially. This pattern, which fits the European picture, was supported by considerable investments in improved lightning and mechanical ventilation (Murray & Silvestre, 2015).[64] Crucially, most of these developments were completed before the end of the century. This means that the rise in markdowns we document in the early 20th century is unlikely to have been imposed on workers to make them pay for the cost of these safety-oriented investments.

[63] A similar argument has been raised in the living standards debate, in which pessimistic appraisals underlined that optimistic conclusions regarding 18th- and 19th-century wage growth forewent the negative impact of industrialization on non-wage working and living conditions (for a recent overview and comprehensive analysis, see Gallardo-Albarrán & de Jong, 2021).

[64] We also provided evidence of this in Figure 1a.

Figure C.3: **Number of fatal casualties in Liège-based coal mining (per 10.000 workers), 1850-1970**



Notes: Plotted are the decadal averages. No data is shown for the period 1910-1920.

Source: Coal mining accident data and employment are from the published accounts of the *Administration des Mines*, as cited in Leboutte (1991).

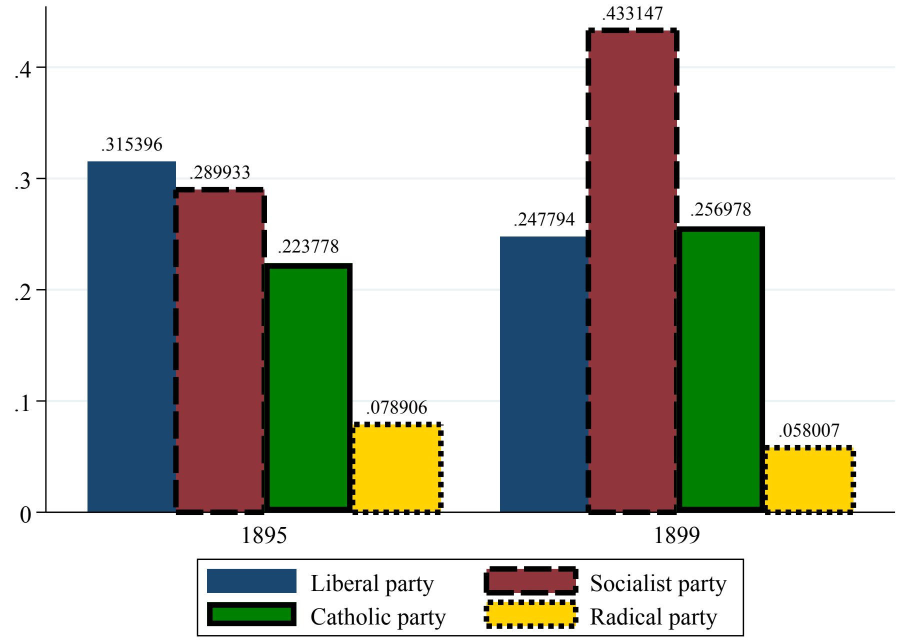
C.3 Political changes and democratization

The social movements of the final decades of the 19$^{\text{th}}$ century were successful in increasing political participation among workers in Belgium. From Belgium's inception in 1830, voting rights were distributed according to a system of census suffrage, in which only the wealthiest - about 7% of the adult male population on average - were able to vote (Stengers, 2004, 249). This was undoubtedly a contributing factor to Belgium's total commitment to a *laissez-faire* policy stance regarding labor and social issues. The emergence of the Belgian socialist party *Parti Ouvrier Belge* (POB) as well as increasing progressive voices within the liberal and catholic parties paved the way towards universal suffrage, although with plural voting rights such that the highest taxpayers maintained a disproportionate amount of political control.

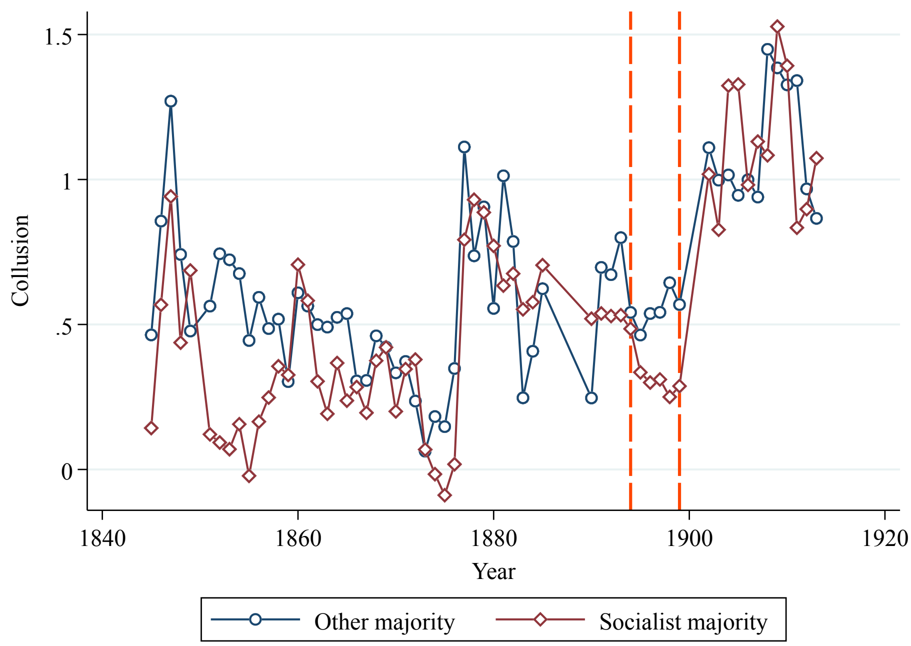
Figure C.4a documents the voter shares of the first two elections at the community level with universal suffrage, showcasing the popularity of the new POB within the Liège and Namur industrial areas. The question is now whether this newfound political independence of the working class translated into improvements of the workers' bargaining position. In Figure C.4b, we provide a first answer to this complicated question. We compare the evolution of employer collusion in socialist-dominated communities with those in which other parties had a political majority. It is apparent that socialist rule was not able to counter the documented upswing in employer collusion, with both categories experiencing a similar structural break in our collusion estimates.

Figure C.4: **Local election results in the coal communities of Liège and Namur, 1895-1899**

(a) **Evolution of voter shares**



(b) **Market-level median collusion by political majority**



Notes: The upper panel documents the substantial and increasing support of the POB in the communities of our sample. In the lower panel, we differentiate between communities with a socialist or another-party majority based on the results of the 1899 local elections. The two dashed vertical lines represent the 1895 and 1899 elections respectively.

Source: Local election results can be found in the archives of the Belgian ministry of internal affairs. This source was digitized by the *Quetelet Center for Quantitative Historical Research* (Ghent University).

Two caveats are to be placed with this tentative analysis. First, we forego the fact that other traditional parties also adapted their program to cater to the increasing demand for social policies.[65] This limits the validity of this counterfactual analysis, and monopsony and employer collusion could have even surged more in the absence of this emerging labor movement. Second and more importantly, many of the demands by the emerging labor movement would only be made a reality after the First World War. True universal male suffrage was only granted in 1919, allowing the POB to finally play an important role on the national political scene.[66] At the same time, however, the cartel era gained further steam, and cartels became increasingly formalized, even encouraged, by the Belgian government (Vanthemsche, 1983). It remains to be seen how these diverging trends affected market power and collusion on labor and product markets, as this period falls beyond the scope of our historical sources. We leave this intriguing question for future research.

[65] An important example is the 1891 encyclical of Pope Leo XIII, *Rerum Novarum* or *Rights and Duties of Capital and Labor*, which had a revolutionary impact on the Belgian christian party. In this letter, the Catholic leader also expressed his condemnation of what we would now call monopsony: "doubtless, before deciding whether wages axe fair, many things have to be considered; but wealthy owners and all masters of labor should be mindful of this - that to exercise pressure upon the indigent and the destitute for the sake of gain, and to gather one's profit out of the need of another, is condemned by all laws, human and divine" (Leo XIII, 1891).

[66] Uncoincidentially, it was also only in this era that trade unions would become legitimate political institutions as well as recognized partners in the wage bargaining process (see Section 2.2).

C.4 Alternative labor market definitions

Markdown correlations

In the main text, we defined labor markets at the municipality-level. The expansion of the railroad and tramway network could threaten the validity of this market definition. Figure A7 in Appendix A.2 shows that the railroad network expanded mainly from the 1840s to the 1870s, by 1880 all villages in our data set were connected to the railroad network. Starting in the 1880s, a local tramway network was added, which increased commuting options for workers who lived far from the local train station.

To check this, we examine whether wage markdowns differed in villages that were connected to the railroad or tramway network, given that 10% of workers commuted between 10 and 60 km, which indicates the usage of trains or tramways. As shown in Table C.1, we do not find that wage markdowns differed between villages connected to transport infrastructure and unconnected villages, and find no difference between urban and rural municipalities.

Table C.1: **Markdown correlates**

	log(Markdown)		log(Markdown)	
	Est.	SE	Est.	SE
1(Railroad)	-0.005	0.057	0.001	0.049
1(Tramway)	-0.059	0.053	0.026	0.066
1(Urban)	0.067	0.044	0.000	0.000
One firm	0.069	0.222	0.084	0.140
Two firms	0.100	0.079	0.136	0.077
Three firms	0.032	0.083	0.041	0.067
Mine FE	No		Yes	
Year FE	Yes		Yes	
R-squared	.124		.129	
Observations	3215		3215	

All these estimates indicate that labor markets were unconcentrated and flexible and that firms did not derive labor market power from being located in concentrated or isolated labor markets because workers could move around. This is consistent with the fact that Belgian coal mines, even those in rural areas, were located close to industrial urban centers, which offered outside employment options to the miners.[67] It is also consistent with the low geographical wage variation observed across the Liège and Namur coal basin, as we show in the next paragraph.

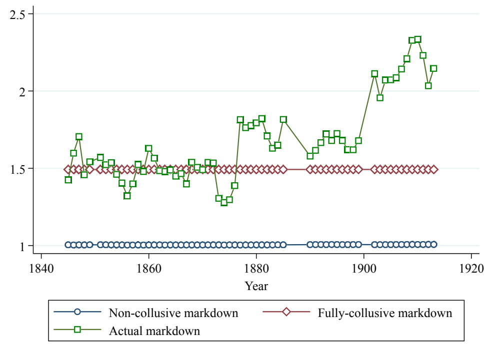
Changing the labor market definitions

Still, it could be that we defined labor markets too narrowly or too broadly. In order to check the robustness of our results, we re-estimate the lower and upper markdown bounds under zero and full collusion at different market definitions. In Figure C.5, we define labor markets consecutively at the single-digit postal code level, which corresponds to provinces, and the two-, three-, and four-digit postal code levels. The four-digit postal code level corresponds to municipalities, which is the market definition in the baseline specification. At the one- and two-digit levels, labor markets are so wide that individual firms have close to zero market shares, which implies that the non-collusive markdown in the Cournot model is close to one: individual firms have no wage-setting power. Using these market definitions, firms were already fully colluding on the labor market prior to forming the cartel, and reach a markdown above the collusive upper bound after the cartel. Contrary to this, defining labor markets at the three-digit level, which corresponds to groups of three to five municipalities, delivers very similar markdown bounds to those in the baseline specification.

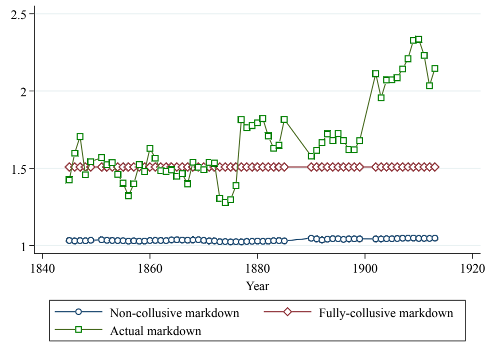
[67]This stands in stark contrast with the well-known examples of isolated mining towns in the U.S. (such as in Fishback, 1992). Rubens (2022) shows that in such a setting, looking at the Illinois coal mining sector, markdowns did vary with local labor market structure.

Figure C.5: **Median employer collusion index: different market definitions**

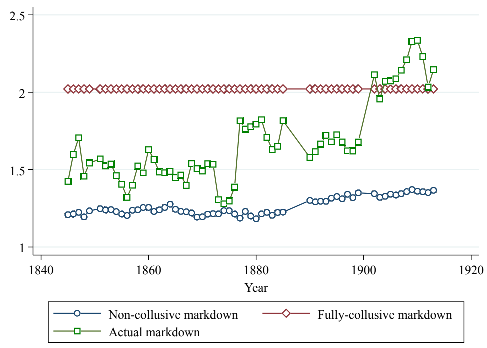
(a) **1-digit (Province) level**



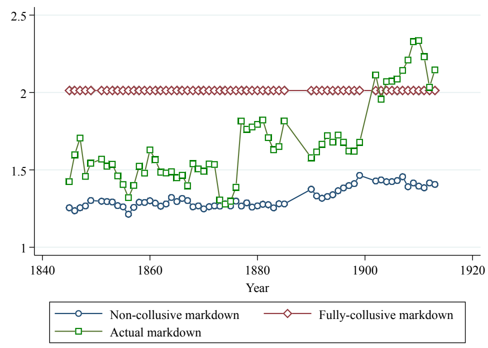
(b) **2-digit level**



(c) **3-digit level**



(d) **4-digit (Municipality) level**



Notes: This graph plots the evolution of median wage collusion, by year, together with block-bootstrapped confidence intervals between 1845-1913 (200 iterations).

D Wage markdown interpretation

In this Appendix, we show that the variable μ^l_{ft} can be interpreted as a 'wage markdown', being the ratio of the marginal revenue product of labor over the wage. Assume that firms maximize the following joint profit function, which is the profit maximization analogue of the cost minimization problem in Equation (3). Assume, for simplicity, that the product and labor market coincide at i; this is without loss of generality. Again denote the set of employers in market i in year t as $\mathcal{F}_{i(f)t}$.

$$\max_{L_{ft},M_{ft}} \Bigg(\underbrace{P_{ft}Q_{ft} + \sum_{g\in\mathcal{F}_{i(f)t}\setminus f} (\lambda_{fgt}Q_{gt}P_{gt})}_{\text{joint marginal revenue}} - \underbrace{W^l_{ft}L_{ft} - W^m_{ft}M_{ft} - \sum_{g\in\mathcal{F}_{i(f)t}\setminus f} (\lambda_{fgt}L_{gt}W^L_{gt} + M_{gt}W^M_{gt})}_{\text{joint marginal costs}} \Bigg) \tag{D.1}$$

Define the marginal (joint) revenue product of labor at firm f as:

$$MRPL_{ft} \equiv \frac{\partial(\Big(P_{ft}Q_{ft} + \sum_{g\in\mathcal{F}_{i(f)t}\setminus f}(\lambda_{fgt}Q_{gt}P_{gt}))}{\partial L_{ft}}$$

Working out the first-order condition for labor usage at firm f gives:

$$1 + \psi^l_{ft} + \sum_{g\in\mathcal{F}_{i(f)t}\setminus f} (\lambda_{fgt}\psi^l_{fgt}\frac{W^l_{gt}L_{gt}}{W^l_{ft}L_{ft}}) = \frac{MRPL_{ft}}{W^l_{ft}}$$

Hence, the term $\mu^l_{ft} = 1 + \psi^l_{ft} + \sum_{g\in\mathcal{F}_{i(f)t}\setminus f}(\lambda_{fgt}\psi^l_{fgt}\frac{L_{gt}W^l_{gt}}{W^l_{ft}L_{ft}})$ has the interpretation of a 'wage markdown': it is the ratio of the marginal joint revenue product of labor at firm f over its wage.