# Working time reductions and monopsony power

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May 28, 2025

**Abstract**

This paper studies the consequences of working time reductions when labor markets may be monopsonistic. A toy model shows that the marginal utility of a small working time reduction is negative when workers control schedules but positive when firms set hours. However, the policy increases wage rates in perfect competition but decreases monopsonistic wage rates. I test these predictions empirically by evaluating the first-ever working time reduction in Belgium: the maximum 9h workday in 1910's coal mines. I find that the policy had sizable negative effects on profits, employment and earnings. To assess welfare, I build a directed search model with matching frictions where firms have heterogeneous productivity and post wages and hours. Utilitarian welfare is expressed in terms of a sufficient statistic whose application to the 1910 reform suggests that the value of leisure was particularly large.

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# 1 Introduction

Since the Industrial Revolution, labor movements have fought for higher wages and shorter working time per day, per week and per year. Government-mandated working time reductions emerged at the beginning of the 20th century and remain highly heterogeneous across countries to this date. For instance, in France minimal paid time off was set at two weeks in 1936 and amounts to five weeks today, while the United States do not have any nationwide mandate on vacations.

The present paper studies the consequences of working time reductions for wages and welfare. It shows that these effects depend on the timing (i.e. who chooses what) as well as the extent of imperfect competition of the labor market.

In the first part of the paper, I build a simple general equilibrium toy model of the labor market where production features decreasing returns to hours and workers face the canonical leisure-consumption tradeoff: an extra hour worked increases utility through consumption but decreases utility through leisure. This model brings two key findings.

First, the welfare effects depend on *who sets schedules*. If workers choose hours as in neoclassical labor supply theory, the marginal utility of an extra hour worked must be zero. Conversely, when firms choose hours, the labor contract will feature long hours and workers would welcome a working time reduction for a given wage. This suggests that workers are more likely to support government intervention on working time when they do not control schedules.

Second, the wage effects depend on *who sets wages*: a working time reduction decreases wage rates in an oligopsonistic labor market but the very same policy increases wage rates in perfect competition. Intuitively, in the pure monopsony case, labor supply increases in wages such that a working time reduction must be associated with a wage cut. Conversely, in a perfectly competitive labor market, workers' earnings are equal to their marginal product. Decreasing returns per hour implies that a working time reduction by one unit engenders a reduction of marginal product by less than one unit. Hence, earnings decrease proportionally less than hours worked, which implies that competitive wage rates have increased after the reform.

In order to evaluate these empirical predictions, the paper studies the first-ever working time reduction implemented in Belgium: the 9 hour maximum workday in coal mines in 1910. It is an ideal setup for at least two reasons. First, as one of the first piece of labor legislation in the country, the law was not coupled with compensatory measures nor wage regulations such that we should be able to observe the pure effect of the policy.[1] Second, there was no downward nominal wage rigidity at the time which should allow to test for wage cuts.

I digitized and assembled administrative datasets from archival sources covering the near-universe of coal mines in the country from 1903 to 1913. The identification strategy follows an event study design and relies on comparing post-reform outcomes of firms with different scheduling practices before the reform. I find sizable, short-run, negative effects of the reform on profits: a one-hour reduction in miners' working day reduces profits by 93%. I also find negative yet imprecise effects on employment and wages: a reduction of working time by one hour decreases employment and wages by 6% on average over affected firms.

While leisure increased, wages, employment and profits fell. To assess whether this reform was welfare-improving, I embed the model and these results into a directed search model and competitive search equilibrium of the labor market à la Moen (1997) where firms are heterogeneous in productivities. Matching frictions ensure that all participating workers have some non-degenerate job-finding probability. Hence, when a government grants extra holidays, ex-post utilities increase conditional on employment but job-finding probabilities might decrease. In turn, this model aggregates individuals' micro leisure-consumption trade-offs in a macro arbitrage between wages, employment and hours worked.

As in Vergara (2023), this competitive search equilibrium is compatible with any degree of monopsony power. Indeed, when a firm increases wage rates, it will attract new applicants. Yet, because of matching frictions, the probability that these additional applications fill a vacancy is less than one. Workers internalize these frictions such that only a finite number apply. As a result, the labor supply curve observed by the firm is not infinitely elastic and this creates some monopsony power in equilibrium. I derive two main findings.

First, I study how heterogeneous firm sort in the contract space. It is shown that firms with higher productivity offer contracts with higher wage rates, shorter hours, and a higher job quality but lower job-finding probability. On the workers' side, a local increase in the preference for leisure leads to a higher equilibrium wage rate and lower hours worked.

[1] For example, the French 35h workweek reform studied in Chemin and Wasmer (2009) was accompanied with payroll tax cuts. In the US, Roosevelt's working time reductions were accompanied with wage regulations (see Fishback et al. (2024) for the National Industrial Recovery Act of 1933 and Costa (2000) for the Fair Labor Standards Act of 1938).

Second, I derive sufficient statistics and quantity welfare gains. Interestingly, welfare may be assessed without assumptions on production nor on the degree of monopsony power in labor markets, which is known to vary significantly across contexts and industries (Azar et al., 2022; Card, 2022). I estimate that the average utility gains in leisure must have been sizable for the Belgian reform to produce welfare gains.

Overall, the paper makes two kind of contributions. On the positive side, the paper derives empirical predictions for the wage effects of working time reductions and shows that they differ with the degree of firms' labor market power, i.e. monopsony power. These results can act both as a characterization of monopsony power as well as a detection test. On the normative side, the paper derives sufficient statistics for welfare evaluation of any working time regulation in a general equilibrium environment with rich heterogeneity, matching frictions and imperfect competition in the labor market. In terms of policy, the paper suggests that working time reductions are appealing for workers in monopsonistic markets but their equilibrium effects on wages and employment may offset the welfare gains.

Section 2 discusses the relationship with the literature. Section 3 presents the toy model which contrasts the effect of working time reductions on marginal utility and wage rates depending on who sets hours and wages. Section 4 presents a reduced-form empirical evaluation of the Belgian coal mines 1910 maximum workday and test for these predictions. Section 5 generalizes the model with a competitive search equilibrium between firms with heterogeneous productivities and workers with heterogeneous leisure preferences and it studies the effects on welfare. Section 6 concludes.

# 2 Literature

**Canonical labor models** This paper merges two standard models in labor economics. On the one hand, leisure-consumption trade-offs determines labor market equilibrium like in Rosen (1974, 1986)'s hedonic theory of wages. On the other hand, the model features directed search and competitive search equilibrium[2]. While matching frictions were added to hedonic wages by Hwang et al. (1998) and Lang and Majumdar (2004), they assumed random search rather than directed search. The present paper adds working time and hedonic wages to Vergara (2023) who studied minimum wages in a competitive search equilibrium. As a result, labor supply is not derived from utility-maximization but from profit maximization under a utility constraint.

[2]Key references include Acemoglu and Shimer (1999), Eeckhout and Kircher (2010a, 2018), Guerrieri et al. (2010), Kircher (2009), Moen (1997), Vergara (2023), and Wright et al. (2021)

**Working time regulations** Descriptive facts on vacations can be found in Altonji and Oldham (2003) and Altonji and Usui (2007). Marimon and Zilibotti (2000) and Rocheteau (2002)[3] considered that a working time reduction is desirable if it reduces unemployment. In the present paper, social welfare encompasses the tradeoff between the terms of jobs and the number of jobs. Carry (2023) studied a unique minimum workweek policy in France and builds a model with quasilinear utilities and random search. All of these papers model wage-hour determination as the outcome of bargaining while the present model has contract posting which features two advantages. First, it allows me to escape the assumption that bargaining power is invariant to policy changes, which seems implausible in the present context. Second, posting has been found more relevant than bargaining empirically for low-wage jobs (Caldwell & Harmon, 2019; Hall & Krueger, 2012; Lachowska et al., 2022).

Importantly, Fishback et al. (2024) studied the effect of the introduction of the maximum workweek in the US during the Great Depression which was accompanied with wage and earnings floors. There are several important differences with the current paper. First, the policy in the US was motivated by work-sharing arguments in a acute recession where unemployment was plaguing the economy. This is not the case in the Belgian 1910 context: the business cycle was neither booming nor recessionary. Second, they find massive positive effect on employment while we find the opposite effect. Third, they study a perfectly competitive labor markets with voluntary unemployment, while we allow for the possibility of monopsony power and involuntary unemployment.

**Hours and employment** Empirical studies found conflicting effects of wage and hours regulations. Some papers documented that increases in minimum wages lead to decreases in hours worked (Di Nola et al., 2023; Gandhi & Ruffini, 2022; Jardim et al., 2022; Kim et al., 2023) but Vergara (2023) finds no effect. Most minimum wage studies finds no effect on employment (Cengiz et al., 2019; Manning, 2021). Gravoueille (2023) showed that an increase in low-earners wage subsidies led to an increase in hours worked but a decrease in wage rates. Carry (2023) finds that low-hours contract restrictions led to a decrease of low-hour jobs at the extensive margin and an increase in the intensive margin of full-time jobs. The present paper provides a unifying theory for such results. Its key elements are the output elasticities of hours versus hires as well as the degree of monopsony power.

[3] Other related papers include Fagnart et al. (2023), Lang and Majumdar (2004), Osuna and Rıos-Rull (2003), and Willington and Navarro (2015). Chemin and Wasmer (2009) studied the French 35-hour workweek and Fishback et al. (2024) studied the Roosevelt working time reduction during the Great Depression.

**Amenities** The literature has focused on positive questions[4] such as the relationship of amenities to earnings and productivity (Mas & Pallais, 2017, 2020; Ouimet & Tate, 2023; Sockin, 2022; Sorkin, 2018), monopsony power (Lamadon et al., 2022), job search (Hall & Mueller, 2018), and minimum wages (Clemens, 2021; Clemens et al., 2018). However, the normative aspects of regulating amenities have not been addressed such that the present paper complements this literature. A notable exception is Nekoei (2023) who suggests that mandating amenities can improve efficiency if there is adverse selection à la Akerlof. Yet, in Nekoei (2023) amenities do not have productive value for the firm per se, contrary to hours worked in the present paper.

# 3 Toy model: who chooses what?

In this section, I contrast the theoretical effects of working time reductions on wages and utility depending on who sets hours and wages. I build a simple general equilibrium model of the codetermination of wages and hours.

A firm produces using only hours, denoted by $l$, through a production function $F(l)$ which is assumed to be increasing and concave. Hours are bounded above by a natural constraint, normalized to 1 such that the government must chose a legal maximum $\bar{l}$ in the interval $[0, 1]$. The labor contract specifies a quantity of hours worked $l$ at a unit price $w$ such that firm's profits $F(l) - wl$ must be nonnegative for it to participate.

Workers have a utility function $u(c, l)$ that is increasing in consumption $c$ and decreasing in hours worked $l \in [0, 1]$. They have an outside option to the labor contract that gives a reservation utility $u_r$. When working, their consumption is equal to their earnings $c = wl$. Interestingly, the marginal utility of an extra hour $\frac{\partial u(\cdot)}{\partial l} = wu'_c + u'_l$ has an ambiguous sign: at low hours, workers would like to work more at the wage rate $w$ because the positive consumption effect dominates the negative leisure effect while this is reverted for long hours. For regularity, I assume that the workers' preferred schedule is neither 0 nor 1[5].

I have two main objects of interest. First, I will sign the marginal utility of an extra hour $\frac{\partial u(\cdot)}{\partial l}$ before the introduction the policy $\bar{l}$. When it is negative, workers would like to work less at the given wage rate such that they would welcome a working time reduction with rigid wages. Second, I study how the introduction of a small binding working time reduction $\bar{l} < l$ affect equilibrium wage rates.

[4]See Lavetti (2023) for a recent review.

[5]Formally, I impose that for any $w$ we have a $l^* \in (0, 1)$ such that $\frac{\partial u(wl^*, l^*)}{\partial l} = 0$.

The theoretical predictions depend on the definition of strategy sets: who chooses hours and who chooses wages? I will consider four different models. In model 1, workers choose hours to maximize utility and wage rates are competitive. In model 2, workers choose hours but the firm sets wage rates. In model 3, the firm sets hours to maximize profits but wage rates are competitive. In model 4, the firm sets both hours and wage rates. Models 1 and 2 use the neoclassical theory of labor supply while models 3 and 4 use the hedonic theory of labor supply. Models 1 and 3 correspond to perfectly competitive wages while models 2 and 4 correspond to monopsonistic wages. These models are illustrated in Figure 1.

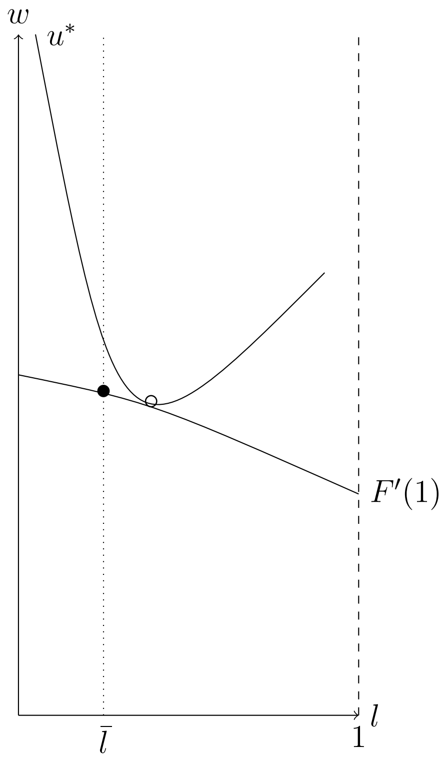
In model 1, workers choose hours to maximize utility such that one must have that $l = \arg\max u(wl, l)$ for any given $w$ and $l \in [0, \bar{l}]$. Hence, it must be that the marginal utility of working an extra hour is nonnegative $\frac{\partial u(\cdot)}{\partial l} \geq 0$ in equilibrium and equal to $0$ in interior solutions. Because wage rates are competitive, workers are paid at their marginal product and $w = F'(l)$. Concavity in production function implies that the marginal product is decreasing in hours such that a binding working time reduction must increase $F'(l)$ and hence equilibrium wage rates $dw \geq 0$.

In model 2, workers set again hours such that $\frac{\partial u(\cdot)}{\partial l} \geq 0$. However, firm sets monopsonistic wage rates to maximize profits internalizing the neoclassical labor supply. This gives rises to the standard Robinson (1933) monopsony equation $F'(l) - w = \frac{l}{l'(w)}$ where $l'(w)$ is the derivative of the labor supply function. When $l(w)$ is increasing[6], a working time reduction must necessarily be associated with a decrease in equilibrium wage rates $dw \leq 0$.

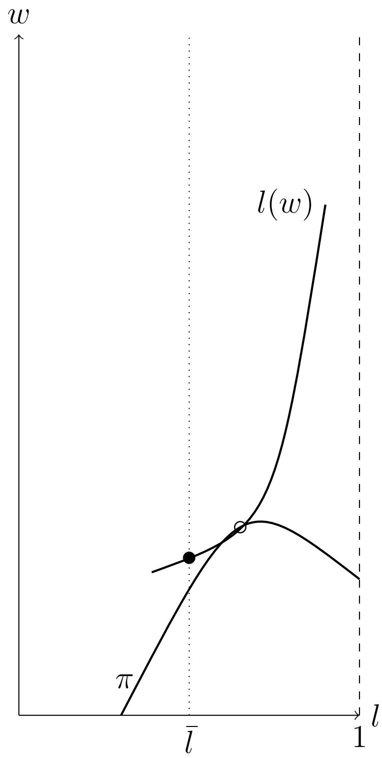
In model 3, the firm chooses hours to maximize profits and wages are competitive $w = F'(l)$ such that the optimal schedule solves $l = \arg\max F(l) - lF'(l)$. Because $F(\cdot)$ is concave, this objective increases in $l$ such that the solution is a corner solution: hours will be set at their largest admissible value, that is $l = \bar{l} \leq 1$. When workers have no leisure and $l = 1$, they will welcome a working time reduction such that $\frac{\partial u(\cdot)}{\partial l} \leq 0$. Here again, because $F'(l)$ is decreasing in hours, a working time reduction increases wage rates in equilibrium $dw \geq 0$.

Finally, in model 4, firms choose both wage rates and hours to maximize profits. Equivalently, the firm chooses the profit-maximizing contract on the workers' reservation indifference curve $u_r$. Necessarily, this is a contract with long hours and low wage

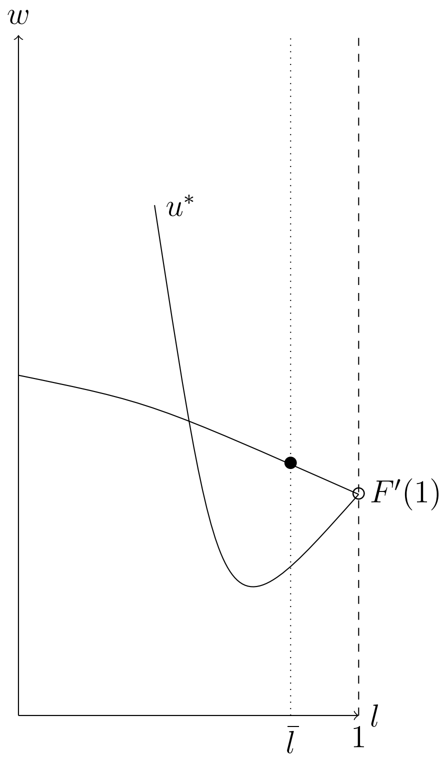
[6]The fact that $l(w)$ is increasing implies that the substitution effect dominates the income effect in the Slutsky equation of workers. This guarantees that workers are paid below their marginal product $w < F'(l)$ which is a widely-documented empirical fact by the monopsony literature (see Card (2022) e.g.).



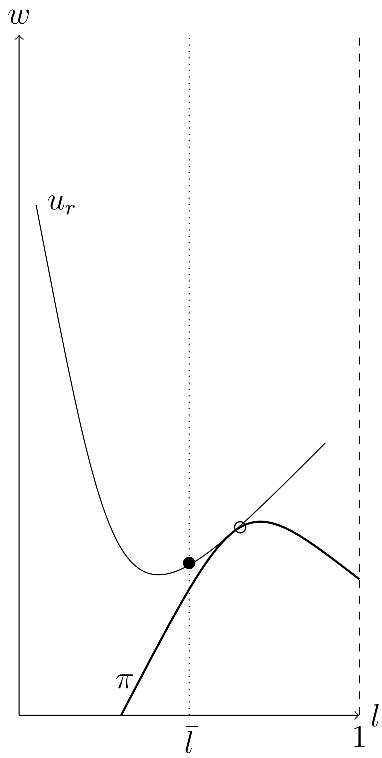

(a) Model 1: workers choose hours, competitive wage rates




(b) Model 2: workers choose hours, firm chooses wage rates




(c) Model 3: firm chooses hours, competitive wage rates




(d) Model 4: workers choose hours and wage rates

Figure 1: Equilibrium before (○) and after (•) a small binding working time reduction $\bar{l} < l$.

| Who sets $l$ ? | Utility-maximizing $l$ | | Profit-maximizing $l$ | |
|---|---|---|---|---|
| Who sets $w$ ? | Competitive $w$ | Firm sets $w$ | Competitive $w$ | Firm sets $w$ |
| | *Model 1* | *Model 2* | *Model 3* | *Model 4* |
| Marginal utility of $l$ | $\frac{\partial u(\cdot)}{\partial l} \geq 0$ | $\frac{\partial u(\cdot)}{\partial l} \geq 0$ | $\frac{\partial u(\cdot)}{\partial l} \leq 0$ | $\frac{\partial u(\cdot)}{\partial l} \leq 0$ |
| Equilibrium after $\bar{l} < l$ | $dw \geq 0$ | $dw \leq 0$ | $dw \geq 0$ | $dw \leq 0$ |

Table 1: Summary of theoretical predictions in the four different models.

rates such that the marginal utility of an extra hour at that wage rate is negative $\frac{\partial u(\cdot)}{\partial l} \leq 0$ and workers would welcome a working time reduction. However, in equilibrium they must remain on the same indifference curve $u_r$, such that the utility gains generated by the policy on leisure will be fully compensated by a loss in wage rates, such that $dw < 0$.

In Table 1, I summarize the theoretical predictions on $\frac{\partial u(\cdot)}{\partial l}$ and $dw$ for the four models. The main results of this section can be summarized as follows. First, if wages are rigid, workers are more likely to be favorable to government-mandated working time reductions when firms set hours. Second, the very same working time reduction increases competitive wage rates but decreases monopsonistic wage rates[7].

All these results are derived with only one labor input in the production function. In Appendix A, I consider a production function $F(N, l)$ that may have an imperfect sustainability between jobs $N$ and hours worked $l$. I show that the main results carry over provided that the output elasticity of hours exceeds the output elasticity of jobs $lF'_l > NF'_N$. In section 5, I build a search and matching model of the labor market with production function $F(N, l)$ and study the welfare effects of the policy.[8]

# 4 Reduced-form policy evaluation

## 4.1 Institutional context

At the time of the reform, Belgium's coal industry was mature and the coal-producing provinces were among the highest GDP per capita regions in Europe (Rosés & Wolf, 2021). As the first country to industrialize on the European continent, Belgium relied heavily on coal extraction to provide manufacturing industries with cheap energy (Philips & Buyst, 2020).

[7]Interestingly, the Roosevelt administration introduced the minimum wage alongside a working time reduction, see Fishback et al. (2024).

[8]It would be easy to show that models 1 and 2 imply that working time reductions are inefficient while models 3 and 4 give a redistributive role to working time reductions. Welfare when production includes employment is less obvious (and therefore more interesting) because working time reductions affect not only the quality but also the quantity of jobs.

The policy under study is the first major piece of labor regulation affecting prime-age males in the country.[9] Meanwhile, neighboring countries already had some form of working time regulations in the mining industry: for example, France had a maximum workday of 10 hours in 1900 and 8 hours in 1905.[10] Compared their competitors, Belgian coal mines were relying more on manual labor and less on mechanized extraction (Denoël, 1909). They also exhibited a smaller mortality risk (Leboutte, 1991) despite longer workdays (Cousot, 1908).

The policy was passed on December 31, 1909 and imposed that a workday for underground workers could not exceed 9 hours 30 minutes from January 1, 1911 and 9 hours from January 1, 1912.[11]. Before this, there was no regulations on daily schedules. Exceptions were granted for some specific underground occupations such as horseman or cagers, but these exceptions may not exceed one hour per day. Violations were subject to civil fines or criminal charges.

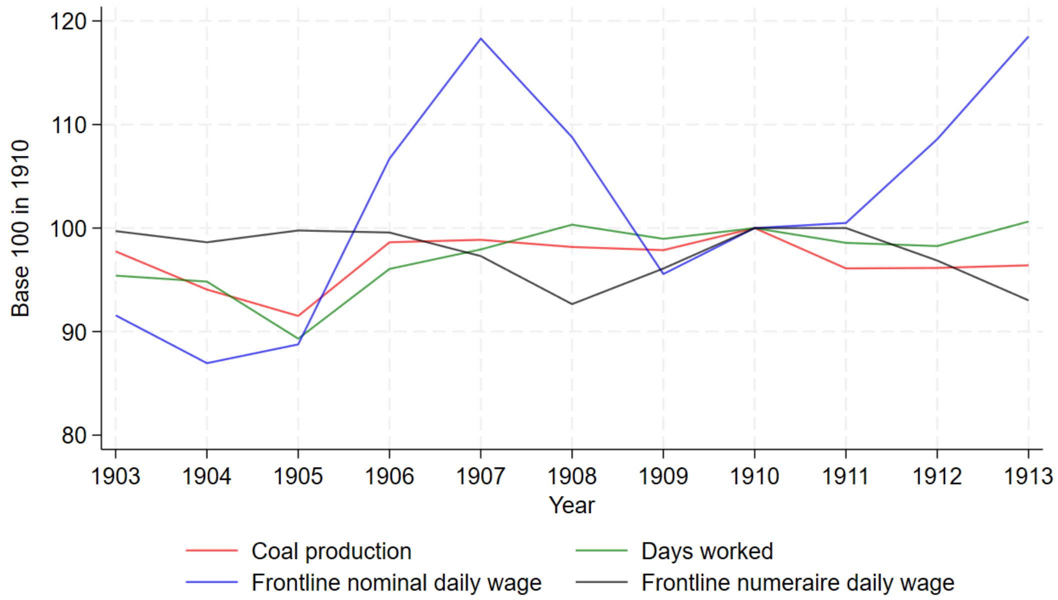
There are two main reasons why studying this reform is interesting with respect to our research question. First, there is no confounding policy at the same time: there was no payroll tax and barely any other labor regulations. This contrasts with modern-day reforms on working time where these policies are typically coupled with support measures such as payroll tax reductions, rendering identification of the pure impact of working time reductions tedious.

Second, there was no downward wage rigidity at the time. In Figure 2, we show that wages display a striking cyclicality both in nominal and real terms. This holds both for the average firm-level wage in panel (a) and for the aggregate variables in panel (b). It also holds in terms of average wage per worker as well as firm-level labor expenditures. In principle, if working time reductions were inducing equilibrium wage cuts $dw \leq 0$, our setting should allow us to observe them.

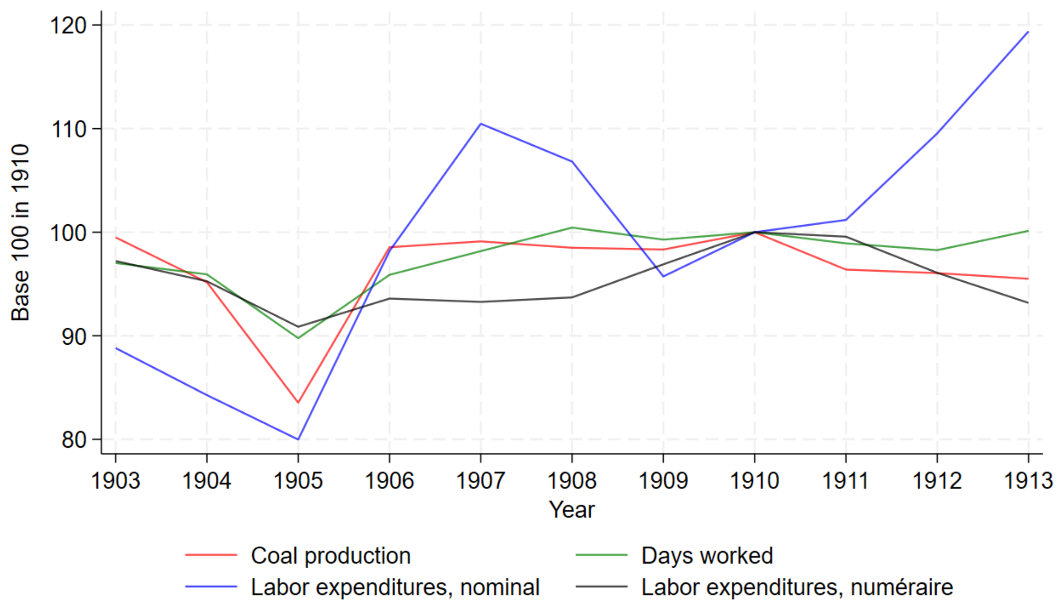
[9] Earlier regulations were mostly targeted to female and child labor. In the mining industry, underground labor was prohibited for women younger than 21 and male children below 12 from 1892 onward (Annales des Mines, 1907). The 1910 refrom was among the first policies to break the *Laissez-faire* tradition on which Belgium was built, which consisted in low tariffs and few regulations (Abbeloos, 2008).

[10] In the Netherlands, the maximum workday was 8.5 hours in 1908. In Prussia, the maximum workday was 8 hours in 1905 and even limited to 6 hours in mines where temperature exceeds 28 degrees Celsius (Cousot, 1908).

[11] Working time must be understood as *from bank to bank*, i.e. the time from the surface at the beginning of the working day to the time at the surface at the end of the working day. Hence, it includes the time in the lift as well as time needed to walk from the lift to the work station.




(a) Evolution of the cross-sectional average for selected firm outcomes with respect to base year 1910. Coal production is measured in tons of coal while total days worked include all occupations within the firm. The frontline daily wage is the firm-level average wage paid for a working day to frontline miners. The blue line is the nominal wage in current Belgian francs while the black line is expressed in terms of the numéraire, i.e. divided by the price of output.




(b) Evolution of aggregates over firms for selected outcomes with respect to base year 1910. Coal production is measured in tons of coal while total days worked include all occupations within the firm. The blue line is the nominal labor expenditures in current Belgian francs while the black line is expressed in terms of the numéraire, i.e. divided by the price of output.

Figure 2: Descriptive statistics over the business cycle of Belgian coal mines, 1903-1913.

## 4.2 Data

I use administrative data retrieved from archival sources. The coal mining industry was closely scrutinized by the government for several reasons. First, coal mines were subject to a tax (composed of a fee and a linear rate), although it only raised a modest amount: 1.5 million BEF in 1903 i.e. 0.3% of the state's revenue (Chamber of Representatives, 1903). Second, coal mines were important to the state for industrial, political, social, and economic factors. More than 100,000 workers were directly employed in coal mining while 37% of GDP was produced by the manufacturing sector (Buyst et al., 1995). Third, as all mineral resources belonged to the state but were leased for private exploitation[12], the government was keen on monitoring production.

As a result, the Mining Administration kept a consistent record of data of remarkable quality for the time. Each year in August, state officials[13] were sent to each mine to collect statistics on production, prices, employment and wages. These reports were then collected by the administration to establish a firm-level panel dataset. In Figure C.1, I provide examples of a report in (a) and of the panel dataset in (b).

I digitized the panel dataset for the province of Hainaut while Delabastita and Rubens (2025) digitized the provinces of Liège and Namur. In 1910, the province of Hainaut accounted for 71% of national coal production and 67% of labor expenses. The combination of these efforts yields a dataset covering the universe of mines in the country from 1903 to 1913.

This dataset contains firm-level information on annual production, costs, employment and wages but not on daily working time. Yet, as one of the first piece of labor legislation, this reform was highly controversial in parliament[14] which initiated a parliamentary commission. This commission produced over 3000 pages of documents and requested information on daily hours worked to the Mining Administration. The latter collected firm-level hours worked in August 1900 and published the data in parliamen-

[12]This tradition was inherited from the French domination rather than the Dutch domination. The Imperial Law of April 21, 1810 promulgated by Napoleon set the basis for such leasing on minerals and served as backbone of Belgian legislation on mining. By contrast, in 1900 the Dutch government still had a monopoly on two third of national production.

[13]These officials were public servants with a high level of education such as mine engineers. Besides collecting statistics, these officials also had a role of policing, advising and studying the mines.

[14]The bill was introduced by socialist M.P. Destrée in 1903. From 1884 and until World War I and despite electoral reforms toward universal suffrage, the Catholic party had an absolute majority and initially opposed the maximum workday in the coal mines, as did King Leopold II. In 1907, some Catholic MP flipped their vote and created a political crisis which culminated in the resignation of the prime minister and mine owner Count de Smet de Nayer (Neuville, 1981). The new government initiated a Parliamentary Commission. Documents contain interviews of workers and mines owners but also technical reports from academics in economics and engineering.

tary proceedings in 1907 while noting that "*the situation has barely changed since then*" (Annales des Mines, 1907, p.556). Table 2 reports summary statistics for this cross-sectional data on hours worked by geological region.

| **Hours** | **Mons** | **Centre** | **Charleroi** | **Namur** | **Liège** | **Total** |
|---|---|---|---|---|---|---|
| $(7.5, 9]$ | 2 | 2 | 0 | 5 | 30 | 39 |
| $(9, 9.5]$ | 2 | 0 | 4 | 1 | 9 | 16 |
| $(9.5, 10)$ | 1 | 0 | 0 | 0 | 2 | 3 |
| $[10, 12]$ | 13 | 8 | 31 | 5 | 4 | 61 |
| **Total** | 18 | 10 | 35 | 11 | 40 | 114 |

Table 2: Firm-level average daily hours worked for frontline workers before the reform, by geological region.

Before the reform, more than 70% of the mines were above the 9 hour threshold. While geology seems to play a role as workdays are longer in Mons than in Liège geological regions (Vandervelde, 1911), there also exists within-region variation.

Overall, the cross-section of hours worked contains 114 firms which is a fraction of the universe of firms contained in the panel. All estimations below are computed on a dataset matching this panel with the cross-section of hours worked. As reported in appendix Table C.2, this matched dataset covers more than 96% of production and employment. The unbalanced panel of firms contains entities that merged, were acquired or exited the market. In the remainder, I consider that a merged entity is a new firm while an acquired firm espouses the identity of its acquirer. For details on the construction of variables, I refer the reader to Appendix C.2.

Besides datasets, these archival sources also provide qualitative information on the context of the reform. In particular, the parliamentary commission interviewed mine owners and workers in various locations and asked their opinion on the reform. These interviews are helpful to understand the labor conflict : all owners opposed the reform and threatened to compensate its effect by cutting wages. On the workers' side, all were in favor of a reform cutting hours holding wages constant. Some were in favor of the reform even if wages were cut while others opposed wage cuts (Parliamentary Commission, 1909). This qualitative evidence is consistent with model 4 in section 3 where firms set both hours and wages and the marginal utility of an extra hour is negative $\frac{\partial u(\cdot)}{\partial l} \leq 0$.

### 4.3 Policy evaluation

The empirical strategy uses pre-reform hours worked as a measure of exposure to the reform. I construct the continuous variable $\text{Exposure}_j$ as the difference between the hours worked by frontline workers at firm $j$ and the maximum workday of 9 hours. It is set to 0 for a firm which was already below the 9h threshold before the reform.

$$\text{Exposure}_j = \max\{\text{Frontline\_Hours}_j - 9; 0\}$$

The average $\text{Exposure}_j$ among firms with positive exposure is 1.03 hours with a standard deviation of 0.43. The main specification follows the following regression equation:

$$y_{j,t} = \beta_0 + \sum_{k \neq 1909} \beta_k \times \text{Exposure}_j \times \mathbf{1}_{t=k} + \mu_j + \nu_{r,t} + \beta X_{j,t} + \epsilon_{j,t}$$

where $y_{j,t}$ denotes the outcome for firm $j$ in year $t$, $\mu_j$ and $\nu_{r,t}$ are firm and region-by-year fixed effects respectively, $X_{j,t}$ are a set of controls and standard errors $\epsilon_{j,t}$ are clustered at the firm level. The coefficients $\beta_k$ are the objects of interest. Because of the construction of $\text{Exposure}_j$, $\beta_k$ can conveniently be interpreted as the average effect in year $k$ across treated firms of a mandated one-hour reduction. The omitted year is set to 1909 which is the last year before the law is passed. As compliance is unobserved, this effect should be interpreted as an intention to treat.

This strategy is standard in the policy evaluation literature (Carry, 2023; Harasztosi & Lindner, 2019; Saez et al., 2019). The identifying assumption is that firms with different hours worked before the reform would have had parallel evolution in their outcomes if the reform had not happen. This assumption could be rejected if $\beta_k$ significantly differs from $0$ in years prior to the reform.

**Profits**. I find a large and negative effect of the reform on profits: a reduction of one hour per day reduces profits by 7962 and 6009 tons of coal in 1911 and 1912 respectively as reported in Figure 3. These effects are economically significant as the average profit for firms above the 9h threshold before 1910 was 8473 tons of coal. This confirms anecdotal evidence that the reform was not anticipated and had largely adverse effects on mine owners. I now decompose the results into firms' reactions along the extensive and the intensive margins.

**Extensive margin** Given adverse effects on profits, firms may react to the policy along the extensive margin by exiting the market. In Table C.3, I report the count of firms' exit per year. While only one firm exited the market in the period 1903-1909, 6

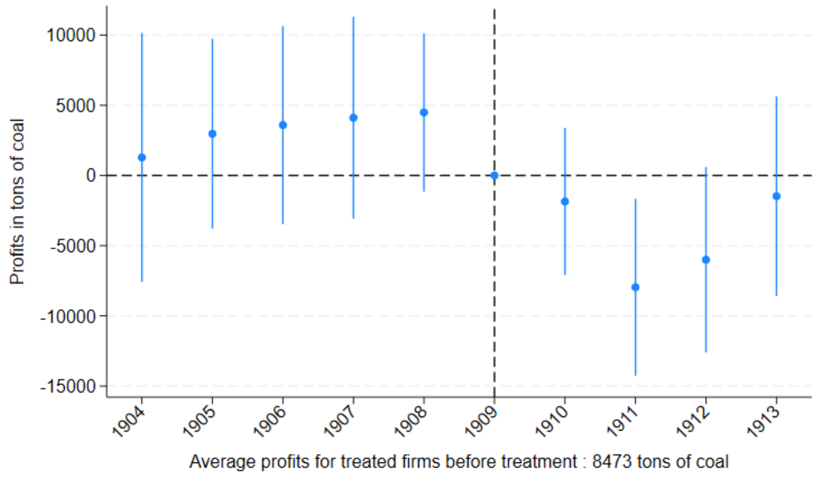


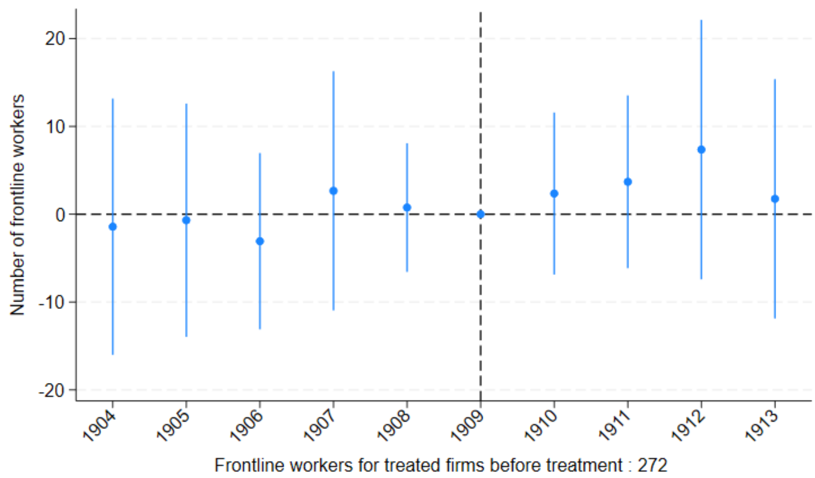

Figure 3: $\beta_k$ for each year if $y_{j,t}$ are firms' profits in units of the numéraire. Controls $X_{j,t}$ are size of exploitation at the surface in squared meters, TFP, average power of coal veins, share of frontline workers, share of underground workers and tons of coal of auto-consumption. The p-value for testing $H_0 : \beta_k = 0 \ \forall k < 1909$ is 0.64. The within R-squared is $0.3207$.

firms shut down operations after 1909.

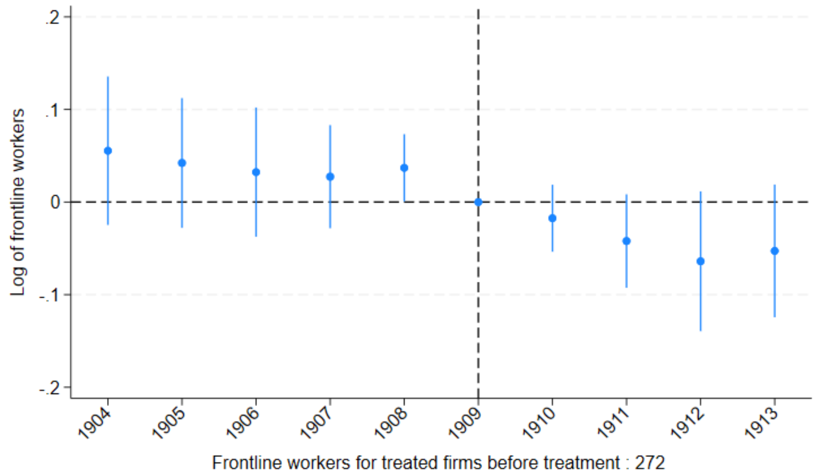
**Intensive margin: employment** The intensive margin reactions are computed on the subsample of firms that never shut down operations.[15] In Figure 4, I report the values of $\beta_k$ for regressions with $y_{j,t}$ being the number of frontline workers in panel (a) and the log of that number in panel (b). Both effects are somewhat noisily estimated and should be interpreted with caution: panel (a) suggests that a mandated reduction of working time by one hour does not affect differentially firms with unequal Exposure$_j$ in absolute terms but panel (b) suggests a negative effect in relative terms. In Table C.3, I show that firms with positive Exposure$_j$ (i.e. targeted by the reform) were on average twice larger than firms with zero Exposure$_j$ (i.e. non-targeted) before the reform. Hence, these results are consistent with a story where the reform increases the number of frontline workers by a similar magnitude in both targeted and non-targeted firms, which implies that the percentage change is larger in the latter than the former.

**Intensive margin: earnings** In Figure 5, I show $\beta_k$ for each year if the dependent variable is either the log of frontline workers' earnings in panel (a) or the log of all underground workers' earnings in panel (b). Both panels suggests that a working time reduction has a non-positive effect on earnings although here again the estimation is noisy: a mandated working time reduction of an hour reduces average earnings for underground worker by 6.18% in targeted firms related to non-targeted firms in 1912.

[15]This is motivated by the fact that intensive margins responses are comparable when one uses log transformations for which $0$ values create indeterminacy. See Chen and Roth (2024) for a characterization of the problem and motivations for splitting results along the intensive and extensive margins.

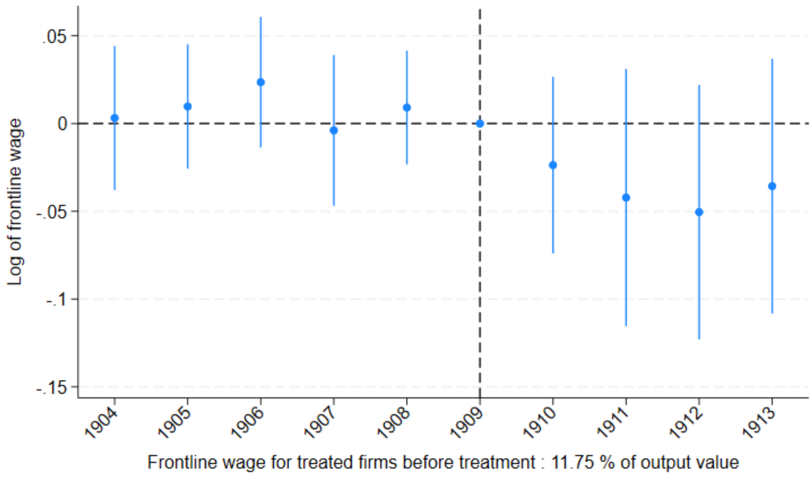



(a) Number of frontline workers. The p-value for $H_0$ is $0.73$. Within R-squared is $0.55$.

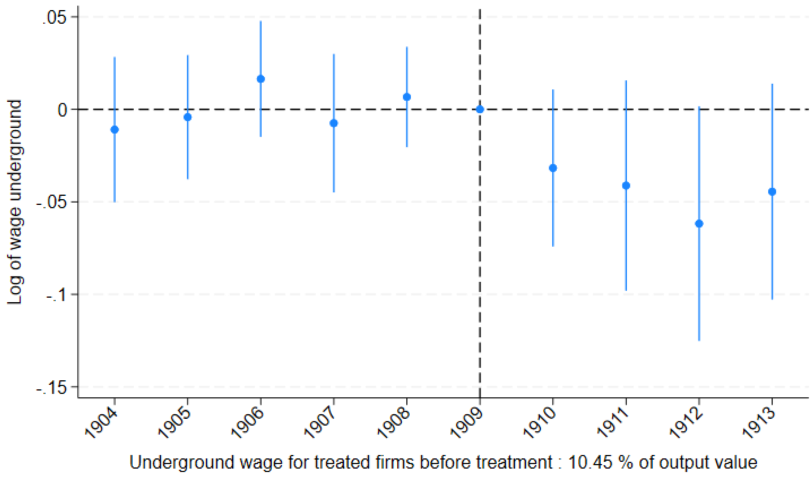



(b) Log of the number for frontline workers.The p-value for $H_0$ is $0.34$. Within R-squared is $0.45$.

Figure 4: $\beta_k$ for each year. Standard errors are reported at 95% confidence level. I report the p-value of the joint statistical test with $H_0 : \beta_k = 0$ for all $k < 1909$. Controls $X_{j,t}$ are size of exploitation at the surface in squared meters, TFP, average power of coal veins, share of frontline workers, share of underground workers and the output price in current BEF.




(a) Log of earnings of frontline workers. The p-value for $H_0$ is $0.16$. Within R-squared is $0.66$.




(b) Log of earnings for underground workers.The p-value for $H_0$ is $0.10$. Within R-squared is $0.72$.

Figure 5: $\beta_k$ for each year. Standard errors are reported at 95% confidence level. I report the p-value of the joint statistical test with $H_0 : \beta_k = 0$ for all $k < 1909$. Controls $X_{j,t}$ are size of exploitation at the surface in squared meters, TFP, average power of coal veins, share of frontline workers, share of underground workers and the output price in current BEF.

In Table C.4, I show that the results obtained here with event-study regressions are broadly consistent with those obtained with standard difference-in-differences strategy, whether the treatment is binary as in the second column or continuous as in the third column. Overall, hours worked $l$ decreased by $7.6\%$ on average while earnings $wl$ decreased by a smaller proportion which implies that average wage rates must have increased and $dw \geq 0$ as in Model 3 of section 3. Importantly, these average effect may hide significant heterogeneity across firms which is studied in the next section.

# 5 General model

In this section, I embed models 3 and 4 of section 3 where firms set hours into a larger model where firms have heterogeneous productivities. This is consistent with the observation that coal mines workers were not free to choose their hours. The labor market features directed search and contract posting[16] as in the seminal paper by Moen (1997) but it is kept static as in Vergara (2023).[17]

## 5.1 Directed search model

**Labor market** Consider a set of measure $L$ of workers who are each endowed with a unit of time.[18] Firms are posting vacancies with a pair $m = (w_m, l_m)$ of wage rate and hours worked. All vacancies $v_m$ at a given pair $m$ form a submarket and there may be potentially many submarkets for each type. Workers are applying to one vacancy among the various submarkets $m$ and the number of applicants for a given submarket is denoted by $a_m$.

**Matching** There is a technology $\mathcal{M}(a_m, v_m)$ matching applicants and vacancies in a submarket. I assume that it is constant returns to scale.[19] As a result, one can compute the job-finding probability as

$$p_m = \frac{\mathcal{M}(a_m, v_m)}{a_m} = \mathcal{M}(1, \theta_m) = p(\theta_m)$$

where $\theta_m = \frac{v_m}{a_m}$ is the submarket tightness. Similarly, the job-filling probability is

$$q_m = \frac{\mathcal{M}(a_m, v_m)}{v_m} = \mathcal{M}(\frac{1}{\theta_m}, 1) = q(\theta_m)$$

and $q_m = p(\theta_m) \times \frac{1}{\theta_m}$. It is further assumed that the matching technology is twice continuously differentiable, increasing and concave. Hence,

$$\frac{\partial p(\theta_m)}{\partial \theta_m} > 0 \qquad \frac{\partial q(\theta_m)}{\partial \theta_m} < 0$$

[16]There is a long literature exploring the relevance of posting in labor market. For example, Eeckhout and Kircher (2010b) showed that price posting (sorting workers types ex-ante) emerges as an equilibrium trading mechanism rather than auctions (screening workers types ex-post) when the meeting technology is sufficiently rival. A review can be found in Wright et al. (2021).

[17]The key difference with Vergara (2023) is the presence of leisure.

[18]All the analysis in this section could be carried out in a model where workers have heterogeneous types as long as firms observe it and the labor market is segmented.

[19]See Hall and Schulhofer-Wohl (2018) and Petrongolo and Pissarides (2001) for empirical evidence on the matching function.

In other words, the tighter submarket, the higher will be the job-finding probability and the lower will be the job-filling rate.

**Workers** Each worker decides whether or not to enter the labor market. Workers are only heterogeneous in their disutility of participation, denoted by $d$ and drawn from a cdf $G(\cdot)$. They have preferences over consumption and leisure represented by an ordinal utility function $u(c, l)$. The government grants some benefits $B$ to all nonemployed agents, be they inactive or unemployed.[20]. I assume that each worker may only apply to one submarket, such that the expected utility of participating to the labor market for a worker of disutility of participation $d$ reads

$$\max_m \left\{ p_m u(w_m l_m, l_m) + (1 - p_m) u(B, 0) \right\} - d$$

An individual worker applies by taking $p_m$ as given but the aggregate behavior of all workers will pin down $p_m$. Hence, in equilibrium, it must be that all agents have the same expected utility[21] (net of their $d$) that I will denote by $\bar{U}$.[22] However, the fact that all workers of the same type enjoy the same expected utility ex-ante does not imply that they all enjoy the same ex-post utility.

The key mechanism of the model is already visible here: a worker prefers submarkets that pays higher income $w_m l_m$ for lower hours worked $l_m$ but their tightness $\theta_m$ will be lower. In other words, as elsewhere in competitive search models, there is a tradeoff between favorable terms of trade and probability of trade. Observe that this equation also defines the level of tightness $\theta_m$ on the equilibrium path. In particular, we have equilibrium tightness as an implicit function of three variables $\theta(\underset{-}{w_m}, \underset{+-}{l_m}, \underset{+}{\bar{U}})$.

A worker of type $d$ participates if and only if $\bar{U} \geq d + u(B, 0)$ such that the total number of participants is given by $G(\bar{U} - u(B, 0)) \times L$.[23]

**Firms** All firms face perfect competition in the single output market whose homogeneous good is set as the numéraire. Indeed, Delabastita and Rubens (2025) documented

[20] This formulation supposes that inactives are entitled to the same benefit coverage $B$ than unemployed. This is made solely for analytical tractability, as it is typically not the case in actual economies. Germain (2023) studies this mismatch in depth. For the value of nonemployment versus unemployment, see Jäger et al. (2020).

[21] Proof: assume it is not the case such that $m'$ yields higher expected utility than $m$. Then some agents will move towards $m'$, which decreases $\theta_{m'}$ and decreases $p_{m'}$ in turn. This marginally reduces $U(m')$. The process continues until $U(m) = U(m')$.

[22] This is called the *market utility* by (Wright et al., 2021).

[23] We can mention current endeavors in the literature to estimate $G_i(\cdot)$, that is to compute workers' outside options (Caldwell & Danieli, 2024; Caldwell & Harmon, 2019; Caldwell & Oehlsen, 2018; Jäger et al., 2020, 2022, 2023).

that Belgian coal mines had no price-setting power in their output market. Firms are only heterogeneous in their total factor of productivity $\psi_j$.[24] They share the same production technology $F(N, l)$ whose inputs are jobs $N = qv$ and hours worked $l$. Firms internalize workers' decisions such that their job-filling probabilities $\tilde{q}_m$ are implicitly defined by equation (3) with $\tilde{q}_m = q(\theta(\underset{-}{w_m}, \underset{+-}{l_m}, \underset{+}{\bar{U}})$. Conditional on entering the labor market, they maximize expected profit by choosing the number of vacancies $v_m$ to post in each submarket $m$ along with the associated wage-hours $(w_m, l_m)$:

$$\pi(\psi_j) = \max_{\forall m: w_m, l_m, v_m} \int_m \psi_j F(\tilde{q}_m v_m, l_m) - \tilde{q}_m v_m w_m l_m - k(v_m) dm$$

where $k(\cdot)$ is the increasing and convex cost of vacancy posting. Because firms face a cost of creating vacancies independently of the hours worked in that vacancy, it is *ex-post* more costly to hire two workers each working half-time rather than one full-time worker, *ceteris paribus*. However, *ex-ante* the probability that vacancies will be filled might differ between half-time and full-time contracts.[25]

**Firms entry** A set of measure $K$ contains capitalists who are heterogeneous in productivity $\psi_j$ drawn from a compact set $[\underline{\psi}, \bar{\psi}]$. A capitalist enters the labor market if and only if their expected profit is greater than a fixed cost denoted by $x$. Because the profit function is monotonically increasing in $\psi_j$, there exists a decisive $\psi^*$ such that $\pi(\psi^*) - x = 0$. All capitalists with $\psi_j < \psi^*$ abstain from entering the labor market and remain inactive while all with $\psi_j \geq \psi^*$ participate.

**Economy, allocation and equilibrium** The directed search economy $e$ is a set of vNM agents of measure $L$ with leisure preferences $\succsim$ and disutility of participation $d$ drawn from a cdf $G$, as well as a set $K$ of firms with productivity $\psi_j$, the vacancy posting cost function $k(\cdot)$, the entry cost $x$ and the production function $F(\cdot)$ and the matching function $\mathcal{M}$.

$$e = \left\{ L, \succsim, G, \{\psi_j\}_{\forall j \in K}, k, x, F(\cdot), \mathcal{M} \right\}$$

**Definition 1.** *An allocation is a* ***competitive search equilibrium*** *for $e$ if it is characterized by the market utility $\bar{U}$, the zero-profit firm $\psi^*$, applications $a_m$, vacancies $v_m$ in each submarket $m = (w_m, l_m)$ as well as a mapping $P(\cdot)$ from productivity to submarkets*

1. ***Firms are expected profit-maximizers:***
   *The tuples $(v_m, w_m, l_m)$ solve the FOC of firms of type $\psi_j = P^{-1}(m)$ for $m \in [P(\psi^*), P(\bar{\psi})]$*

[24] The analysis in this section would be unchanged if $\psi_j$ was assumed to be the productivity of the match between firms and workers, both of them having heterogeneous skills, as long as the skill-matching function exhibits supermodularity. See Eeckhout and Kircher (2010a, 2018) for a rigorous treatment.

[25] See Carry (2023) for empirical evidence of such imperfect substitutability the French case.

*taking $\psi^*$ and $\bar{U}$ as given*

$$
\begin{aligned}
v_m: &\quad \tilde{q}_m^i(\psi_j F_N' - w_m l_m) \leq k'(v_m) && \textit{with equality if } v_m > 0 \quad (1)\\
w_m: &\quad v_m \tilde{q}_{m,w}'(\psi_j F_N' - w_m l_m) \leq q_m v_m l_m && \textit{with equality if } w_m > 0 \quad (2)\\
l_m: &\quad v_m \tilde{q}_{m,l}'(\psi_j F_N' - w_m l_m) + \psi F_l' \geq \tilde{q}_m v_m w_m && \textit{with equality if } l_m < \bar{l} \quad (3)
\end{aligned}
$$

*where $\bar{l} \leq 1$ the legal maximum workweek, and the partial variation of tightness with respect to wages and hours worked are denoted by $\tilde{q}_{m,w}' = \frac{\partial \tilde{q}_m}{\partial w}$ and $\tilde{q}_{m,l}' = \frac{\partial \tilde{q}_m}{\partial l}$.*

2. ***Firm's entry constraints** :*

$$\psi^* \textit{ solves } \pi(\psi^*) = x \qquad \textit{taking } \bar{U} \textit{ given} \tag{4}$$

3. ***Across-submarket equilibrium condition** :*
*Applications in a submarket ensures that all submarkets yields market utility*

$$a_m \textit{ solves } \bar{U} = p_m u(w_m l_m, l_m) + (1 - p_m) u(B, 0) \tag{5}$$

*with $p_m = p(\frac{v_m}{a_m})$, taking $\psi^*, v_m, l_m, w_m$ as given for $m \in [P(\psi^*), P(\bar{\psi})]$*

4. ***Workers' participation constraints** :*

$$\bar{U} \textit{ solves } \int_{P(\psi^*)}^{P(\bar{\psi})} a_m dm = G(\bar{U} - u(B, 0)) \times L \tag{6}$$

*taking $\psi^*, u$ and $a_m$ as given.*

## 5.2 Properties

I now turn to the properties of the competitive search equilibrium just defined.

**Firm and submarket sizes** In a single submarket may be found vacancies from several firms. Say that we find two firms $\psi_j > \psi_k$ in some given submarket $(w, l)$. By equations 1 and 3 respectively, it must be that

$$
\begin{aligned}
\psi_j F_N'(v_j q, l) &= \psi_k F_N'(v_k q, l)\\
\frac{1}{v_j}\psi_j F_l'(v_j q, l) &= \frac{1}{v_k}\psi_k F_l'(v_k q, l)
\end{aligned}
$$

In other words, the marginal product of jobs must be equal for both firms, and their relative number of posted vacancies must be proportional to their relative marginal product of hours. As a consequence, their marginal rate of technical substitution must be equal.

Conversely, can a single firm post vacancies in several submarkets in equilibrium? Observe that production is separable in submarkets, such that the model assumes away potential complementarities between submarkets in production. However, in general firms will post vacancies in several submarkets, i.e. equation 1 may be saturated for many $m$. This is so because the presence of risk and non-degenerate job-filling probabilities induces a portfolio choice for the firm, whose optimal strategy may consists in diversification to hedge against risk. To see why firms are not risk-neutral, observe that (i) the vacancy posting cost $k(v)$ is paid almost surely and (ii) concave production may imply risk aversion. Hence, consistent with the empirical setup studied in section 4, this model produces large firms in the sense of Eeckhout and Kircher (2018).

**Monopsony power** Although search is competitive, the labor market remuneration might not be. Indeed, this model produces an earnings markdown and workers are paid below their marginal product. If the firm-specific wage elasticity of labor supply is $\epsilon_m^w = \frac{\partial \tilde{q}_m v_m}{\partial w_m} \frac{w_m}{\tilde{q}_m v_m}$, then equation 2 reads

$$\frac{\psi_j F_N' - w_m l_m}{w_m l_m} = \frac{1}{\epsilon_m^w}$$

which is the original Robinson (1933) markdown equation: the earnings markdown is inversely proportional to the firm-specific elasticity of labor supply. It is noteworthy that the present model has two sources of monopsony power.[26] As models 2 and 4 in section 3, there is monopsony power because agents' utility function implies that the wage elasticity of labor supply is finite. Yet, contrary to section 3, there is monopsony power because of matching frictions. Indeed, observe that when matching frictions increase, $\epsilon_m^w$ decrease and the earnings markdown increase.

Given this proximity to standard monopsony equations, it can be shown that a working time reduction may also have negative equilibrium effects on wage rates $dw \leq 0$ provided the production function satisfies $lF_l' \geq NF_N'$, i.e. that the marginal product of an hour exceeds the marginal product of a job. In that case, workers workers have a negative marginal utility of hours worked and would like to work less conditional on wage rates. As a result, the analysis of the wage effect of working time regulations follow the same line as model 4 in section 3 and appendix A.2.

[26] Berger et al. (2024) quantifies the empirical importance of several determinants of monopsony power including preferences and search frictions.

**Contract dispersion and sorting** The model produces wage dispersion among (observably) identical workers[27] which is a long-standing finding of empirical labor studies (see Card et al. (2018)) because there is a continuum of submarkets in equilibrium. It is naturally interesting to study how heterogeneous firms are sorting in the contract space. Taking the total derivative of equation 1 in a particular submarket away from corner solutions one gets

$$dv \underbrace{\left(\tilde{q}^2 \psi F_N'' - k''(v)\right)}_{<0 \text{ if } F_N'' \leq 0} + dw \underbrace{\left(\tilde{q}_w' (\psi F_N' - wl) - \tilde{q} l + \tilde{q} v \tilde{q}_w' \psi F_N''\right)}_{<0 \text{ by equation } 2} + dl \left(\gamma_l\right) + d\psi \underbrace{\left(\tilde{q} F_N'\right)}_{>0} = 0$$

where indices are omitted for brevity. Hence, a firm with higher productivity $\psi_j$ will post more vacancies and higher wages. With respect to hours worked, the coefficient $\gamma_l$ multiplying $dl$ is difficult to sign in the general case. However, if one assumes that labor production follows the toy model's $F(N, l) = N^\alpha l^\beta$ with $\alpha < \beta < 1$, one gets that $\gamma_l > 0$, such that higher productivity firms post contracts with shorter hours. The proof is relegated to appendix B.

Under these assumptions, firms with higher productivities offer higher wage rates, and lower hours worked, hence a higher ex-post utility to their workers. However, ex-ante utilities are equal for all workers. This implies that job-finding probabilities are smaller in firms with higher productivities. In other words, the larger number of vacancies in these firms is dominated by the larger number of applications such that equilibrium tightness $\theta_m = \frac{v_m}{a_m}$ decreases with firms' productivity.

We can also study comparative statics when the preferences for leisure of agents locally increase: the slope of its indifference curve gets steeper. This does not affect labor supply in level, but it affects labor supply elasticities. As a result, the firm reacts by modifying $w_m$ and $l_m$ according to equations 2 and 3 . In particular, observe that a simple rearrangement of these equations for interior solutions yields

$$-\frac{\tilde{q}_l' l}{\tilde{q}_w' w} = \frac{\psi F_l'}{\tilde{q} v w}$$

where the left handside coincides with the marginal rate of substitution derived from $u(\cdot)$ at the particular contract. Hence, when the indifference curve gets steeper, the left handside decreases. The equilibrium conditions imposes that on the right handside firms must marginally increase $w$ or decrease $l$. As a consequence, a marginal increase in the preference for leisure locally increases wage rates and decreases hours worked.

[27] It escapes the Diamond (1971) paradox of homogeneous contract in search models by allowing heterogeneous firms' productivities.

## 5.3 Welfare analysis

The competitive search equilibrium features monopsony power, large firms, and sorting patterns that are consistent with the empirical context of section 4. Moreover, the welfare effects of the policy is ambiguous here because the negative effects on wages and employment may be offset by positive effects on leisure. In this section, I quantify welfare gains and losses of the Belgian 1910 coal mine reform using the directed search model.

As discussed above, the market utility $\bar{U}$ summarizes workers' ex-ante welfare. Interestingly, it features a trade-off between jobs quantity and job quality. I now express it in terms of sufficient statistics as in Vergara (2023). Recall that for each submarket $m$ we have

$$
\begin{aligned}
\bar{U} &= p_m u(w_m l_m, l_m) + (1-p_m)u(B,0) \\
a_m[\bar{U} - u(B,0)] &= N_m[u(w_m l_m, l_m) - u(B,0)]
\end{aligned}
$$

where $N_m$ is the number of workers employed in submarket $m$. Integrating over submarkets yields

$$
\begin{aligned}
[\bar{U} - u(B,0)] \int_m a_m dm &= \int_m N_m[u(w_m l_m, l_m) - u(B,0)]dm \\
\bar{U} - u(B,0) &= \frac{\int_m N_m[u(w_m l_m, l_m) - u(B,0)]dm}{G(\bar{U} - u(B,0)) \times L}
\end{aligned}
$$

where the last equation is obtained using equation 6. The denominator is simply the total number of workers participating to the labor market and the numerator is a weighted sum of utilities across submarkets whose weights are the submarkets' employment size $N_m$. This ratio is simply giving the average utility among active workers. To see this, observe that the last equation can be written as

$$
\begin{aligned}
\bar{U} - u(B,0) &= \frac{\int_m N_m dm}{G(\bar{U} - u(B,0)) \times L} \frac{\int_m N_m[u(w_m l_m, l_m) - u(B,0)]dm}{\int_m N_m dm} \\
&= \mu \mathbb{E}_m[u(w_m l_m, l_m) - u(B,0)]
\end{aligned}
$$

where $\mu$ is the employment rate and $\mathbb{E}_m[u(w_m l_m, l_m)]$ is the average utility of a job among workers. It is straightforward to show the following result.

**Proposition 1.** *A small working time reduction*[28] $d\bar{l}$ *has a positive impact on on ex-ante welfare* $\frac{d\bar{U}}{d\bar{l}} > 0$ *if*

$$\eta^N + \eta^u > 0$$

*where* $\eta^N$ *is the percentage change in employment rate due to the reform and* $\eta^u$ *is the percentage change in workers' average (ex-post) utility.*

Taking the total derivative of $u(c,l)$ with respect to $\bar{l}$ we can write the percentage change in utility $\eta^u$ as a function of the percentage change in consumption and leisure:

$$\frac{du}{d\bar{l}} = u_c' \frac{dc}{d\bar{l}} + u_l' \frac{dl}{d\bar{l}}$$
$$\eta^u = \frac{\bar{l}}{u}\frac{du}{d\bar{l}} = \frac{cu_c'}{u}\frac{\bar{l}}{c}\frac{dc}{d\bar{l}} + \frac{lu_l'}{u}\frac{\bar{l}}{l}\frac{dl}{dl} = \zeta_c^u \eta^c + \zeta_l^u \eta^l$$

where $\eta^c$ and $\eta^l$ are the percentage change in consumption and hours worked while $\zeta_c^u$ and $\zeta_l^u$ are the elasticity of the utility function to consumption and hours respectively.

These sufficient statistics are strikingly simple. One can assess welfare effects of the reform simply by observing the average treatment effect of the reform on employment, earnings and leisure and postulating a cardinal utility function. In particular, it does not require to take any stance on the production side nor the extent of imperfect competition in the labor market, which is known to vary significantly across contexts and industries (Azar et al., 2022; Card et al., 2018). I note that these elasticities must be understood as macro-elasticities in the sense of Landais et al. (2018), i.e. incorporating all general equilibrium effects. The estimates derived in section 4 may be used to compute the welfare effects using these sufficient statistics.[29] However, two caveats must be raised.

First, I must assume a cardinal utility function to derive $\zeta_c^u$ and $\zeta_l^u$. Obviously, wel-

[28]In order to enforce such reforms, governments must observe hours and hence contract $(w, l)$ which contrasts with the typical assumption in public finance since Mirrlees (1971) that only income is observed. If governments observe $(w, l)$, why don't they use lump-sum transfers to decentralize any first-best allocation rather than using the maximum workweek? In this model, we may reconcile the second-best environment of Mirrlees (1971) with an information set that contains $w$ and $l$ by assuming that the government does not observe the identity of firms in a particular submarket, hence the second fundamental theorem of welfare economics may not be used.

[29]The estimates of section 2.4 are expressed as the effect of a working time reduction by one hour, while these statistics are the effect of the overall reform. This does not change the analysis because multiplying $\eta^N + \eta^u$ by a scalar does not modify the sign. Moreover, the mean working time reduction was 1.03 hour such that our estimates are quantitatively close to the average impact of the reform.

fare assessment will be sensitive to this choice.[30] Second, the estimates of section 4 are average treatment effects on the treated. As a result, I apply the welfare analysis only on workers from treated firms i.e. workers whose hours worked were above the maximum workweek prior to the reform. I also assume that the number of workers sending job applications to these firms is unaffected by the reform, which is a conservative assumption for my results.[31]

The point estimates from section 4 give us $\hat{\eta}^N = -6$ and $\hat{\eta}^c = -6$ while $\hat{\eta}^l = -7.9\%$. If preferences can be represented by a Cobb-Douglas utility, $\zeta_c^u = \delta = 1 - \zeta_l^u$, the reform is increasing treated workers' ex-welfare if

$$\begin{aligned} -6 + \delta(-6) - (1-\delta)(-7.9) > 0 \\ 1 - \delta > 0.86 \end{aligned}$$

In others words, workers must spend at least 86% of their income buying leisure for this reform to be welfare-improving in the Cobb-Douglas case. In future iteration of the paper, I intend to use the equilibrium conditions in equations 2 and 3 to pin down values of $\zeta_c^u$ and $\zeta_l^u$ and then estimating these moments with my data to provide a nonparametric welfare estimation.

# 6 Conclusion

The paper has studied theoretically and empirically the effects of working time reductions on wages, employment, profits and welfare. On the normative side, we have shown that the empirical effect of working time reductions on employment, wages and profits are sufficient for welfare evaluation. The empirical application uncovered large and negative effects on profits, wages and employment in the first-ever working time reduction in Belgium such that the overall welfare effects may only be positive if workers had a large value attached to leisure.

There are several ways in which this line of research can be extended. First, the interaction with progressive taxes is of obvious interest for public economists. Second, the characterization of optimal policy and efficiency has been left aside, while hetero-

[30] One could have picked Boppart and Krusell (2020) utility function who show in a structural macro exercise that the functional form consistent with labor supply dynamics over the past century take the form of $u(w, l) = w\, l\phi(l\, c^{\frac{\nu}{1-\nu}})$ with $\phi$ a decreasing function, where $\nu \in (0, 1)$ is such that if productivity grows by $g$, then hours decrease at a rate $g^\nu$ and consumption increase at a rate $c^{1-\nu}$. However, 1910 mine workers were unlikely to use the preferences that lead to the decline in hours worked over the century that succeeds them.

[31] To see this, observe that $\eta^N = \frac{d\mu}{d\bar{l}} \frac{\bar{l}}{\mu} = \frac{dN}{d\bar{l}} \frac{\bar{l}}{N} - \frac{dA}{d\bar{l}} \frac{\bar{l}}{A}$ where $A$ is the number of applicants. Assuming the latter term to be equal to 0 pushes $\eta^N$ upwards.

geneous preferences for leisure would allow us to discuss the desirability of gendered holidays or retirement policies. Third, the (counter)cyclicality of working time regulations could be interesting to relate to the literature on short-time work (Giupponi & Landais, 2023).

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# A Frictionless hedonic model with employment

This section presents a general equilibrium model that unbundles hours and jobs but does not feature search and matching frictions. The determination of hours worked is hedonic, in the sense that hours are set by firms contrary to the neoclassical labor supply theory where hours are utility-maximizing. First, I present a game-theoretic microfoundation for the model. Second, I explain the sufficient conditions for the results of the toy model in section 3 to be preserved in the frictionless model.

## A.1 A game-theoretic microfoundation

I build a game-theoretic model where firms set schedules and which is compatible with any degree of monopsony power and nest the case of perfect competition.[32] It generalizes models 3 and 4 of section 3.

**Labor supply** There is a mass of workers with a utility function $u(c, l)$ which is increasing and concave in consumption $c$ and decreasing in hours worked $l$. Workers receive a wage rate $w$ for each hour worked such that $c = wl$ in equilibrium. Workers are only heterogeneous in an outside option to the labor market which gives utility $d \geq 0$ distributed by a strictly increasing and concave cumulative distribution function $G(d)$. As a result, labor supply $N_s$ is given by $N_s(w, l) = G(u(wl, l))$ and it follows from workers' preferences that $N_s(w, l)$ is increasing in wage rates $w$ and inversely U-shaped (hence concave) in hours worked $l$.

**Labor demand** Consider $J$ identical firms whose profits are defined by the difference between their production $F(N_j, l_j)$ and their total wage bill $N_j w_j l_j$ where $N_j$ is the number of workers employed at firms $j$ while $w_j$ and $l_j$ define the wage rate and hours worked. Firms choose which contract $(w_j, l_j)$ to offer, understanding that all workers accept the utility-maximizing contracts. Firms participate to the market only if profits

[32]Interestingly, this game-theoretic model can be seen as the labor market equivalent of the Cournot-Bertrand games of d'Aspremont and Dos Santos Ferreira (2021) who study imperfect competition on output markets (à la Dixit and Stiglitz (1977)) when firms choose both prices and quantities, thereby competing both for the market size and the market share. Here, the product market is competitive but the labor market is oligopsonistic.

are nonnegative. As a result, the problem for the firm $j$ reads:

$$\max_{w_j,l_j,N_j} F(N_j,l_j) - N_j w_j l_j$$

$$\mathrm{N}_j \leq \begin{cases} 0 & \text{if } u(w_j l_j, l_j) < \max_{-j\in J\setminus\{j\}} u(w_{-j}l_{-j}, l_{-j}) \\ \dfrac{N_s(w,l)}{J} & \text{if } u(w_j l_j, l_j) = u(w_{-j}l_{-j}, l_{-j}) \quad \forall -j \in J\setminus\{j\} \\ N_s(w_j,l_j) & \text{if } u(w_j l_j, l_j) > \max_{-j\in J\setminus\{j\}} u(w_{-j}l_{-j}, l_{-j}) \end{cases}$$

Given that this maximization program holds for all $(w_{-j}, l_{-j})$, it also completely describes the best-response function of firm $j$. The following proposition will be useful.

**Theorem A.1.** *If production is concave in $N$, any Nash equilibrium of this game with positive production and participation is symmetric.*

*Proof.* I prove the statement for the duopsony case where $J = 2$.
By contradiction, consider $(w_1^*, l_1^*) \neq (w_2^*, l_2^*)$ but $\{(w_1^*, l_1^*), (w_2^*, l_2^*)\}$ is a Nash equilibrium of this game.

*Step 1 : in a Nash equilibrium we must have $u(w_1^*, l_1^*) = u(w_2^*, l_2^*)$.*
By contradiction, imagine that $u(w_1^*, l_1^*) < u(w_2^*, l_2^*)$ such that $\pi_1^* = 0$ and $\pi_2^* = F(N_s(w_2^*, l_2^*), l_2^*) - N_s(w_2^*, l_2^*) w_2^* l_2^*$.
If $\pi_2^* < 0$ then it violates the participation constraint of firm 2. If $\pi_2^* = 0$ then earnings are equal to average product. Yet, first order conditions indicate that $F'_N > w_2^* l_2^*$ and concavity implies that average product is larger than marginal product. As a result, it must be that $\pi_2^* > 0$.
If firm 2 has positive profits, observe that agent 1 can simply deviate by replicating agent 2's strategy. Agent 1's profits by deviating would be

$$\begin{aligned} \pi_1^d &= F(\frac{N_s(w_2^*, l_2^*)}{2}, l_2^*) - \frac{N_s(w_2^*, l_2^*)}{2} w_2^* l_2^* \\ &= F(\frac{N_s(w_2^*, l_2^*)}{2}, l_2^*) - \frac{N_s(w_2^*, l_2^*)}{2} \left( \frac{F(N_s(w_2^*, l_2^*), l_2^*)}{N_s(w_2^*, l_2^*)} - \frac{\pi_2^*}{N_s(w_2^*, l_2^*)} \right) \\ &= F(\frac{N_s(w_2^*, l_2^*)}{2}, l_2^*) - \frac{F(N_s(w_2^*, l_2^*), l_2^*)}{2} + \frac{\pi_2^*}{2} \end{aligned}$$

Because of Jensen's inequality, the last line is positive which contradicts that $(w_1^*, l_1^*)$ is a best-response to $(w_2^*, l_2^*)$. The argument proves that it cannot be the case that $u(w_1^*, l_1^*) < u(w_2^*, l_2^*)$ in equilibrium. A symmetric argument can be made to prove the converse strict inequality. Hence, in must be that $u(w_1^*, l_1^*) = u(w_2^*, l_2^*)$ and all firms offer contracts on the same indifference curve and hire the same number of of employees $\frac{N_s}{2}$.
*Step 2 : In a Nash equilibrium, we must have $\pi_1^* = \pi_2^*$.*

If it were not the case, say $\pi_1^* < \pi_2^*$, we would have a profitable deviation for firm 1 : mimicking 2's strategy does not affect the number of workers employed in firm 1 and yet increases profits. As a consequence, firms lie on the same iso-profit curve.

*Step 3 : In a Nash equilibrium, we must have* $(w_1^*, l_1^*) = (w_2^*, l_2^*)$
By contradiction, assume $l_1^* > l_2^*$. By step 1, equal utility imposes that $w_1^* l_1^* > w_2^* l_2^*$ as utility function is strictly decreasing in $l$. Hence we have

$$\begin{aligned} \pi_1^* = F(\frac{N_s}{2}, l_1^*) - \frac{N_s}{2} w_1^* l_1^* &< F(\frac{N_s}{2}, l_1^*) - \frac{N_s}{2} w_2^* l_2^* \\ &\leq F(\frac{N_s}{2}, l_2^*) - \frac{N_s}{2} w_2^* l_2^* = \pi_2^* \end{aligned}$$

which contradicts step 2. A symmetric argument can be made for the case $l_1^* < l_2^*$. Hence, it must be that $l_1^* = l_2^*$. Given that utility is strictly increasing in consumption, we must have $w_1^* = w_2^*$. This completes the proof. ■

A consequence of this proposition is that each firm faces that same program that can be written

$$\begin{aligned} &\max_{w,l,N} F(N, l) - Nwl \\ &\text{s.t. } N \leq \frac{N_s(w, l)}{J} \end{aligned}$$

where $j$ subscripts may be omitted for brevity. The associated Lagrangian for this problem reads

$$\mathcal{L} = F(N, l) - Nwl + \lambda[\frac{N_s(w, l)}{J} - N]$$

where $\lambda \geq 0$ is the Lagrangian multiplier. The remaining KKT conditions are

$$F'_N - wl = \lambda \tag{A.1}$$

$$F'_l - wN + \lambda \frac{1}{J} \frac{\partial N_s}{\partial l} = 0 \tag{A.2}$$

$$lN = \lambda \frac{1}{J} \frac{\partial N_s}{\partial w} \tag{A.3}$$

$$\lambda[\frac{N_s(w, l)}{J} - N] = 0$$

When $J = 1$, these KKT conditions are describing a pure monopsony problem where the Robinson wage markdown is obtained by susbtituting out $\lambda$ using equation A.3 in equation A.1. Moreover, equation A.3 implies that $\lambda > 0$ whenever there is positive production. Hence, the inequality constraint is binding in equilibrium and all participating workers are employed in the monopsony equilibrium : there is no involuntary unemployment.

Now in perfect competition, firms loose their wage-setting power and competitive wage rates adjust so that each worker gets paid at its marginal productivity, i.e. $F'_N = wl$. The problem for the firm reads:

$$\max_{l,N} F(N,l) - Nwl$$
$$\text{s.t. } N \leq \frac{N_s(w,l)}{J} \text{ and } F'_N = wl$$

The associated Lagrangian for this problem reads

$$\mathcal{L} = F(N,l) - Nwl + \lambda[\frac{N_s(w,l)}{J} - N] + \mu[F'_N - wl]$$

where $\lambda \geq 0$ and $\mu \in \mathbb{R}$ are the Lagrangian multipliers. The remaining KKT conditions are

$$F'_N - wl - \lambda + \mu F''_N = 0 \tag{A.4}$$
$$F'_l - Nw + \lambda \frac{1}{J}\frac{\partial N_s}{\partial l} + \mu(F''_{N,l} - w) = 0 \tag{A.5}$$
$$\lambda[\frac{N_s(w,l)}{J} - N] = 0 \qquad F'_N = wl \tag{A.6}$$

To prove again that the inequality constraint must be binding in equilibrium, observe that if it were not the case, by equation A.4 we should have $\lambda = 0 = \mu$ such that equation A.5 implies that $F'_l - Nw = 0 = F'_N - wl$. This can only hold whenever the marginal rate of technical substitution is 1, that is when hours and jobs are perfect substitutes. In the general case, we have $N_j = \frac{N_s(w,l)}{J}$ and there is no involuntary unemployment. This contrasts with the search and matching model where matching frictions engender involuntary unemployment.

Observe that combining the equality constraints with equations A.4 and A.5 implies that competitive hours are set by firms such that

$$F'_l - Nw + \lambda\left(\frac{1}{J}\frac{\partial N_s}{\partial l} + \frac{F''_{N,l}}{F''_N} - \frac{F'_N}{lF''_N}\right) = 0 \tag{A.7}$$

## A.2 Wage-hour covariance and imperfect competition

In this section, I derive a set of sufficient conditions for the results of the toy model with a general production function $F(N,l)$ increasing in its arguments. I assume $F(\cdot,0) = F(0,\cdot) = 0$.

### A.2.1 Perfect competition

The competitive equilibrium wage is characterized by $F'_N - wl = 0$ and $N_j = \frac{N_s(w,l)}{J}$. Taking the total derivative of the former, one gets

$$dw\left(\frac{1}{J}\frac{\partial N_s}{\partial w}F''_N - l\right) + dl\left(\frac{1}{J}\frac{\partial N_s}{\partial l}F''_N + F''_{N,l} - w\right) = 0 \quad \text{(A.8)}$$

The coefficient multiplying $dw$ is negative if $F''_N \leq 0$.
With respect to the coefficient multiplying $dl$, observe that

$$\begin{aligned} sign\left(\frac{\partial N_s}{\partial l}F''_N + F''_{N,l} - w\right) &= -sign\left(\frac{\partial N_s}{\partial l} + \frac{F''_{N,l}}{F''_N} - \frac{F'_N}{lF''_N}\right) \\ &= sign\left(F'_l - wN\right) \end{aligned}$$

where the last equality is obtained by using equation A.7. Hence, a sufficient condition for the coefficient multiplying $dl$ to be positive is that

$$F'_l - wN > F'_N - wl = \lambda \geq 0$$

which is true whenever

$$lF'_l > NF'_N$$

To sum up, sufficient conditions for a negative equilibrium covariance between hours worked and wage rates in perfect competition are the concavity of production in jobs and the assumption that the output elasticity of hours exceeds the output elasticity of jobs.

$$\begin{aligned} F''_N &\leq 0 \\ lF'_l &> NF'_N \end{aligned}$$

The latter can be justified by experience effect: the marginal hours produced by existing workers should yield more output than those done by the marginal hire.

### A.2.2 Pure monopsony

In the case where $J = 1$, equations A.1 and A.3 imply that the monopsony equilibrium wage is characterized by $\frac{\partial N_s}{\partial w}(F'_N - wl) = N_s l$. The total derivative reads

$$dw\left(\frac{\partial^2 N}{\partial^2 w}(F'_N - wl) + (\frac{\partial N}{\partial w})^2 F''_N - 2\frac{\partial N}{\partial w}l\right) + dl\left(\frac{\partial^2 N}{\partial w \partial l}(F'_N - wl) + \frac{\partial N}{\partial w}(\frac{\partial N}{\partial l}F''_N + F''_{N,l} - \frac{F'_N}{l}) - \frac{\partial N}{\partial l}l\right)$$

and must be equal to 0 in equilibrium. Observe that the coefficient multiplying $dw$ is negative whenever $\frac{\partial^2 N}{\partial^2 w} \leq 0$ and $F''_N \leq 0$. Note that the latter was already required by the perfect competition equilibrium. As to the former, observe that $N_s(w,l) = G(u(wl,l))$ implies that

$$\frac{\partial^2 N_s}{\partial^2 w} = (lu'_c)^2 \frac{\partial g(u(wl,l))}{\partial d} + g(u(wl,l))l^2 u''_c$$

Hence, the concavity of the labor supply $N_s$ with respect to $w$ is an immediate consequence of the concavity of the cdf $G(d)$ and the concavity of utility in consumption. With respect to the coefficient multiplying $dl$, it is positive if

$$\frac{\partial N_s}{\partial l} \leq 0 \tag{A.9}$$

$$\frac{\partial^2 N_s}{\partial w \partial l} \geq 0 \tag{A.10}$$

$$\frac{\partial N_s}{\partial l} F''_N + F''_{N,l} - \frac{F'_N}{l} \geq 0 \tag{A.11}$$

With respect to equation A.9, observe that observe that substituting out $\lambda$ in the first-order condition A.2 using A.1 yields

$$\frac{\partial N_s}{\partial l}(F'_N - wl) + F'_l - wN = 0$$

$$\frac{\partial N_s}{\partial l}(F'_N - wl) + \frac{N}{l}(\frac{l}{N}F'_l - wl) = 0$$

Hence, sufficient condition A.9 is verified whenever

$$\frac{l}{N}F'_l - wl \geq F'_N - wl = \lambda > 0$$

$$lF'_l \geq NF'_N$$

This is exactly the same condition as in the perfect competition case : the marginal product of an hour must be larger than the marginal product of a job. Under this assumption, we obtain equation A.9 which says that the marginal utility of an extra hour worked is negative in the monopsony equilibrium : workers would like to work less at the monopsony wage rate.

With respect to sufficient condition A.10, it consists in saying that labor supply should be supermodular: in other words, the wage elasticity of labor supply increases when schedules get longer. I now provide sufficient conditions on the utility functions for it to be the case.

$$\frac{\partial^2 N_s}{\partial w \partial l} = \frac{\partial g(u(wl,l))}{\partial d}(u'_c w + u'_l)u'_c l + g(u(wl,l))(u'_c + wlu''_c + lu''_{c,l})$$

The first term must be positive because $G(\cdot)$ is assumed to be concave[33] and equation A.9 implies that the marginal utility of hours $(u'_c w + u'_l)$ is negative. As a result, a sufficient condition for *A*.10 to be true is that the second term is positive, i.e.

$$\frac{wlu''_c + lu''_{c,l}}{u'_c} \geq -1 \tag{A.12}$$

An example of utility functions satisfying A.12 are separable utility functions $u(c,l) = v(c) - \phi(l)$ with an Arrow-Pratt coefficient of relative risk aversion $-\frac{cv''_c}{v'_c} \leq 1$. This includes, among others, $v(c) = \log c$.

To sum up, the set of sufficient conditions for obtaining a positive equilibrium covariance between wage rates and hours worked in monopsony are

$$lF'_l \geq NF'_N$$
$$\frac{wlu''_c + lu''_{c,l}}{u'_c} \geq -1$$
$$\frac{\partial N_s}{\partial l} F''_N + F''_{N,l} - \frac{F'_N}{l} \geq 0$$

# B Competitive search model : additional results

## B.1 Sorting

We prove here that $\gamma_l > 0$ in interior solutions whenever production is $F(N,l) = N^\alpha l^\beta$ with $\alpha < \beta < 1$.

$$\gamma_l = \tilde{q}'_l(\psi F'_N - wl + \tilde{q} v F''_N) + \psi \tilde{q} F''_{N,l} - \tilde{q} w$$

Substituting equation (2.5) for the last term yields

$$\gamma_l = \tilde{q}'_l(\tilde{q} v F''_N) + \psi \tilde{q} F''_{N,l} - \psi F'_l \frac{1}{v}$$

[33] Concavity of the cdf of outside option means that there are less and less individuals with higher and higher outside options. For example, Pareto distributions have this property.

Multiplying by $v$ preserves the sign

$$v\gamma_l = v\tilde{q}_l'(\tilde{q}vF_N'') + \psi\tilde{q}vF_{N,l}'' - \psi F_l'$$

Developing using the functional form and using the identity $N = \tilde{q}l$, one gets

$$\begin{aligned}
v\gamma_l &= v\tilde{q}_l'(\psi\alpha(\alpha-1)N^{\alpha-1}l^{\beta}) + \psi\alpha\beta N^{\alpha}l^{\beta-1} - \psi\beta N^{\alpha}l^{\beta-1} \\
&= (\alpha-1)\psi N^{\alpha}l^{\beta-1}\left(\beta + \alpha l\frac{\tilde{q}_l'}{\tilde{q}}\right)
\end{aligned}$$

We are left with signing the last bracketed factor. Observe that equation (2.5) can be written as

$$v\tilde{q}_l' = -\frac{\psi F_l' - \tilde{q}vw}{\psi F_N' - wl}$$

Hence we get

$$\begin{aligned}
l\frac{\tilde{q}_l'}{\tilde{q}} &= -\frac{\psi\beta N^{\alpha-1}l^{\beta} - wl}{\psi\alpha N^{\alpha-1}l^{\beta} - wl} \\
\beta + \alpha l\frac{\tilde{q}_l'}{\tilde{q}} &= (\alpha-\beta)\frac{wl}{\psi\beta N^{\alpha-1}l^{\beta} - wl}
\end{aligned}$$

This prove that the bracketed factor is negative whenever $\alpha < \beta$. Hence, it must be that $\gamma_l > 0$, proving that firms with higher productivity $\psi_j$ offer contracts with shorter hours worked.

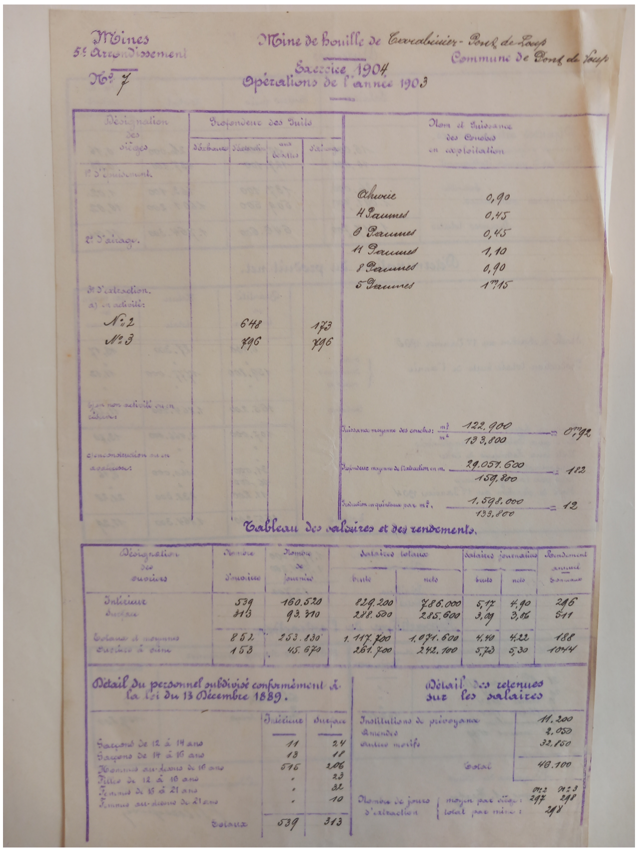
# C Empirical appendix

## C.1 Data collection

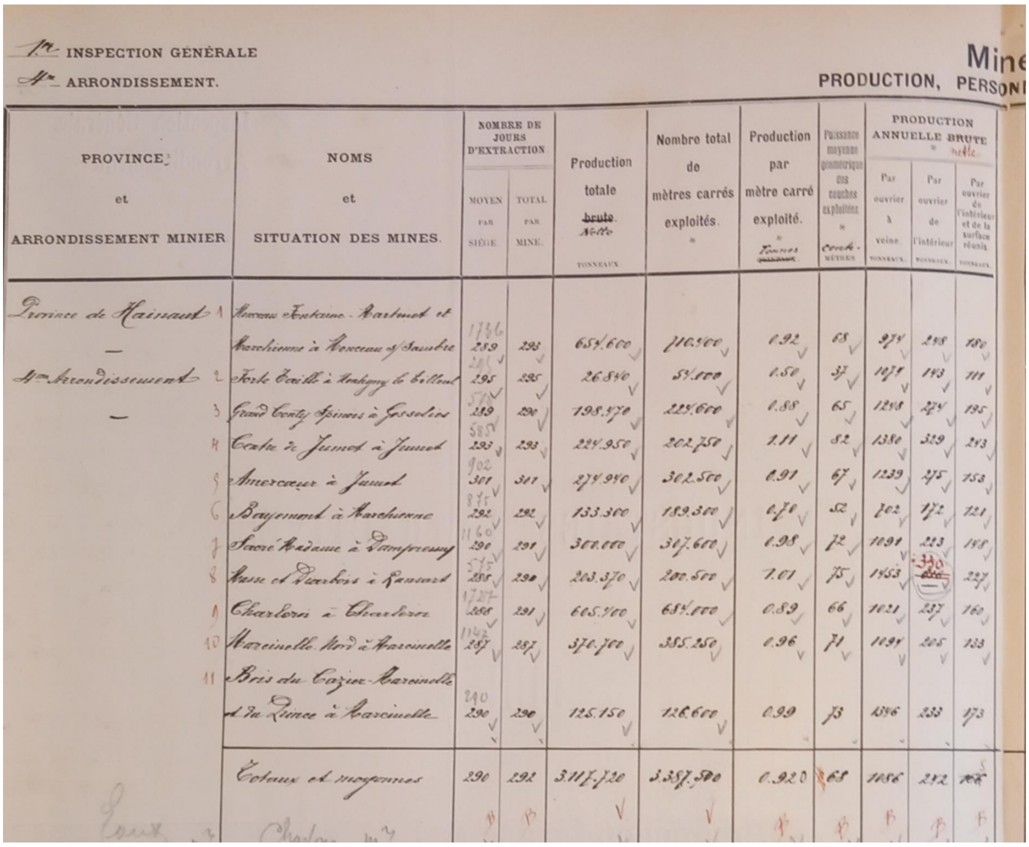
## C.2 Construction of variables

### C.2.1 Profits

I construct profits as the difference between total revenue and total expenses. Total revenue is computed as the sum of sales and the change in stock of coal evaluated at the firm's market price. The variable is expressed in real terms by deflating with the price of output, such that profits are measured in tons of coal.



(a) A report for the mine *Carabinier-Pont du Loup* in 1903.



(b) A slice of the panel dataset which shows some outcomes for the 4th arrondissement in the province of Hainaut in 1913.

Figure C.1: Pictures of the data collection

### C.2.2 Earnings

Earnings are measured as the fraction of the monetary value of production that is paid to the worker.

$$y_{j,t} = \frac{\text{Daily wage in current BEF for frontline worker}_{j,t}}{\text{Sales price in current BEF}_{j,t} * \text{Daily production per frontline worker}_{j,t}}$$

Daily production per frontline worker is obtained by dividing the annual production by the average days worked in the firm (which is total days worked in the firm divided by the total number of all workers). I obtained annual production per worker by dividing the annual quantity produced by the firm by the number of frontline workers.

### C.2.3 TFP

TFP is used as control variable in various regressions. To measure it, I assume a Cobb-Douglas production function and take the log to obtain a regression equation of the form

$$\ln q_{j,t} = \beta_1 \ln l_{j,t} + \beta_2 \ln m_{j,t} + \ln \psi_{j,t} \tag{C.13}$$

where $q_{j,t}$ is the output in tons of coal and $l_{j,t}$ and $m_{j,t}$ are labor and non-labor expenditures, respectively and $\psi_{j,t}$ is unobserved TFP. Estimating this equation with OLS leads to bias estimates because unobserved productivity shocks are positively correlated with observed input choices, the well known simultaneity bias.

The typical way to overcome this identification challenge is to rely on the control function approach since Levinsohn and Petrin (2003) and Olley and Pakes (1996). Delabastita and Rubens (2025) estimate production functions of Belgian coal mines in that spirit. I pinpoint two differences with their estimation. First, the present paper has a much smaller set of years but a larger number of firms. Second and related, the present paper does not have information on capital. As a result, these methods may not be used.

I assume that $\ln \psi_{j,t}$ is a Markov process of order 1 with productivity shocks $\epsilon_{j,t}$. I consider the following moment restriction:

$$E[\epsilon_{j,t} | \ln l_{j,t-1}, \ln m_{j,t-1}] = 0$$

This moment restriction allows to retrieve $\beta_1$ and $\beta_2$ by GMM estimation. The results are reported below.

Despite differences in sample and in methodology, the estimates obtained by the GMM approach in the present paper are remarkably similar to those of Delabastita and

| Outcome | ln **production**$_{j,t}$ | ln **production**$_{j,t}$ | ln **production**$_{j,t}$ |
|---|---|---|---|
| ln `labor expenses` $\beta_1$ | 0.745 (0.026) | **0.654 (0.052)** | 0.661 (0.041) |
| ln `nonlabor expenses` $\beta_2$ | -0.070 (0.021) | **0.315 (0.050)** | 0.237 (0.080) |
| ln `capital` | n/a | n/a | 0.102 (0.088) |
| Serial corr $\ln \psi_{j,t}$ if AR(1) | 0.967 (0.008) | 0.879 (0.018) | 0.853 (0.157) |
| Years covered | 1903-1913 | 1903-1913 | 1845-1913 |
| Firms covered | Near universe | Near universe | Liège, Namur |
| Method | OLS | GMM (own) | Delabastita and Rubens (2025) |

Table C.1: Production function estimation

Rubens (2025) both in their magnitudes and in their precision. The present paper computes $\psi_{j,t}$ for each firm-year cell by predicting equation C.13 using the GMM estimated $\hat{\beta}_1, \hat{\beta}_2$. The use of lags implies that TFP cannot be estimated for 1903 such that the main results only show 1904-1913. For firms with positive production in year $t > 1903$ but zero production in $t-1$, I set the value of $\psi_{j,t}$ equal to the one of $\psi_{j,t+1}$.

## C.3 Additional empirical results

| Year | Matched | Population | Share of Covered (%) | |
|---|---|---|---|---|
| | | | Output | Days Worked |
| 1903 | 114 | 124 | 99.51 | 99.33 |
| 1904 | 113 | 122 | 99.24 | 98.98 |
| 1905 | 112 | 121 | 99.26 | 98.74 |
| 1906 | 111 | 122 | 98.70 | 98.53 |
| 1907 | 111 | 125 | 98.37 | 98.11 |
| 1908 | 111 | 126 | 98.30 | 98.23 |
| 1909 | 111 | 125 | 98.16 | 98.03 |
| 1910 | 110 | 129 | 97.73 | 97.47 |
| 1911 | 110 | 132 | 97.44 | 97.12 |
| 1912 | 109 | 132 | 96.95 | 96.57 |
| 1913 | 108 | 132 | 96.86 | 96.17 |

Table C.2: Number of firms for which there is information on hours worked (*Matched*) versus the total number of firms in the country (*Population*) by year.

Observe that there are 7 events of mergers and acquisitions in Table C.3 while there are only 6 firms less in 1913 than in 1903 in Table C.2. This comes from the fact that one firm, *Charbonnages de Haine Saint Pierre, La Hestre et Houssu*, was divided in 2 parts merged with two different firms in 1912: the *Houssu* merged with *Ressaix* while the *Haine-Saint-Piere et La Hestre* merged with *Mariemont*.

| Year | Mergers or Acquisitions | Firm exit |
|---|---|---|
| 1903 | | |
| 1904 | 1 | 1 |
| 1905 | 1 | |
| 1906 | 1 | |
| 1907 | | |
| 1908 | | |
| 1909 | | 1 |
| 1910 | 1 | |
| 1911 | | 2 |
| 1912 | 2 | |
| 1913 | 1 | |

Table C.3: Count of mergers & acquisitions and firm exits per year. A firm exit is defined as a zero coal production in the calendar year.

| | Non-targeted | Targeted |
|---|---|---|
| *TFP* | 1.043 | 1.045 |
| | (0.234) | (0.153) |
| *Coal autoconsumption in tons* | 8,883.33 | 24,280.00 |
| | (11,618.93) | (20,329.29) |
| *Surface land size in squared meters* | 143,886.06 | 282,538.33 |
| | (177,947.45) | (189,259.33) |
| *Share of workers underground* | 0.769 | 0.715 |
| | (0.056) | (0.055) |
| *Share of frontline workers among underground* | 0.266 | 0.243 |
| | (0.143) | (0.045) |
| *Average coal vein power* | 0.692 | 0.676 |
| | (0.196) | (0.153) |
| *Sales price in current BEF* | 14.434 | 14.544 |
| | (2.375) | (2.712) |
| **Profits in tons of coal** | 4,018.93 | -904.49 |
| | (14,260.24) | (34,466.69) |
| **Frontline employment** | 124.06 | 261.76 |
| | (169.36) | (192.36) |
| **Frontline earnings** | 0.134 | 0.114 |
| | (0.073) | (0.033) |
| **Average product per frontline worker** | 1,042.84 | 1,004.75 |
| | (484.67) | (305.31) |
| Observations | 33 | 78 |

Table C.4: Summary statistics of various variables in levels for the baseline year 1909. Means are reported while standard deviations are between brackets. Control (outcome) variables are in italics (bold).

| Outcome | $Treated_j$* $Post$ | $Exposure_j$* $Post$ | Sample |
|---|---|---|---|
| Profits in levels | -8432.417** | -7076.853** | Full |
| | (3232.001) | (2742.410) | |
| $\ln$ frontline employment | -0.081 | -0.076* | Non-closing firms |
| | (0.049) | (0.040) | |
| $\ln$ frontline earnings | -0.047* | -0.045 | Non-closing firms |
| | (0.028) | (0.030) | |
| $\ln$ frontline hours worked | -0.076*** | -0.079*** | Non-closing firms |
| | (0.008) | (0.003) | |

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table C.5: Difference-in-differences (DiD) estimates. The second column reports the DiD results for various outcomes whenever the $Treated_j$ dummy takes value $1$ if Exposure$_j$ > 0 while the second column uses Exposure$_j$ as continuous treatment variable. Regressions for outcome $y_{j,t}$ use the same controls as their event-study counterpart in the main text. Frontline hours are computed assuming perfect compliance to the reform.