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Abstract

In this paper we present an unemployment model with labour market frictions and monopolistic competition in the goods market. We consider different collective wage-setting systems and compare wages, the unemployment rate and labour market tightness at firm, sector and national (centralized) levels. We find that the Calmfors-Driffill hypothesis is maintanined under labour market frictions. In other words, unemployment will be thighest when the bargaining occurs at an industry-wide level. We find, both empirically and analytically, that regulation in the goods market plays a crucial role in explaining these findings. It may contribute to explaining the historical relationship between wage bargaining institutions and unemployment. Additionally, we show that the Calmfors-Driffill results are conditioned by the tax structure and the progressivity of labour income taxes. This fact might explain the lack of robustness in the findings relating to the relationship between wage bargaining institutions and unemployment of many empirical studies on the Calmfors-Driffill hypothesis.

Keywords: Disequilibrium Unemployment, Monopolistic Competition, Wage Setting Systems, policy reforms.

JEL number: E24, O41.

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1 Introduction

The Great Recession has been characterized by an unprecedented decline in economic growth and a rise in unemployment rates in OECD countries. This economic downturn has been particularly hard in Europe, particularly in Southern European countries such as, Spain, Portugal, Italy and Greece. All these countries, as is well known, share a common system of collective bargaining: sector-level wage bargaining. This fact led to strong political and economic debate in these countries regarding the reform of employment relations between different social agents (unions, employees and government). Lastly, in order to tackle unemployment and growth problems, the governments have implemented reforms, such as in the case of Spain, in order to shift towards a more decentralized bargaining system.

This recommendation is based on the seminal article by Calmfors and Driffill (1988), which pointed out that highly centralized and decentralized bargaining systems perform better than intermediate ones on wage demands. This relationship is known in specialized literature as the inverted-U shape between unemployment and the degree of centralization, or the Calmfors and Driffill´s hypothesis. In an excellent survey, Aidt and Tzanatos (2008) show that evidence supporting the hump hypothesis is weak: fewer than half the studies supported this hypothesis. More specifically, the authors pointed out that "the favour evidence comes from the first generation of studies relied on simple correlations test and that thus failed to control for other determinants of economic performance".

In order to overcome the discrepancy between theoretical models and the empirical evidence, we develop a general framework that allows us to determine under what conditions the inverted-U shape can be found. It is important to point out that our analytical framework merges three elements that characterize the European labour market. Namely, monopolistic competition in goods markets, labour taxation and finally, frictions and collective wage bargaining in the labour market.

There is a growing consensus about the key importance of product market regulation in influencing labour market performance. Blanchard and Giavazzi (2003), for example, or more recently, Fiori et. al (2012) show the effect of deregulation in goods and labour market on the unemployment rate using a simple general equilibrium model where they assume monopolistic competition in the goods market. We therefore use the monopolistic competition set-up because it is the natural framework *for analyzing different systems of wage setting.*

Labour taxation is also a labour market institution that affects unemployment through its impact on the wage[1]. When taxes on labour are introduced, the tax wedge between labour costs paid by an employer (gross wage) and net wage received by an employee ap-

[1]Blanchard and Wolfers (2000) analyze the role of a great diversity of shocks and institutions in the rise of unemployment.

pears. It is precisely the net wage received by an employee that is crucial in determining the wage negotiated under a collective bargaining agreement. Related to the previous issues on labour taxation, a relevant component in advanced economies is the progressive tax on income perceived by an employee. It is therefore no surprise that there is a wide-ranging theoretical and empirical literature that has tried to relate progressivity and unemployment. According to this literature, it is well established that progressive taxation has wage-moderating effects, thus stimulating employment in wage bargaining models without frictional cost (see, e.g., Holm and Koskela (1996); Koskela and Vilmunen (1996); Koskela and Schöb (1999). More recently, effects of labour taxation haves also been analyzed in the search for a theoretical framework by Pissarides (1988) and Mortensen and Pissarides (2001), among others. Pissarides (1998) shows that under the standard wage bargaining assumption progressive taxation boosts job creation and thereby increases employment.

Models with labour market frictions have proliferated in recent years to explain the unemployment rate. The typical framework in this literature is built on the search and matching models in the Diamond-Mortensen-Pissarides tradition (see, for example, Pissarides (2000) and Mortensen and Pissarides (1994)) where there is individual wage setting. However the wage determination mechanism in Western European countries is, essentially, the collective bargaining. To date, however, little work has been done to incorporate frictions within a collective wage bargaining framework. The major exceptions are Delacroix (2006), Ebell and Haefke (2006) Krusell and Rudanko (2012), and more recently, Ranjan (2013).

Bearing in mind all the above features, the purpose of this paper is to examine the relation between unemployment and the degree of centralization in wage bargaining in a unified framework that characterizes the most developed economies. More specifically, we construct a labour market model with collective wage settlement and frictions, where the trade unions and employers bargain over wages while firms make decisions about employment (right-to-manage model). Moreover, we assume a progressive income tax on employees and monopolistic competition in the output market. We calculate the amount of employment and labour market tightness when wages are set at the firm, sector and national level and compare them to see under which conditions the hump-shaped hypothesis postulated by Calmfors and Driffill (1988) holds true.

To put our paper into context with respect to the existing literature, we briefly review the main theoretical findings on labour market. Our approach is closely related to the following papers. Like Ranjan (2013), we use a Cobb-Douglas production function (AL^{α}), but by adding imperfect competition, we can study and compare different levels of collective wage setting: at a firm, sector and national level.

We expand on Ebell and Haefke (2006), assuming a Cobb-Douglas production function

(lineal, that is, AL, in their paper) and firm collective and national wage setting, so that we are able to compare different levels of collective wage setting. Ebell and Haefke, on the other hand, only compare individual and collective wage setting. García Sánchez and Vázquez Méndez (2008) also further developed the Ebell and Haefke paper, with firm collective wage setting. We then improve on García Sanchez and Vázquez Mendez, by assuming a Cobb-Douglas production function and obtaining a result for the national wage setting. Delacroix (2006) presents a model with lineal production functions where some sectors set the wage at the firm level, while others do so at the sector level. We then extend it, assuming a Cobb-Douglas production function and national collective wage setting. Wages, are nevertheless set at the same level across all sectors. We also improve on García and Sorolla (2014) and Spector (2004), by introducing frictions in the labour market.

This paper makes the following contributions: we show that in labour markets with matching frictions and market power, given a certain level of *progressivity and tax structure*, the employment rate is higher when wages are set at the firm level than when employment is set at the national or sector level. Moreover, when wages are set at the sector level, there is less employment, in other words, the inverted U relationship between unemployment and the degree of centralization in wage setting postulated by Calmfors and Driffill holds true.

These results hold given the same level of progressivity and the tax structure in the OECD countries included in our sample. Nevertheless, as we point out later in Table 3, there is a great disparity between both the labour tax structure and the degree of progressivity set by the different countries. This empirical evidence can help us to explain, in our theoretical model that we later develop, the lack of robustness in the empirical analysis of the Calmforms-Driffil hypothesis. Evidently, this is not the only explanation, and other ones do exist in the specialized literature, such as the social expenditure internalization argument put forward by Alesina and Perotti (1997), Doménech and García (2008) and García and Sorolla (2014).

The remainder of the paper is organized as follows. In section 2 we summarize the OECD data that we use throughout our theoretical anaysis. In section 3, we set out the labour market model and present the analysis of different wage bargaining settings: sector, firm and national level. Lastly, we discuss the results and implications for unemployment. Section 4 outlines the conclusions.

2 Stylized facts for some OECD countries

The Great Recession is characterized by an unprecedented decline of GDP and a sharp increase in the unemployment rate in many countries. However, there are major differences

across the OECD countries in labour market outcomes; more specifically, the increase in the unemployment rate between 2007 and 2009 was 9.7% in Spain, 7.2% in Ireland and 4,7% in United States. In the other OECD economies, the increase in unemployment was between 1% and 2,5% (for example, in Italy, Portugal and France) while other countries underwent an increase of less than 1% (for example, Norway and Austria). These differences might be explained by the size of the negative demand shock, the different macroeconomic policy responses (expansionary monetary and fiscal policy), as well as the structure of the labour markets. This paper focuses on this third possible reason for international differences in the labor-market response to the Great Recession: the national labour-market institution and, more precisely, the wage bargaining system. However, our theoretical and empirical analysis goes further, because we add other institutional features, rigidities and fiscal parameters that also affect wage bargaining outcomes. We include the degree of competition in the output market, as well as both the labour tax structure and income labour progressivity.

In the theoretical and empirical literature, the notion that wage bargaining institutions play a fundamental role in shaping economic outcomes has received a great deal of attention, at least since the 1980s, when unemployment rose sharply and remained high in most of the major OECD economies[2]. Many empirical studies attempt to link cross-country differences in unemployment to the degree of centralization characterizing the bargaining in question (for a survey, see Flanagan (1999)).

One particular influential perspective, first formulated in the seminal paper by Calmfors and Driffil (1988), confirmed that wage bargaining at sector level produces worse results, in terms of employment, than by more decentralized or centralized wage bargaining systems. Wage bargaining systems depend on multiple factors, including trade union density, coverage by collective agreements (union coverage), the centralization and co-ordination of wage bargaining, and a number of labour laws that affect the institutional bargaining framework and socio-economic conditions of the labour market. Thus, it is clear that the wage bargaining system is too complex for just in one or two indicators to capture all the complexities and heterogeneity of this labour institution. Despite potential limitations, we have constructed an index of the wage bargaining system that bears the major number of elements in mind. More specifically, our index is defined as the average of the bargaining level and coordination multiplied by union coverage using Visser (2013) data. The index runs from zero to five[3].

[2]The OECD Jobs Study (1994) points out the role of labour market rigidities in accounting for the high and persistent unemployment in Europe, and therefore, suggests that greater deregulation is the solution.

[3]Calforms and Driffill (1988) ranked countries according to similar criteria. More specifically, their ranking is based on the sum of bargaining level and Coordination. The difference between our classification and that elaborated by Calforms and Driffill (1988), within the same dates, is minimal. However, we include union coverage in our classification due to the importance of extensions to collective contracts in Europe regardless of whether or not they are unionized. For more details, see chapter 3 of the OECD

Table 1 provides a classification into three groups of countries, which we have named ANGLO, EUCON and NORDIC, according to their composite index over collective wage bargaining institution.

The first group, ANGLO, includes countries with the lowest score in our composite index. In this case, we assume that this group of countries has a low level of centralization/coordination in the wage bargaining system. In contrast, the NORDIC group of countries constitutes the other extreme, with a high degree of centralization/coordination.

Tables 2 and 3 provide information on different institutional indicators for the period 1990-2013. The countries in these tables are classified according to their wage bargaining system as shown in Table 1. The theoretical study below examines in greater detail the mechanism through which these variables affect the unemployment rate.

Table 2 summarizes the average behaviour of the harmonized unemployment rate (U), the degree of rigidity in the goods market (PMR), and finally, the tax wedges (TW)[4]. All these variables contribute, a greater or lesser degree, to determining the wage bargaining, and thus, the unemployment rate as we will see later in the theoretical model.

The most striking results to emerge from the data for EUCON countries, compared to the rest of the countries, are as follows: first, and foremost, the EUCON countries on average, have the most regulated goods market (Table 2, PMR average 1.86) compared to Anglo and Nordic countries. Second, as far as the tax wedge is concerned, we find that EUCON countries haves a higher level than Anglo countries, but lower than Nordic countries.

Regarding the tax wedge, we intend to go one step further, taking into account the composition of the tax wedge and the progressiveness of the income tax. In order to do so, we include the income tax (IT) in the tax wedge, as well as social security contributions paid by workers and employer (WSC and WSE respectively) .

Table 3. Columns 2 to 4, dysplay the composition of the tax wedge (TW) and an index of progressivity based on Holter et. al (2014). As can be seen from Table 3, there are large differences in the composition of the tax wedge across OECD countries over the period 1990-2013. In general, countries with the highest labour tax are also those which tend to have the highest social contributions paid directly by employers.

As shown below, in a theoretical analysis, more tightly regulated goods markets and higher social contributions paid by employers lead to more unemployment in a sector-level wage-setting system. These characteristics thus reinforce the higher mean unemployment rate of this group, regardless of the degree of centralization of the system, and suggest that

Employment Outlook (2004).

[4]We capture the effect of product-market institutions, which has received growing attention in recent literature (e.g Blanchard and Giavazzi, 2003; Fiori et. al. 2012) through an indicator of aggregate product market regulation (PMR). The tax wedge (TW) used here include personal income taxes (IT), as well as employer and employees social security contributions (WSC,WSE).

Table 1
Some labour markets institutional indicators in OECD countries.

	Bargaining level	Coordination	Union Coverage	Index
ANGLO				
USA	1	1	15.2	0.15
New Zealand	1.09	1	32.3	0.34
Canada	1	1	33.9	0.34
UK	1.18	1	35.9	0.39
Japan	1	4.36	19.3	0.52
EUCON				
Australia	2.18	2.18	60.8	1.33
Switzerland	3	3	44.7	1.34
Portugal	3.29	2.62	93.08	1.37
France	2	2	92.6	1.85
Ireland	4.45	3.86	42.8	1.85
Greece	4.09	2.27	65	2.07
Germany	3	3.82	69.2	2.36
Spain	3.41	3.09	80.9	2.63
Italy	3	3.27	85	2.67
NORDIC				
Norway	3.36	4.09	72.1	2.69
Netherlands	3.23	3.68	83.1	2.87
Denmark	3.09	3.95	84.1	2.96
Sweden	3.18	3.86	84.7	2.99
Austria	3	4	98.5	3.45
Finland	4.27	4.27	87.3	3.73
Belgium	4.55	4.68	96	4.43

Source:The Bargaining level is an index on the predominant level(s) at wich wage bargaining takes place with a range from 1 to 5. Visser (2013) use a five-point scale instead of using a three-point scale used by Calmfors and Driffill (1988). More concretly, 1= Bargaining takes place at the local or company level, 3= the bargaining takes place at the sector or industry level and 5 the bargaining takes place at cental level. The number 2 and 4 represent two mixed situations. Source data is the variable Level of Visser (2013). Coordination is an index that measure the bargaining coordination to wage-setting between employers and employees with a range from 1 to 5 based on Kenworthy 2001a and 2001b.The range goes to 1, when the wage bargaining is fragmented, confined largely to individual firms or plants to 5 when the wage setting is realized by centralized bargaining. The variable index is defined as the average of the of bargaining level and coordination multiplying by union coverage. Database Visser (2013). Sample: Average over 1990-2011.

EUCON countries have the institutional characteristics to generate a higher unemployment rate than other countries.

Finally, we conclude this empirical analysis by testing the hump hypothesis and its robustness. As mentioned above, Calmfors and Driffill (1988) found a hump-shaped relationship between an index of coordination and the unemployment rate. We examine these

Table 2
Rigidities and institutions.

	U	PMR	TW
ANGLO			
USA	6.13	1.31	0.23
New Zealand	6.48	1.31	0.27
Canada	8.16	1.62	0.28
UK	6.89	1.18	0.25
Japan	3.97	1.58	0.24
average	*6.32*	*1.4*	*0.25*
std desv	*1.36*	*0.17*	*0.02*
EUCON			
Australia	6.82	1.45	0.17
Switzerland	3.78	1.88	0.22
Portugal	7.43	2.13	0.23
France	9.98	1.78	0.39
Ireland	9.62	1.56	0.27
Greece	11.25	2.30	0.30
Germany	8.12	1.68	0.36
Spain	15.99	1.81	0.30
Italy	9.21	1.73	0.40
average	*9.42*	*1.86*	*0.31*
std desv	*3.16*	*0.25*	*0.07*
NORDIC			
Norway	4.01	1.61	0.37
Netherlands	4.42	1.30	0.35
Denmark	6.05	1.43	0.40
Sewden	7.13	1.54	0.46
Austria	4.68	1.57	0.38
Finland	9.75	1.52	0.44
Belgium	8.04	1.71	0.42
average	*5.91*	*1.37*	*0.36*
std desv	*2.27*	*0.44*	*0.1*

Notes:The harmonized unemployment rate U represents unemployed persons as a percentage of the labor force (the total number of people employed plus the unemployed). The OECD Indicators of Product Market Regulation (PMR) are a comprehensive and internationally-comparable set of indicators that measure the degree to which policies promote or inhibit competition in areas of the product market where competition is viable. It is increasing in the degree of regulation in the goods markets and has a range from 0 to 4. This series is only availabe for 1998, 2003, 2008 and 2013 (See Koske et. al. (2015) for more detail). The source of the database is OECD (2015), Product Market Regulation Database, www.oecd.org/economy/pmr. The Tax Wedge (Tw) is equal to the sum of the income tax (IT), and employees' and employers' contributions (WSC and ESC respectively).

issues below taking into account our relative index of collective bargaining. Figure 1 plots a scatter diagram of the unemployment rate against our relative index. In the period under study, there is weak evidence in support of the hump hypothesis. Additionally, given this scatter plot, we can now draw the line that best fits the data using an ordinary least

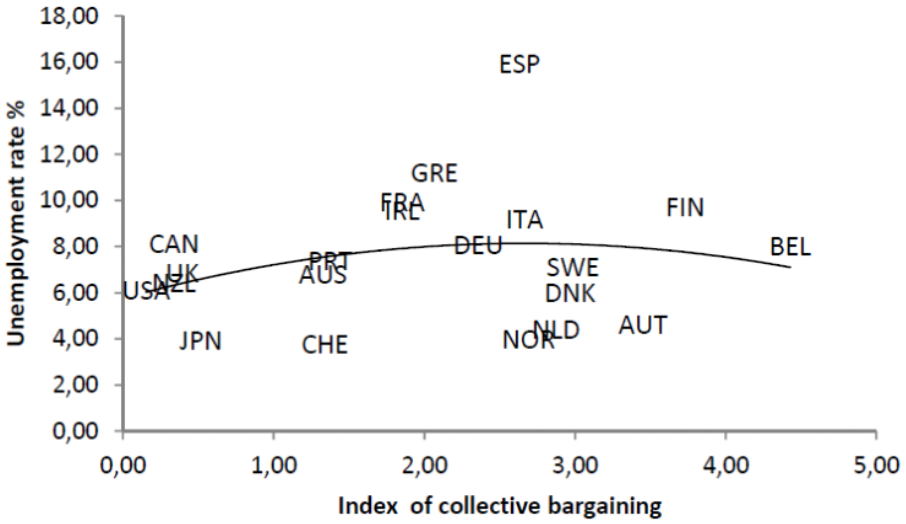
Table 3

Tax structure and progressivity

	IT	WSC	ESC	PI
ANGLO				
USA	0.11	0.05	0.06	0.14
New Zealand	0.27	0.00	0.00	
Canada	0.18	0.04	0.06	0.19
UK	0.13	0.05	0.07	0.20
Japan	0.09	0.08	0.09	0.10
average	*0.15*	*0.04*	*0.05*	*0.15*
std desv	*0.06*	*0.02*	*0.03*	*0.04*
EUCON				
Australia	0.17	0.00	0.00	
Switzerland	0.11	0.05	0.05	0.13
Portugal	0.07	0.06	0.09	0.14
France	0.08	0.09	0.22	0.14
Ireland	0.16	0.03	0.07	0.23
Greece	0.06	0.12	0.14	0.2
Germany	0.11	0.12	0.13	0.22
Spain	0.09	0.04	0.17	0.15
Italy	0.13	0.06	0.21	0.18
average	0.10	0.07	0.14	0.17
std desv	0.03	0.03	0.06	0.03
NORDIC				
Norway	0.17	0.07	0.13	0.17
Netherlands	0.11	0.16	0.08	0.25
Denmark	0.38	0.02	0.00	0.26
Sewden	0.23	0.04	0.20	0.22
Austria	0.13	0.12	0.14	0.19
Finland	0.21	0.05	0.18	0.24
Belgium	0.17	0.08	0.17	
average	0.18	0.07	0.12	0.19
std desv	0.09	0.04	0.06	0.06

Notes: Personal income tax (IT) is defined as the ratio of revenues from taxes on income, profits and capital gains of indivuals to the tax base, which consists of wages and the property and entrepreneurial income of households and the operating surplus of incorporated enterprises. Employees' and employers' social contributions tax (WSC) and (ESC) respectively are defined as the ratio of social security contributions paid by employees and by employers to the tax base, which consists of wages. All the effective tax rates have been computed, as suggested in Boscá, García and Taguas (2005), using the methodology proposed by Mendoza et. al (1994). Progressivity Index (PI) measuring the average tax progressivity in OECD countries in the period 2000-07 based on the paper of Holter et. al (2014). This measure take into account income tax for different family types (single, married without children etc.). It is equal to zero for a proportional tax code for all income levels and increases with the raise in the average tax rate as earnings go up. The value of PI range between 0 to 1. Sample: Average level 1990-2013 except PI.

squares regression of unemployment on the squared relative index and the relative index.



The regression results confirm the minimal relationship between these two variables. More specifically, the equation estimated yields ($\hat{u} = 5.75 + 1.84$ (Index) - 0.17 (Index)^2 with a standard error of (s.e 1.83) and (s.e 0.43) respectively and ($R^2 = 0,064$).

Figure 1. Scatter plot of the unemployment rate and relative index of collective bargaining with the regression line.

From the graph above we can see that there is a weak hump-shaped pattern between bargaining structure and the index of collective bargaining for the time period and country under study. This result is not entirely surprising in light of existing literature testing the hump hypothesis[5].

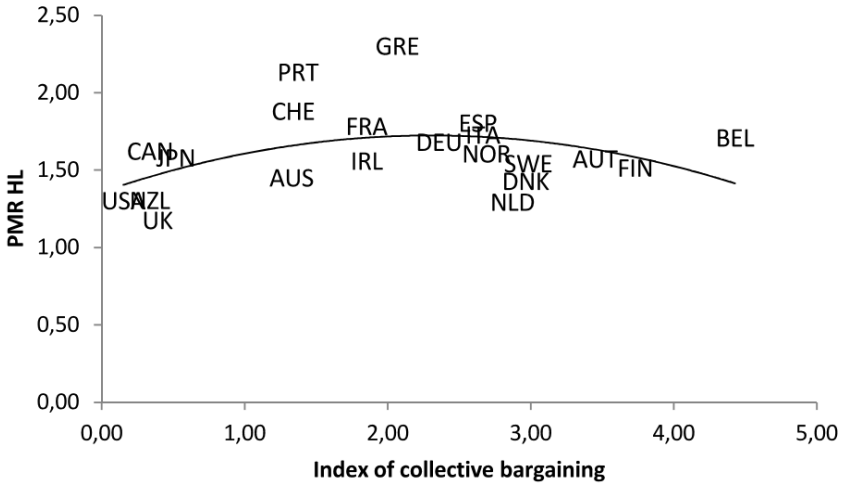
Furthermore, in the academic literature, a large body of research supports the view that lower product market regulation reduces the unemployment rate. Accordingly, we explore the relationship between the variable product market rigidity and our relative index.

Figure 2. Scatter plot of product market regulation and index of collective bargaining with the regression line.

Figure 2 is a scatter plot (with the best fitting regression line). The estimated expression is $\hat{PMR}$ =1.35+ 0.31 (Index) - 0.06 (Index)^2 with (s.e 0.16) and (s.e 0.03) respectively and ($R^2 = 0.18$). From the graph and estimated expression above we can see that there is a clear hump-shaped pattern between bargaining structure and the degree of rigidity in the goods market. This result indicates the strong interdependence between the labour wage bargaining setting and product market regulation as a key factor to consider when implementing policy reforms in Eucon countries. However, given this strong interdependence, what is the explanation for the lack of robustness of the hump-shaped hypothesis predicted by Calmfors and Driffill (1988) in our sample period?

We provide a possible answer to explain this lack of robustness in the findings relating

[5]See Aidt and Tzanatos (2008), for an excellent survey of these issues.



to the relationship between the unemployment rate and bargaining structure based on a third factor (for example, labour tax structure and or progressivity of labour tax income), which affects unemployment and also exhibits, or not, an inverted-U shaped relationship in regard to bargaining structure [6]. This third factor can reinforce or moderate over time the hump-shaped hypothesis to lessen the importance of the wage bargaining structure relative to other determinants of macroeconomic labour performance[7]. Furthermore, within group of countries that belong to a certain wage bargaining system, for example the EUCON countries, we can explain the different unemployment rate performance through this heterogeneity of fiscal variables.

The purpose of the next theoretical section is to provide a more detailed discussion about the relationship between unemployment rate and the wage bargaining system and some factors that, simultaneously, determine the unemployment rate under the different wage bargaining systems.

3 The Labour Market

In this section, we present a model of the labour market with matching frictions, where we compute the equilibria under different levels of centralization in wage bargaining: firm, sector and centralized, and then compare them. We assume, as is typical in the Pissarides

[6] When one analyzes the influence of taxes on unemployment, it seems that other elements must be taken into account in order to explain the data. The empirical evidence presented by Daveri and Tabellini (2000) supports the view that in more corporate and decentralized countries, labour taxes are less distortionary than in countries with an intermediate level of wage bargaining. However, this paper does not take into account, for example, rigidity in the goods market.

[7] Recent studies suggest that institutions interact with each other, and thus the effect of one institution or policy may vary depending on the institutional context. Hence, it seems to be necessary when focusing on the unemployment rate problem to take into account the interactions and complementarities between these institutions in the labour market. See, for example, the seminal theoretical paper of Coe and Snower (1997), or more recently, the empirical papers of Belot and Van Ours (2004) and Bassanini and Duval (2009).

matching model, that each worker has one unit of labour to devote to market activities at every instant of time. Thus, in this framework each worker can be employed or unemployed.

3.1 Equilibrium of Flows in the Labour Market

The labour market is characterized by a standard search and matching Mortensen-Pissarides framework. The change in employment is determined by unemployment inflows and outflows. In its steady state (flow equilibrium), employment is constant. Thus, the equilibrium of the labour market flows imply that the number of matches or inflows in the labor market denoted by X is equal to the number of outflows, which is equal to the existing amount of employment L multiplied by an exogenous destruction rate λ. This means:

$$X = \lambda L \tag{1}$$

that is:

$$\frac{X}{U}U = \lambda L \tag{2}$$

The matching function is $X = m(V, U)$ where V are vacancies, U the amount of unemployment and then $U = (N - L)$ where N is the total size of the workforce. We assume that m has constant returns to scale and $m_V > 0$ and $m_U > 0$. For notational convenience, we define the degree of the labour market tightness as $\theta \equiv \frac{V}{U}$. The matching function can be used to calculate both the rate at which vacant jobs become filled as $\frac{X}{V} = m(1, \frac{1}{\frac{V}{U}}) \equiv q(\theta)$ and the rate with which an unemployed worker finds a job $\frac{X}{U} = \frac{V}{U}\frac{X}{V} = \theta q(\theta)$ given $q' < 0$ and $\frac{d(\theta q(\theta))}{d\theta} > 0$.

Substituting $\frac{X}{U} = \theta q(\theta)$ and $U = (N - L)$ into the equilibrium labour market flows equation (2) we obtain:

$$\theta q(\theta)(N - L) = \lambda L \tag{3}$$

rewriting this expression we obtain an equation that determines the employment level in terms of the degree of the labour market tightness:

$$L = \left[\frac{\theta q(\theta)}{\lambda + \theta q(\theta)}\right] N = \left[\frac{1}{1 + \frac{\lambda}{\theta q(\theta)}}\right] N \tag{4}$$

where $\frac{\partial L}{\partial \theta} > 0$, meaning that if the number of vacancies per unemployed person (labour market tightness) increases, more employment is needed in order to have equilibrium of flows $\left(\frac{X}{U}\frac{U}{L} = \lambda\right)$.Roughly speaking, if we have more matches, more workers must be out and in order to have more workers out, we need more employment.

3.2 Wage Setting at the Sector Level

3.2.1 Employment at the sector level with frictions and monopolistic competition.

We formalize the interaction between the representative union and the representative firm as a three-stage game, where wage settlement is bargained by the union and the firm. First the firm opens vacancies, then the wage is negotiated, and finally the firm chooses the amount of employment. This is the right-to-manage model where wages are set by considering the employment function[8].

3.2.2 The goods market.

The economy is characterized by monopolistic competition in the goods market. We assume $J \in [0,1]$ sectors with one firm per sector that produces a different good, Y_j:

$$Y_j = F(L_j). \tag{5}$$

The aggregate demand function facing firm J is

$$Y_j = \left(\frac{P_j}{P}\right)^{-\sigma} I, \tag{6}$$

where $\sigma > 1$ is the constant elasticity of demand of product J with respect to its price, I denotes the total real income, $P_j(t)$ is the price of product j, $P(t)$ is a price index with the usual properties and $Y_j(t)$ is the corresponding quantity demanded of the good produced by firm j.

3.2.3 Firm´s problem

The firm in sector j chooses L_j and V_j in order to maximize the sum of expected discounted profits taking the nominal wage and $\theta(t)$ as given

$$\Pi_j = \int_0^\infty e^{-\rho t}[P_j(t)F(L_j(t)) - (1+\tau^f)W_j(t)L_j(t) - cP(t)V_j(t)]dt \tag{7}$$

subject to

$$\dot{L}_j(t) = X_j(t) - \lambda L_j(t) = q(\theta(t))V_j(t) - \lambda L_j(t) \tag{8}$$

[8]In models with frictions and individual wage setting, employment and wages are usually set at the same time, calculating the Nash equilibrium or employment is set before having the Stole and Zwiebel solution. As noted by Cahuc and Wasmer (2001) both solutions coincide when the production is linear.

and

$$Y_j(t) = \left(\frac{P_j(t)}{P(t)}\right)^{-\sigma} I(t), \tag{9}$$

where c is the constant flow cost per vacancy, $V_j(t)$ is the number of vacancies posted by the firm, $W_j(t)$ is the before-tax wage and τ_f denotes the payroll tax rate paid by employers.Taking (6) into account, we rewrite the firm objective as

$$\Pi_j = \int_t^{\infty} e^{-\rho t}[P(t)I(t)^{\frac{1}{\sigma}}F(L_j(t))^{1-\frac{1}{\sigma}} - (1+\tau^f)W_j(t)L_j(t) - c(t)P(t)V_j(t)]dt \tag{10}$$

subject to

$$\dot{L}_j(t) = X_j(t) - \lambda L_j(t) = q(\theta(t))V_j(t) - \lambda L_j(t) \tag{11}$$

The first order condition (see Ebell and Haefke (2006) or García Sánchez and Vázquez Méndez (2008)) gives the amount of employment (the employment equation) at the sector level in terms of the exogenous variables W_j, τ^f, P and I[9], that is:

$$PI^{\frac{1}{\sigma}}(1-\frac{1}{\sigma})F(L_j)^{-\frac{1}{\sigma}}F_L(L_j) = (1+\tau^f)W_j + \frac{(\rho+\lambda)cP}{q(\theta)} \tag{12}$$

or:

$$F(L_j)^{-\frac{1}{\sigma}}F_L(L_j) = \frac{m}{PI^{\frac{1}{\sigma}}}\left[(1+\tau^f)W_j + \frac{(\rho+\lambda)cP}{q(\theta)}\right] \tag{13}$$

where $m \equiv \frac{1}{1-\frac{1}{\sigma}}$ is the market power degree.

For calculation purposes, we assume a Cobb-Douglas production function: $F(L_j) = AL_j^{\alpha}$, whereby the amount of employment (13) is:

$$A^{-\frac{1}{\sigma}}(L_j)^{-\frac{\alpha}{\sigma}}\alpha A(L_j)^{\alpha-1} = \frac{m}{PI^{\frac{1}{\sigma}}}\left[(1+\tau^f)W_j + \frac{(\rho+\lambda)cP}{q(\theta)}\right] \tag{14}$$

or equivalently:

$$\alpha A^{\frac{\sigma-1}{\sigma}}(L_j)^{-\left(1-\alpha+\frac{\alpha}{\sigma}\right)} = \frac{m}{PI^{\frac{1}{\sigma}}}\left[(1+\tau^f)W_j + \frac{(\rho+\lambda)cP}{q(\theta)}\right] \tag{15}$$

we also assume that the cost of hiring is proportional to nominal wage, thus $cP = \gamma W_j$, where γ is a positive constant having

$$\alpha A^{\frac{\sigma-1}{\sigma}}(L_j)^{-\left(1-\frac{\alpha}{m}\right)} = \frac{m}{PI^{\frac{1}{\sigma}}}\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]W_j \tag{16}$$

[9]One may be tempted to call L_j the labour demand of the firm, but note that this is not the case because L_j is really the number of units of labour really hired by the firm. In fact labour demand L_j^d is given by $L_j^d = L_j + V_j$.

Solving the above expression for L, we obtain an explicit employment equation that depends on nominal wages W_j and labour market tightness θ,then amount of employment is given by:

$$L_j = \left[\frac{\frac{m}{PI^{\frac{1}{\sigma}}} \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)} \right] W_j}{\alpha A^{\frac{\sigma-1}{\sigma}}} \right]^{-\frac{1}{(1-\frac{\alpha}{m})}} \tag{17}$$

where one can compute the elasticity of employment with respect to the wage, ϵ_L, as $-\frac{1}{(1-\frac{\alpha}{m})}$.

3.3 Union wage setting at the sector level

In order to write the union´s objective function and set the wages at the sector level, we first need to define the worker asset values. The value of being employed in firm j, E_j, is given in flow terms by the following value function[10]

$$\rho E_j = (1-\tau^w)W_j - a \ + \lambda \ (U_j - E_j) \tag{18}$$

where ρ is the discount rate and U_j denotes the asset value of an unemployment worker. Furthermore, a and τ^w are tax parameters such that the income tax paid by an employed worker per period is $T = a + \tau^w W(t)$. This tax includes income tax plus the social security contribution paid by employees. When $\tau^w > 0$ and $a = 0$ the tax schedule is purely proportional. With $a < 0$, the tax schedule is progressive and with $a > 0$ is regressive in the sense that average tax rate increases or decreases with income . The after tax income is then given by $(1-\tau^w)W_j - a$.

The asset value equation of an unemployed worker U_j is

$$\rho U_j = B + \theta \ q(\theta) \ (E_j - U_j) \tag{19}$$

where B is the value of unemployment benefit that is not taxed[11]. If the total number of union members in sector j is N[12] and L_j of them become employed, then the expected welfare of a union member is given by

$$\left(\frac{L_j}{N} E_j + \frac{N - L_j}{N} U_j \right) \tag{20}$$

We suppose that the fallback position of the union is U_j when the firm rejects the union´s wage offer. Thus, following Ranjan (2012), the aggregate surplus or union´s

[10] To determine the net wage for a worker in this context, we assume the equivalence between the optimal consumption and the labour income, see for example, Galí (2010) and Langot (2014).

[11] Alternatively, it can be the value of leisure or home production.

[12] We assume that the N workers are equally distributed between sectors which, in the unit interval, means $N_j = N$.

objective in flow terms is:

$$V = \left(\frac{L_j}{N}E_j + \frac{N - L_j}{N}U_j\right) - U_j = (E_j - U_j)L_j$$

and using (18) and (19) we obtain[13]:

$$V = \left(\frac{L_j}{N}E_j + \frac{N - L_j}{N}U_j\right) - U_j = (E_j - U_j)L_j = \frac{\left[(1-\tau^w)W_j - a - B\right]L_j}{\rho + \lambda + \theta q(\theta)} \tag{21}$$

On the other hand, the firm´s objective function is given by

$$\Psi = \Pi_j - \hat{\Pi}_j = P(t)I(t)^{\frac{1}{\sigma}}F(L_j(t))^{1-\frac{1}{\sigma}} - (1+\tau^f)W_j(t)L_j(t) \tag{22}$$

because the outside option or the fall-back position of the firm is $\hat{\Pi}_j = -c(t)P(t)V_j(t)$, namely the sunk cost of open vacancies.

We now determine the wage at sector level bargained between the union and the monopolistic firm. To do so, we apply the Nash bargaining solution and employ the "right-to-manage" approach according to which employment is unilaterally determined by the firm. Thus, the bargaining procedure is a two-stage game. In the first stage, the bargaining parties agree on a wage rate using the profit-maximizing level of employment, while in the second stage firms decide employment. As is usual in such models, the relative bargaining power of the union is given by a number $0 \leq \beta \leq 1$ while the firms are endowed with bargaining power $(1 - \beta)$. Applying this bargaining solution the negotiating parties decide on W in order to maximize subject to the employment equation given by (27). Note that setting the wage at the sector level implies using the employment equation derived when the firm takes into account the aggregate demand function. This can be interpreted as saying that there is only one firm per sector and so the wage is set for the firm and then for the sector.

The Nash bargaining maximand is

$$\Omega = V^{\beta} * \Psi^{1-\beta} \tag{23}$$

and the first-order condition with respect to nominal wage yield:

$$\Omega_w = 0 \Leftrightarrow \beta\frac{V_w}{V} + (1-\beta)\frac{\Psi_w}{\Psi} \tag{24}$$

where variables with subscripts refer to partial derivatives (e.g., $V_w = \frac{\partial V}{\partial W}$)

The solution for the wage equation is standard and corresponds to

[13]If the union cares only about insiders, one only substitutes the asset value equation of an employed worker in $(E_j - U_j)L_j$ as, for example, in Ebell and Haefcke (2006).

$$W_j = \left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{(B+a)}{(1-\tau^w)} \tag{25}$$

The bargained nominal wage depends on the model parameters in a very intuitive way. First the higher the workers "bargaining strength", β, the higher is the nominal wage. Second, more generous benefits, B, greater is the increase in the negotiated wage. Third, when a decreases, the negotiated wage decreases, this means, in particular, that with progressive tax rate ($a < 0$), the wage set is lower than the one set with a regressive tax rate ($a > 0$) and, finally the wage increases with market power m. We assume that the government sets $b = \frac{B}{P}$ and $\bar{a} = \frac{a}{P}$, in which case the wage equation is

$$W_j = \left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{P(b+\bar{a})}{(1-\tau^w)} \tag{26}$$

Lastly, we are able to compute the amount of employment, at the sector level, by substituting (25) in (17) yields

$$L_j = \left[\frac{m\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)}}{I^{\frac{1}{\sigma}}\alpha A^{\frac{\sigma-1}{\sigma}}}\right]^{-\frac{1}{(1-\frac{\alpha}{m})}} \tag{27}$$

3.4 Short-run general equilibrium at the sector level

Whith symmetric equilibrium in the output market $L_j = L$ for all j. Furthermore at general equilibrium income is equal to production, i.e. $I = AL^{\alpha}$.Thus, we can substitute I in (27), obtaining an explicit relationship between the amount of employment when wages are set at the sector level and labour market tightness θ equal to

$$L = \left[\frac{m\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)}}{\alpha A}\right]^{-\frac{1}{(1-\alpha)}} \tag{28}$$

It is fairly straightforward to analyze the relationship between employment and the fiscal variables, bargaining weight and market power. It is worth underlining that an increase in θ decreases L because of the increase in labour turnover costs. Lastly, assuming "equilibrium" (inflows=outflows) in the labor market, that is, equation (4) given by

$$L = \left[\frac{\theta q(\theta)}{\lambda + \theta q(\theta)}\right]N \tag{29}$$

and substituting (29) in (28), we get the equilibrium labour market tightness:

$$\alpha A\left[\left(\frac{\lambda+\theta q(\theta)}{\theta q(\theta)}\right)\frac{1}{N}\right]^{(1-\alpha)} = m\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \tag{30}$$

We call this equilibrium with wage setting at the sector level (θ_S, L_s). It is then easy to prove (see appendix) that an equilibrium exists and is unique and $\frac{\partial \theta_S}{\partial m} < 0$, $\frac{\partial \theta_S}{\partial \beta} < 0$, $\frac{\partial \theta_S}{\partial b} < 0$ and $\frac{\partial \theta_S}{\partial \bar{a}} < 0$ and then $\frac{\partial L_S}{\partial m} < 0$, $\frac{\partial L_S}{\partial \beta} < 0$, $\frac{\partial L_S}{\partial b} < 0$ and $\frac{\partial L_S}{\partial \bar{a}} < 0$.

It should be underlined that the level of employment obtained using a Cobb-Douglas production function is more general than the one obtained with the linear production function (AL) used in Ebell and Haefke (2006) and García Sánchez and Vázquez Méndez (2008).Their results represent the special case $\alpha = 1$.

3.5 Short-run general equilibrium at the firm level

We now show that the equilibrium at the firm level is the equilibrium at the sector level for the case $m = 1$. If unions set the wage at the firm level, then they take into account the firm's employment equation which, if we assume infinite firms per sector J in the interval $[0, 1]$, implies that firms take the price P_j as given and then the firm i in sector j chooses L_{ij} and V_{ij} in order to maximize

$$\int_0^\infty e^{-\rho t} P_j(t) F(L_{ij}(t)) - (1 + \tau^f) W_{ij}(t) L_{ij}(t) - cP(t) V_{ij}(t) dt \tag{31}$$

subject to

$$\dot{L}_{ij}(t) = X_{ij}(t) - \lambda L_{ij}(t) = q(\theta(t)) V_{ij}(t) - \lambda L_{ij}(t) \tag{32}$$

and then the first order condition (see Cahuc and Zylberberg (2004) or Ranjan (2012)) gives the employment for firm ij as:

$$P_j F_L(L_{ij}) = (1 + \tau^f) W_{ij} + \frac{(\rho + \lambda) cP}{q(\theta)} \tag{33}$$

or:

$$F_L(L_{ij}) = \frac{1}{P_j} \left[(1 + \tau^f) W_{ij} + \frac{(\rho + \lambda) cP}{q(\theta)} \right]. \tag{34}$$

assuming that it is $Y_{ij} = A(L_{ij})^\alpha$ and $cP = \gamma W_{ij}$, the employment equation is:

$$\alpha A (L_{ij})^{\alpha - 1} = \frac{1}{P_j} \left[(1 + \tau^f) + \frac{(\rho + \lambda)\gamma}{q(\theta)} \right] W_{ij} \tag{35}$$

and solving for L_{ij} we get

$$L_{ij} = \left[\frac{\frac{1}{P_j} \left[(1 + \tau^f) + \frac{(\rho + \lambda)\gamma}{q(\theta)} \right] W_{ij}}{\alpha A} \right]^{-\frac{1}{1-\alpha}} \tag{36}$$

therefore giving $\epsilon_L = -\frac{1}{1-\alpha}$.

The union´s fallback option is the income during the life of an unemployed worker

U_{ij} and then the payoff to the union net of its outside option is the surplus,V, given by

$$V = \left(\frac{L_{ij}}{\bar{L}_{ij}}E_{ij} + \frac{\bar{L}_{ij} - L_{ij}}{\bar{L}_{ij}}U_{ij}\right) - U_{ij} = (E_{ij} - U_{ij})L_{ij} = \frac{[(1-\tau^w)W_{ij} - a - B]\,L_{ij}}{\rho + \lambda + \theta q(\theta)} \quad (37)$$

The payoff net of the outside options for the firm, is expressed as

$$\Psi = \rho(\Pi_{ij} - \hat{\Pi}_{ij}) = P_j(L_{ij})^{\alpha} - (1+\tau^f)W_{ij}L_{ij} \quad (38)$$

where $\hat{\Pi}_{ij}$ is the firm´s fallback option, as explained earlier. The generalized Nash bargaining objective can then be written as:

$$\max_{W_{ij}} \Omega = V^{\beta} * \Psi^{1-\beta} \quad (39)$$

where β and $1-\beta$ represent the bargaining power of the union and the firm, respectively. The wage at the firm level is computed maximizing the previous expression subject to (36) and the optimal wage is

$$W_{ij} = \left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{P(b+\bar{a})}{(1-\tau^w)} \quad (40)$$

and we then compute the amount of employment of firm $_{ij}$ substituting (40) in (36) that gives us

$$L_{ij} = \left[\frac{\frac{P}{P_j}\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)}}{\alpha A}\right]^{-\frac{1}{1-\alpha}} \quad (41)$$

Since all firms are identical they all choose the same wage and thus in equilibrium $L_{ij} = L_j = L$, $P = P_j$ and the amount of employment is given by:

$$L = \left[\frac{\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)}}{\alpha A}\right]^{-\frac{1}{1-\alpha}} \quad (42)$$

namely the Ranjan solution (2012) when $\tau_w = \tau^f = \bar{a} = 0$. Finally, we combine (29) and (42) to obtain an expression for the equilibrium labour market tightness at the firm level:

$$\alpha A\left[(\frac{\lambda + \theta q(\theta)}{\theta q(\theta)})\frac{1}{N}\right]^{1-\alpha} = \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \quad (43)$$

in other words, the equilibrium tightness obtained when wages are set at the sector level with $m = 1$. We call this equilibrium (θ_F, L_F). It then follows that labour market tightness and employment when wages are set at the sector level are lower than labour market tightness and employment when wages are set at the sector level. In other words,

$\theta_F < \theta_S$ and $L_F < L_S$. One might ask why we assume that when wages are set at the sector level, we assume only a monopolistic firm in sector j while when wages are set at the firm level, we assume infinite firms in the interval $[0,1]$ in sector j . The answer is that usually one assumes that at the sector level, the wage is negotiated using a coalition of all firms within the sector (see García Sánchez and Sánchez Méndez (2008) and García and Sorolla (2014)) and then the labour demand of the total coalition of firms coincides with the one of the monopolistic firm when firms are distributed in the interval $[0,1]$ and is the one that must be taken into account.

3.6 Short run general equilibrium at the national level

At the national level the union knows when setting the wage that all firms are going to set the same price because they are identical and then $P_i = P$, that is $I = Y_j = AL_j^{\alpha}$, and that employment is going to be the same and $L_j = L$. This means considering the employment equation given by (15), namely,

$$\alpha A^{\frac{\sigma-1}{\sigma}}(L_j)^{-\left(1-\alpha+\frac{\alpha}{\sigma}\right)} = \frac{m}{PI^{\frac{1}{\sigma}}}\left[(1+\tau^c)+\frac{(\rho+\lambda)\gamma}{q(\theta)}\right]W_j \tag{44}$$

that $I = Y_j = AL^{\alpha}$, $L_j = L$. Hence, by symmetry, at the national level, the union is going to set the same wage for all sectors $W_j = W$, in which case the employment equation becomes:

$$L = \left[\frac{\frac{m}{P}\left[(1+\tau^c)+\frac{(\rho+\lambda)\gamma}{q(\theta)}\right]W}{\alpha A}\right]^{-\frac{1}{1-\alpha}} \tag{45}$$

being then $\varepsilon_L = {}^{-\frac{1}{1-\alpha}}$.

Now the payoff net of outside options for the firm is

$$\Psi = \rho(\Pi - \hat{\Pi}) = PF(L) - (1+\tau^f)WL \tag{46}$$

and, the payoff for the union, net of its outside option V, yields

A

$$V = \left(\frac{L}{\bar{L}}E + \frac{\bar{L}-L}{\bar{L}}U\right) - U = (E_j - U_j)L = \frac{((1-\tau^w)W - a - B)L}{\rho+\lambda+\theta q(\theta)} \tag{47}$$

In order to obtain the wage, we once again maximize the generalized Nash bargaining objective

$$\max_W \Omega = V^{\beta} * \Psi^{1-\beta} \tag{48}$$

subject to (45) and the optimal wage is

$$W = \left[\frac{\beta}{\alpha} + (1-\beta)\right] \frac{(B+a)}{(1-\tau^w)} \tag{49}$$

assuming again $B = Pb$ and $a = \bar{a}P$, we compute total employment substituting (49) in (45) obtaining

$$L = \left[\frac{m\left[(1+\tau^c) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)}}{\alpha A}\right]^{-\frac{1}{1-\alpha}} \tag{50}$$

Finally, we can combine (29) and (50) to obtain an expression for the equilibrium labour market tightness at the national level:

$$\alpha A\left(\left[1 + \frac{\lambda}{\theta q(\theta)}\right]\frac{1}{N}\right)^{(1-\alpha)} = m\left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \tag{51}$$

namely, the equilibrium at the sector level but with $\left[\frac{\beta}{\alpha} + (1-\beta)\right]$ instead of $\left[\frac{\beta m}{\alpha} + (1-\beta)\right]$. We call this equilibrium (θ_N, L_N).

It then follows that for the same parameters of the model $\theta_F > \theta_N > \theta_S$ and, then, $L_F > L_N > L_S$. The reason is that $m\left[\frac{\beta m}{\alpha} + (1-\beta)\right] > m\left[\frac{\beta}{\alpha} + (1-\beta)\right] > \left[\frac{\beta}{\alpha} + (1-\beta)\right]$ this means a "conditional" (to have the same parameters) inverted-U shaped relationship between employment and the level of wage bargaining when there is monopolistic competition in the output market ($m > 1$).Moreover, it is easy to demonstrate that this inverted-U shape increases when market power m rise.

However, this inverted-U shaped relationship may not appear as clearly as it does in the Figure 1, above. Our model provides one possible explanation: a different tax structure and different degrees of labour tax progressivity. It is therefore possible to explain the discrepancy between Calforms and Driffill hypothesis and the mixed empirical evidence focus on fiscal parameter[14]. Additionally, we have verified that this occurs when the union internalizes some degree of social government expenditure as shown by Doménech and García (2008) or Alesina and Perotti (1997). In this case, the social expenditure internalization may provide another justification for the lack of robustness of the Calmfors-Driffil hypothesis[15].

[14] It should be underlined that if the unemployment benefits B was taxed equally, the income labour w, τ^f whoult continue to be a key element when determing the unemployment rate.

[15] Detailed derivations of these results can be obtained from the authors upon request.

4 Conclusions

In this paper we present a labour market model with matching frictions, different levels of collective wage setting: firm, sector and national and monopolistic competition in the goods market. The results suggest an inverted-U shaped relationship between unemployment and the level of wage bargaining system in a labour framework, with matching frictions and regulated goods markets. These findings complement those realized by Calmforms and Driffill (1988). Moreover, our theoretical analysis goes one step further, suggesting that this inverted-U shaped relationship is obtained if the same fiscal policy is maintained, in particular, labour tax structure and the level of tax progressivity. One implication of our findings is that the heterogeneity found in the tax structure and the progressivity on labour income can explain the mixed empirical evidence concerning the lack of robustness of the Calmfors-Driffil hypothesis.

We hope that our results will help establish a complementary perspective of the relationship between wage bargaining system with labour market frictions and unemployment. We point out that rather than focusing on the wage bargaining system alone, future research should explore the relationship between product market regulation and the labour tax structure in greater detail in order to asses how political economy reforms can help to reduce unemployment in countries characterized by wage bargaining at a sector level.

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Appendix A

A.1 The Negotiated Wage at Sector Level.

This appendix develops the expressions for the terms $\frac{V_w}{V}$ and $\frac{\Psi_w}{\Psi}$ in the first-order condition (24) that determines the Nash bargaining solution. We start by looking at the profit response of the firm to a change in the wage rate Ψ_w.

The (net) profit function Ψ is

$$\Psi = P(t)I(t)^{\frac{1}{\sigma}}F(L_j(t))^{1-\frac{1}{\sigma}} - (1+\tau^f)W_j(t)L_j(t) \tag{52}$$

Therefore, the expression for the marginal value of the wage Ψ_w is

$$\Psi_w = P(t)I(t)^{\frac{1}{\sigma}}(1-\frac{1}{\sigma})F(L_j(t))^{-\frac{1}{\sigma}}\frac{\partial F(L_j(t))}{\partial L}\frac{\partial L}{\partial W} - (1+\tau^f)[L_j(t)+\frac{\partial L}{\partial W}]$$

notice that we assume L(w).

If we take into account the Cobb-Douglas function production $F(L_j) = AL_j^{\alpha}$ and multiply all by $\frac{WL}{LW}$,we can rewrite the above expression as

$$\Psi_w = P\ I^{\frac{1}{\sigma}}(1-\frac{1}{\sigma})\ \alpha\ \epsilon_L\ A^{(1-\frac{1}{\sigma})}{L_j}^{-\frac{\alpha}{m}}\frac{1}{W} - (1+\tau^f)\ L_j\ [1+\epsilon_L] \tag{53}$$

Notice that since the environment is stationary, we omit the use of time subscripts.

Furthermore, we also make use of the following relationship between the revenues and costs given by the expression (16) on the labour demand.

$$A^{(1-\frac{1}{\sigma})}(L_j)^{\frac{\alpha}{m}}PI^{\frac{1}{\sigma}} = \frac{m}{\alpha}\left[(1+\tau^f)+\frac{(\rho+\lambda)\gamma}{q(\theta)}\right]W_jL_j \tag{54}$$

Substituting (54) in (53) gives

$$\Psi_w = \frac{(\rho+\lambda)\gamma}{q(\theta)}\epsilon_L\ L_j - (1+\tau^f)\ L_j \tag{55}$$

Finally, substituting the expression (54) in the profits (52) yields, after some further manipulations,

$$\Psi = \frac{(\rho+\lambda)\gamma}{q(\theta)}\frac{\epsilon_L}{(1+\epsilon_L)}W_jL_j - \frac{1}{(1+\epsilon_L)}(1+\tau^f)W_jL_j$$

from which it follows that

$$\frac{\Psi_w}{\Psi} = \frac{1+\epsilon_L}{W} \tag{56}$$

where $\epsilon_L = -\frac{1}{\left(1-\frac{\alpha}{m}\right)}$.

With respect to the trade union´s utility, we find that

$$V = \frac{(1-\tau^w)W_j L_j - L_j(B+a)}{\rho+\lambda+\theta q(\theta)} \tag{57}$$

using (57), we can derive V_w

$$V_w = \frac{[(1-\tau^w)][L_j + \frac{\partial L_j}{\partial W}W_j] - \frac{\partial L_j}{\partial W}(B+a)}{\rho+\lambda+\theta q(\theta)}$$

Thus, it follows that

$$\frac{V_w}{V} = \frac{[(1-\tau^w)][L_j + \frac{\partial L_j}{\partial W}W_j] - \frac{\partial L_j}{\partial W}(B+a)}{(1-\tau^w)W_j L_j - L_j(B+a)} \tag{58}$$

The first-order condition with respect to nominal wage is given by

$$\Omega_w = 0 \Leftrightarrow \beta\frac{V_w}{V} + (1-\beta)\frac{\Psi_w}{\Psi} \tag{59}$$

Next, substituting (56) and (58) in (59) and rearranging yields the expression for the wage negotiated at sector level (25).

It is important to highlight that with a similar procedure as described above we can obtain the wage negotiated at firm and national level.

A.2 The Employment Level at Firm, Sector and National.

To be able to perform this demonstration, we need an explicit matching function. For example, the matching function, X= m(V,U) = $U^{1-\xi}$ V^{ξ} , 0≤ ξ ≤ 1, describes the number of labour contracts, X, that are concluded given the number of job seekers and vacancies (Pissarides,1990). From the matching function, the job-finding rate of the worker can be derived as $\frac{X}{U} = (\frac{V}{U})^{\xi}$.Taking into account the definition of labour market tightness as the relative number of traders in the market $\theta = \frac{V}{U}$, we express the probability that a vacancy will be filled or job-finding rate as equal to $\frac{X}{U} = \theta^{\xi}$.We also define the rate at which vacant jobs become filled as $\frac{X}{V} \equiv q(\theta) = \frac{1}{\theta^{1-\xi}}$.Thus, the term $\theta q(\theta) = \frac{\theta}{\theta^{1-\xi}} = \theta^{\xi}$, namely the job-finding rate.

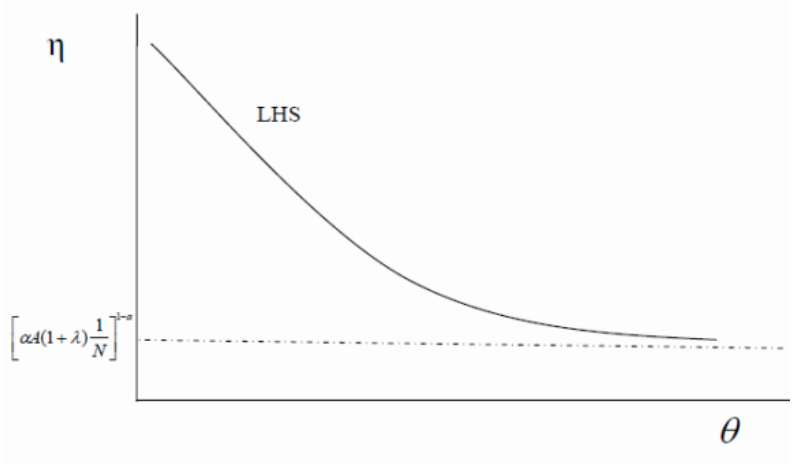
We go on to compare the labour market tightness at the firm, sector and national level. These expressions are given by:

firm level

$$\alpha A\left[(\frac{\lambda+\theta q(\theta)}{\theta q(\theta)})\frac{1}{N}\right]^{1-\alpha} = \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \tag{60}$$

sector level

$$\alpha A\left[\left(\frac{\lambda+\theta q(\theta)}{\theta q(\theta)}\right)\frac{1}{N}\right]^{(1-\alpha)} = \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right] m\left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \tag{61}$$



national level

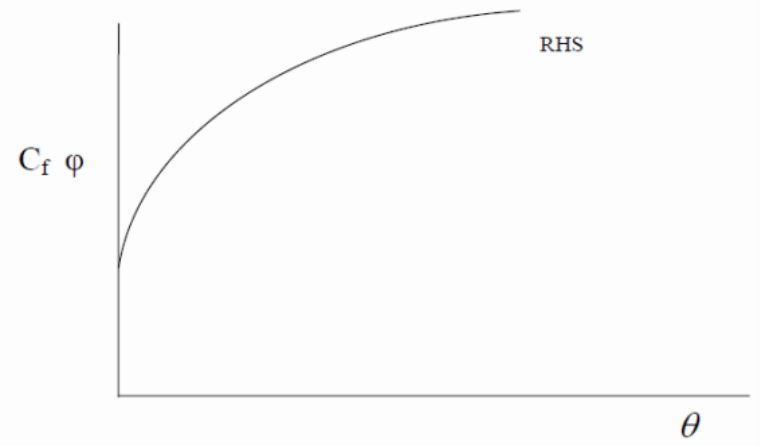
$$\alpha A\left(\left[\frac{\lambda+\theta q(\theta)}{\theta q(\theta)}\right]\frac{1}{N}\right)^{(1-\alpha)}=\left[(1+\tau^{f})+\frac{(\rho+\lambda)\gamma}{q(\theta)}\right]m\left[\frac{\beta}{\alpha}+(1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^{w})} \tag{62}$$

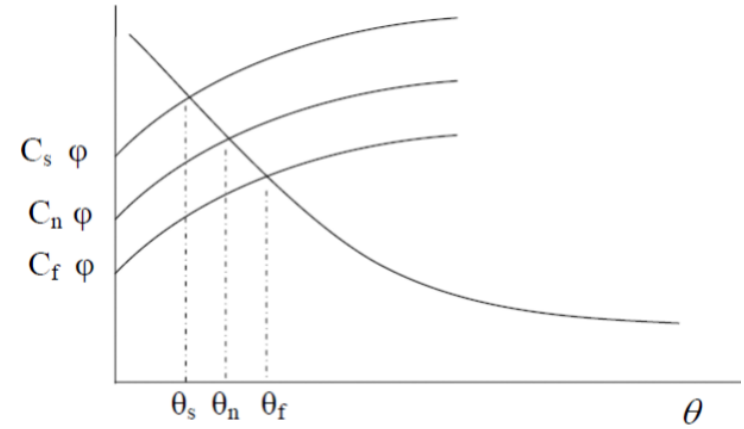
We can clearly see that the left-hand side for all three expressions are identical. The first part of the analysis concentrates on analyzing this common term $\alpha A\left(\left[\frac{\lambda+\theta q(\theta)}{\theta q(\theta)}\right]\frac{1}{N}\right)^{(1-\alpha)}$, which for notational convenience, we will denote as η. This allows us to express the left hand side as a function only of tightness and the same model parameters.

$$\eta=\alpha A\left(\left[\frac{\lambda}{\theta q(\theta)}+1\right]\frac{1}{N}\right)^{(1-\alpha)}=\alpha A\left(\left[\frac{\lambda}{\theta^{\xi}}+1\right]\frac{1}{N}\right)^{(1-\alpha)} \tag{63}$$

By differentiating (63) with respect to θ, we clearly obtain a decreasing relationship. Thus, the left hand side of equations (60), (61) and (62) is a decreasing function of θ for a wide range of reasonable parameters and have the same shape as that appearing in Figure 1.

There is a similar structure for the right-hand side of equations (60), (61) and (62). On the one hand, there is a common term in all equations that, for simplicity, let us define as $\varphi\equiv((1+\tau^{f})+\frac{(\rho+\lambda)\gamma}{q(\theta)})\frac{(b+\bar{a})}{(1-\tau^{w})}$. This terms is clearly an increasing function of θ when considering that $q(\theta)=\frac{1}{\theta^{1-\xi}}$. On the other hand, there are specifics term for each wage bargaining system that depend on product market regulations. We therefore also introduce the following definition:





$$\begin{aligned} C_f &\equiv \left[\frac{\beta}{\alpha} + (1-\beta)\right] \\ C_s &\equiv m\left[\beta\frac{m}{\alpha} + (1-\beta)\right] \\ C_n &\equiv m\left[\frac{\beta}{\alpha} + (1-\beta)\right] \end{aligned} \tag{64}$$

It is important to note that we obtain a model directly comparable to the Calforms-Driffill model.

Therefore, with all of the abovementioned features we find that when parameter m has a value higher than one $C_s > C_n > C_f$. This finding is more relevant given that the term φ is common between all wages bargained given the same *labour tax structure and income progressivity*. This result is best illustrated in the Figure 2 where the right hand side of equations (60), (61) and (62).are plotted as positively sloped curves with respect to θ.

We then graphically show in Figure 3 the right-hand side and left hand side of equations (60), (61) and (62) to find the labour market tightness in equilibrium when the wage is bargained at the firm, sector and national level.

Finally, in a steady state, θ determines the unemployment (or employment) based on

the condition that the measure of laid-off workers in a period must be equal to the measure of unemployed workers gaining employment given by the expression $(29)\theta^{\xi}$.

$$L = \left[\frac{\theta q(\theta)}{\lambda + \theta q(\theta)}\right] N \tag{65}$$

or similarly

$$L = \left[\frac{1}{\frac{\lambda}{\theta^{\xi}} + 1}\right] N \tag{66}$$

Hence, we find that when θ has a higher value, the employment level rises and, consequently, the unemployment rate decreases.

Next, we consider the more general scenario by taking into account the fiscal variables. The right hand side of equations (60), (61) and (62) are respectively

$$\begin{aligned}
\varphi * C_f &\equiv \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right]\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \\
\varphi * C_s &\equiv \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right] m\left[\beta\frac{m}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)} \\
\varphi * C_n &\equiv \left[(1+\tau^f) + \frac{(\rho+\lambda)\gamma}{q(\theta)}\right] m\left[\frac{\beta}{\alpha} + (1-\beta)\right]\frac{(b+\bar{a})}{(1-\tau^w)}
\end{aligned} \tag{67}$$

If we take into account the heterogeneity of the fiscal parameter shown in Table 3, it is easy to demonstrate the disparity in unemployment rate in the OECD countries outside the wage bargaining system. We can conclude, for example, that it is possible to find specific countries with a higher unemployment rate with wage bargaining at the firm level than at the sector level, depending on the fiscal parameter.