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Labor Market Rigidities and the Business Cycle:

Price vs. Quantity Restricting Institutions

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1 Introduction

This paper contributes to a recent, but rapidly growing body of literature that has started to investigate, in the context of closed-economy New Keynesian models, the scope and importance of labor market rigidities for short run fluctuations. This literature has mainly focused on two important types of labor market rigidities: labor market frictions, which capture the institutions - like employment protection legislation, hiring costs and the matching technology - that limit flows in and out of unemployment; and real wage rigidities, intended to capture the institutions - including the wage bargaining mechanism and legislation - which influence the responsiveness of real wages to economic activity. The novelty of this paper is the focus on the interaction of these two types of labor market rigidities and the implications for business cycle patterns across countries. We claim that by distinguishing between institutions that limit price adjustments and institutions that limit quantity adjustments, the observed differential pattern of business cycles can be better explained and more accurate conclusions for the optimal design of monetary policy can be drawn.

Various approaches have been taken to incorporate the labor market into the standard New-Keynesian models. Walsh (2005), for instance, incorporates nominal price stickiness, habit persistence, and policy inertia into a model of labor market search to study the dynamic impact of nominal interest rate shocks. Trigari (2006) and Moyen and Sahuc (2004) emphasize the role of labor market frictions, incorporating intensive (hours) and extensive margin and different wage determination mechanisms. Krause and Lubik (2005) allow for endogenous job destruction and let labor adjustment take place only along the extensive margin. The papers closest in spirit of the model to ours are Christoffel and Linzert (2005) and Blanchard and Gali (2006). Both introduce labor market frictions, real wage rigidities, and nominal price staggering in a standard DSGE model. Christoffel and Linzert (2005) additionally allow for the intensive margin of labor, and distinguish between efficient Nash bargaining and right to manage approaches to wage setting. Focusing on inflation persistence in response to monetary shocks the authors show that wage rigidity translates into less volatile and more persistent movements in inflation only in the right to manage model. Blanchard and Gali (2006) design a simple model to show that the nature of the trade-off between inflation and unemployment stabilization changes when a standard New-Keynesian model is augmented by the above labor market rigidities, and draw the implications for the design of the optimal monetary policy. While some authors have put more emphasis on the modelling and dynamics of labor market variables (Krause and Lubik 2005, Trigari 2004, 2006, Moyen and Sahuc 2004), others have focused on the implications of various labor market rigidities for the inflation persistence in response to monetary policy shocks (Christoffel and Linzert 2005, Walsh 2005, Blanchard and Gali 2006).

Our main focus is instead on the interaction of real wage rigidity and labor market frictions and the implications for the business cycle patterns. We build a simple model that combines the two types of rigidities with price stickiness, and use it to analyse the implications of different degrees and types of labor market rigidities on the business cycle, by looking at three dimensions: (i) the persistence of key economic variables; (ii) their volatility; (iii) the length and intensity of cycles.

Using this framework, we find that the differential pattern of the cycle between the US and the Euro area can partly be explained by their respective labor market institutions. The intuition is rather simple: While higher labor market frictions in the Euro Area tend to amplify the adjustment via prices, they restrict the responses of real variables (unemployment and GDP) making the cycle in the Euro Area smoother but more prolonged than in the US, where adjustment via quantities is facilitated by a more flexible labor market and higher real wage rigidities. Additionally, we analyze the interaction between institutions restricting price and institutions restricting quantity adjustments. We find that if institutions are substitutes in the sense that countries with high labor market frictions tend to have low real wage rigidities and vice versa, effects are reinforcing. This implies a big gap between the respective volatility trade-off, i.e. the ratio between the volatility of inflation and the volatility of unemployment, for the two institutional constellations. If instead institutions are complements effects are offsetting and the trade-off of inflation volatility over unemployment volatility is only marginally different for countries with a very restrictive overall labor market or a rather flexible overall labor market. These results are directly linked to the fact that higher labor market frictions steepen the slope of the Phillips-curve while higher real wage rigidities flatten it.

In an empirical part we associate labor market institutions with the two channels at work in the model and find the main results to be supported by the data in form of simple correlations for a set of OECD countries. Accounting for the differential impact of the two institutions on the volatility trade-off, we estimate a panel model with time-varying volatility measures for three sub-periods and find also here the estimates in line with the model's predictions.

Our results stress the importance of treating labor market frictions differently from real wage rigidities, when addressing optimal policy questions, since they may have opposite effects on business cycle fluctuations. In particular the conduct of monetary policy is affected by the distinction between price versus quantity restricting institutions since a central bank will find it easier to bring inflation in line with its target when the rigidity lies in the quantity as opposed to the price channel. Within the context of a monetary union our results imply that the central bank's task in bringing inflation to its target, becomes much more complicated when the countries' institutions are substitutes as opposed to complements, since in the former case the differential response across countries is much more widespread than in the latter case.

The remainder of the paper is structured as follows: Section 2 outlines the model. The baseline calibration is described in section 3 and section 4 presents the impulse responses and moments of the simulated model under different variations of the labor market. Section five confronts these results to the data of a range of OECD countries. Finally, section six concludes.

2 The model economy

In this section we present a model with nominal rigidities and search frictions in the labor market. The model consists of four building blocks: the households, the intermediate goods firms, the retail firms and a monetary authority. We briefly discuss each sector below.

2.1 Households

Each household is thought of as a very large extended family with names on the unit interval. In equilibrium, some members will be employed and others not; to avoid distributional issues we assume that consumption is pooled inside the family. The representative household maximizes a standard lifetime utility, which depends on the household's consumption and disutility of work:

$$E_t \sum_{s=0}^{\infty} \beta^s \left[\log(C_{t+s}) - \chi N_{t+s} \left(\frac{\bar{H}^{1+\phi}}{1+\phi} \right) \right] = E_t \sum_{s=0}^{\infty} \beta^s \left[\log(C_{t+s}) - \varkappa N_{t+s} \right] \quad (1)$$

Notice that the disutility of work for the household is the aggregate of the individuals' disutility of work. Empirical evidence suggests that most of the labor adjustment takes place at the extensive margin. Accordingly, we assume that each individual works a fixed amount of hours $H_t = \bar{H}$. The utility function is thus linear in the number of the employed people.[1]

Households own all firms in the economy and face, in each period, the following budget constraint:

$$C_t + \frac{B_t}{P_t \left(1+i_t\right)} = D_t + \frac{B_{t-1}}{P_t}$$

where C_t is a standard Dixit-Stiglitz consumption bundle with elasticity of substitution ϵ, P_t is the aggregate price level, $(1+i_t)$ is the gross nominal interest rate of the nominal one-period bond and D_t is the per capita family income in period t[2].

Consumption maximization leads to the standard Euler condition:

$$\frac{C_t^{-1}}{P_t} = \beta \left(1+i_t\right) E_t \left(\frac{C_{t+1}^{-1}}{P_{t+1}} \right)$$

2.2 Firms and the labor market

The model developed here has two main building blocks: nominal rigidities in price setting and search and matching in the labor markets. "One complication is that when firms set prices in a staggered way the job creation decision becomes highly intractable" (Trigari 2006). To avoid this problem, following much of the

[1] An implicit assumption behind this specification is that all family members are identical.

[2] Per capita family income is the sum of the wage income earned by employed family members ($W_t N_t$), the benefits earned by the unemployed and the family share of aggregate profits from retailers and matched firms, net of government lump-sum taxes used to finance unemployment benefits.

literature, we distinguish among two types of firms: retailers and firms in the intermediate sector. Firms produce intermediate goods in competitive markets and sell their output to retailers who are monopolistic competitive. Retailers transform the intermediate goods into final goods and sell them to the households. Price rigidities arise at the retail level, while search frictions arise in the intermediate good sector.

2.2.1 The intermediate sector

In order to find a worker, firms must actively search for workers in the unemployment pool. The idea is formalized by assuming that firms post vacancies. On the other hand, unemployed workers must look for firms. We assume that all unemployed workers search passively for a job.

Vacancies, v_t, are matched to searching workers, s_t, according to the CRS matching technology:

$$m_t = \sigma_m s_t^{\sigma} v_t^{1-\sigma}$$

where σ_m is a scalar reflecting the efficiency of the matching process and s_t, the fraction of searching workers, is

$$s_t = 1 - (1-\rho)N_{t-1} \tag{2}$$

The separation rate ρ represents the fraction of the employed that each period lose their jobs and join the unemployment pool. In the following we assume that ρ is exogenously given.

The probability that any open vacancy is matched with a searching worker is:

$$q_t = \frac{m_t}{v_t} = \sigma_m \left(\frac{s_t}{v_t}\right)^{\sigma} = \sigma_m \left(\frac{1}{\theta_t}\right)^{\sigma}$$

where $\theta_t = \frac{v_t}{s_t}$ is the labor market tightness indicator. The average steady state duration of a job vacancy is $\frac{1}{\bar{q}}$

The probability that any worker looking for a job is matched with an open vacancy is

$$p_t = \frac{m_t}{s_t} = \sigma_m \left(\frac{v_t}{s_t}\right)^{1-\sigma} = \sigma_m \left(\theta_t\right)^{1-\sigma}$$

The average steady state duration of unemployment is $\frac{1}{\bar{p}}$.

Each firm produces according to the CRS production function:[3]

$$Y_t = A_t N_t$$

where A_t is a stationary AR(1) productivity process.

The intermediate good is sold to retailers at relative price $\varphi_t = \frac{P_t^{internediate}}{P_t}$. Employment evolves according to the law of motion:[4]

$$N_t = (1-\rho)N_{t-1} + m_t \tag{3}$$

[3] For simplicity and ease of exposition, we avoid firm-specific indexes.

[4] Assuming that firms in this sector are sufficiently large, the fraction of vacancies they fill in each period with certainty is given by the matching rate for vacancies.

The labor force is normalised to 1. Therefore, the number of unemployed - after hiring takes place - is $u_t = 1 - N_t$.

The cost of posting vacancies, in units of the consumption goods, is:

$$\kappa_t v_t = \frac{\kappa}{\lambda_t} v_t$$

where κ is the utility cost of keeping a vacancy open and $\frac{\kappa}{\lambda_t}$ the corresponding cost in terms of the consumption good.

The representative firm maximizes the expected sum of discounted profits:

$$\max_{v_t} E_t \left\{ \sum_{j=0}^{\infty} \beta^j \frac{\lambda_{t+j}}{\lambda_t} \left[\varphi_{t+j} A_{t+j} N_{t+j} - W_{t+j} N_{t+j} - \kappa_{t+j} v_{t+j} \right] \right\}$$

subject to the employment evolution equation (3).

The solution to this problem gives the optimal price setting condition for a firm in the intermediate sector:

$$\varphi_t = \frac{W_t^R}{A_t} + \frac{\kappa_t}{A_t q_t} - \beta (1-\rho) \frac{\lambda_{t+1}}{A_t \lambda_t} \frac{\kappa_{t+1}}{q_{t+1}} \tag{4}$$

Equation (4) simply states that the relative price of the intermediate good is set equal to its marginal costs, all expressed in terms of the consumption good. Marginal costs are equal to real wages, plus the expected cost of hiring the matched worker $\frac{\kappa_t}{q_t}$,[5] minus the expected saving the following period of not having to generate a new match, all normalized by productivity. Notice that if $\kappa = 0$ we get the standard result $\varphi_t = \frac{W_t^R}{A_t}$, typical of a New Keynesian model with Walrasian labor markets.

In this model, which embeds the NK model as a special case, the presence of hiring costs creates a wedge between the real wage and the marginal costs relevant for the firm, which in turn are essential to explain inflation dynamics. This wedge depends on the marginal hiring costs (the last two terms). The cyclical behavior of marginal costs in a model with labor market frictions can thus depart substantially from that of real wages. As Krause and Lubik (2005) notice, "Hiring frictions generate a surplus for existing matches which give rise to long-term employment relationships. These, in turn, reduce the allocative role of current real wages. As a consequence, the effective real marginal cost can change even if the wage does not change."[6]

2.2.2 Nash Bargained Wages

The presence of search frictions creates a positive rent for existing employment relationships. Following much of the literature, we assume wages are bargained to split this rent between the firm and the employee, according to their respective bargaining power (Nash bargaining).

[5] The number of vacancies to be posted such that expected hires equal one is $\frac{1}{q_t}$, each of which cost κ_t.

[6] Krause and Lubik (2005), p. 11.

Let $0 \leq \eta \leq 1$ denote the relative bargaining power of workers. It can be shown (see the appendix for details) that the Nash bargained wage is given by:

$$W_t^{Nash} = \frac{\varkappa}{\lambda_t} + \frac{\eta}{1-\eta}\left\{\frac{\kappa_t}{q_t} - \beta\left(1-\rho\right)\frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}\left(1-p_{t+1}\right)\right\} \quad (5)$$

$$= MRS_t + \frac{\eta}{1-\eta}PRE_t \quad (6)$$

Intuitively, the Nash wage depends on the reservation wage (here given by the marginal rate of substitution between leisure and consumption, $\frac{\varkappa}{\lambda_t}$) plus a "wage premium", which depends on the size of the rents for existing employment relationships and on the workers' relative bargaining power (the last two terms).

2.2.3 Introducing Real Wage Rigidities

As Christoffel and Linzert note, "sudden and significant shifts in the aggregate wage level are not observed. Due to collective wage bargaining agreements, wage changes only take place on a quite infrequent basis. Therefore, a wage that can be freely adjusted each period assumes a degree of wage flexibility that is hardly consistent with actual practises."[7]

Accordingly, and following much of the recent literature, we introduce real wage rigidity by employing a version of Hall's (2005) notion of wage norm. A wage norm may arise as a result of social conventions that constrain wage adjustment for existing and newly hired workers. One way to model this is to assume that the real wage W_t^R is a weighted average of the Nash bargained wage W_t^{Nash} and a wage norm, which is simply assumed to be the wage prevailing in the last period. Specifically, we assume the real wage is determined as follows:

$$W_t^R = \left(W_t^{Nash}\right)^{1-\gamma}\left(W_{t-1}^R\right)^{\gamma} \quad (7)$$

where γ is an index of the real wage rigidities present in the economy, with $0 \leq \gamma \leq 1$.

2.2.4 Retailers

There is a measure one of monopolistic retailers indexed by z on the unit interval, each of them producing one differentiated consumption good. Due to imperfect substitutability across goods, each retailer faces a Dixit Stiglitz demand function for its product:[8]

$$Y_t^F(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon} Y_t^F$$

Retailers share the same technology, which transforms one unit of wholesale goods into one unit of retail goods, so that $Y_t^F(z) = Y_t(z)$. Firms in the retail sector purchase intermediate goods from wholesale producers at price φ_t and

[7] Christoffel and Linzert (2005), p. 17-18.

[8] For the sake of simplicity, we assume the wholesalers have the same optimal allocations for the differentiated goods as the household.

convert them into a differentiated final good sold to households and wholesale firms.

Final output may then either be transformed into a single type of consumption good or used in vacancy posting. The aggregate resource constraint is thus given by:

$$Y_t = C_t + \kappa_t v_t$$

We introduce nominal rigidities using the formalism à la Calvo (1983). Each period, retailers may reset their prices with a probability $(1-\zeta)$ (independent of the time elapsed since the last revision of prices). The expected time over which the price is fixed is therefore $\frac{1}{1-\zeta}$. The remaining fraction ζ of firms are not allowed to adjust prices.

Log-linearizing around a zero inflation steady state the optimal price setting rule and the price index equation $P_t = \left[(1-\zeta)(P_t^*)^{1-\epsilon} + \zeta(P_{t-1})^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$, we get the New Keynesian Phillips curve:[9]

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \lambda \hat{\varphi}_t \tag{8}$$

where $\hat{\pi}_t$ denotes consumer price inflation and $\lambda = (1-\beta\zeta)(1-\zeta)/\zeta$. Note that, while (8) looks like a standard New Keynesian Phillips curve, the dynamics of the real marginal costs are now substantially different from the ones of a standard NK model, as they are deeply affected by the labor market institutions. In fact, log-linearizing eq.(4) we can rewrite marginal costs as:

$$\hat{\varphi}_t = h_1 \hat{c}_t + h_2 \hat{\theta}_t - h_3 E_t \hat{\theta}_{t+1} + \gamma h_4 \hat{w}_{t-1}^R - \hat{a}_t \tag{9}$$

where the coefficients h_i are functions of the structural parameters characterizing the economy: workers' bargaining power, hiring costs, separation rates, markups, degree of real wage rigidity, and so on. The introduction of hiring costs and real wage rigidities substantially change the dynamics of the marginal costs, which in turn influence the firms' optimal price setting and the inflation dynamics.[10] Equation (9) highlights the determinants of marginal costs. Marginal costs increase with consumption ($\hat{c}_t$) as the firm, in order to increase production, has to pay higher wages to persuade households to provide more labor. An increase in productivity $\hat{a}_t$ has the opposite effect. These are the only channels at work in the standard NK model. The worsening of labor market conditions at time t (i.e. an increase of $\hat{\theta}_t$) increases marginal costs through two channels. A tighter

[9] It can be shown that the optimal price setting rule for a firm resetting prices in period t is given by:

$$E_t \left\{ \sum_{s=0}^{\infty} \theta^s Q_{t,t+s} Y_{t+s/t} \left(P_t^* - \frac{\epsilon}{\epsilon - 1} P_{t+s} \varphi_{t+s} \right) \right\} = 0$$

where P_t^* denotes the price newly set at time t, $Y_{t+s/t}$ is the level of output in period t+s for a firm resetting its price in period t and $\frac{\epsilon}{\epsilon-1}$ is the gross desired markup. $Q_{t,t+s} = \beta^s \frac{C_t}{C_{t+s}} \frac{P_t}{P_{t+s}}$ is the stochastic discount factor for nominal payoffs.

[10] The parameters are as follows: $h_1 = 1 - \frac{\gamma W}{\varphi}$; $h_2 = \varpi\sigma \left[1 + \frac{\eta}{1-\eta}(1-\gamma)\right]$; $h_3 = \beta(1-\rho)\varpi\sigma \left[1 + \frac{\eta}{1-\eta}(1-\gamma)\left(1 - \frac{p}{\sigma}\right)\right]$ and $h_4 = W$, and where $\varpi = \frac{\kappa}{q}\frac{\bar{C}}{\varphi}$

labor market increases both the expected costs of filling a vacancy and the bargained wage, as the rents associated with an existing employment relationship are higher. An expected increase of $E_t\hat{\theta}_{t+1}$ has the opposite effect, as it becomes convenient for the firm to hire at time t in order to be ready for a more difficult labor market in time $t+1$. Finally, when the real wage adjusts sluggishly to the economic activity (i.e. $\gamma > 0$), marginal costs depend positively on lagged wages.

2.3 Monetary Authority

In order to close the model, a characterization of monetary policy is needed.

We assume the Central Bank sets the short term nominal interest rate by reacting to the average inflation and output gap levels in the economy. Specifically, we assume the monetary authority follows the Taylor-type rule:

$$(1+i_t) = \beta^{-(1-\rho_m)}(1+i_{t-1})^{\rho_m}\pi_t^{\phi_\pi(1-\rho_m)}(z_t)^{\phi_z(1-\rho_m)}e^{\varepsilon_t^m} \quad (10)$$

Log-linearising it around the steady state, one can get:

$$\hat{\imath}_t = \rho_m \hat{\imath}_{t-1} + \phi_\pi (1-\rho_m)\hat{\pi}_t + \phi_z (1-\rho_m)\hat{z}_t + \varepsilon_t^m \quad (11)$$

Consistently with empirical evidence, we assume that monetary policy displays a certain degree ρ_m of interest rate smoothing[11]. The parameters ϕ_π and ϕ_z are the response coefficients of inflation and the output gap (denoted with z_t). The term ε_t^m capture an $i.i.d$ monetary policy shock.

In the following sections, we use this stylized economy to understand how different labor market structures are likely to influence the size, shape and characteristics of the business cycle.

3 Baseline Calibration

Parameters values are chosen to replicate the steady state US economy and are fairly standard in the literature.[12] The following table summarizes the values for the key parameters of the model:

Preferences and Technology	β	ϵ	μ	σ	
	0.99	11	1.1	0.5	
Labor market	u	δ	η	p	q
	0.05	0.1	0.5	0.6	0.75
Price and Real Wage rigidities	ζ	γ			
	0.75	0.5			
Interest Rate rule	ρ_m	ϕ_π	ϕ_x		
	0.9	1.5	0		
Shocks' Persistence and Volatility	ρ_a	σ_a^i	σ_ε		
	0.95	0.007	0.002		

[11] See, e.g, Clarida, Gali and Gertler (1999).
[12] The log-linear system of equations is shown in the Appendix.

Preferences and technology: Time is taken as quarters. The discount factor β is set equal to 0.99, which implies a riskless annual return of about 4 percent. The elasticity of substitution between differentiated goods ϵ is set equal to 11, corresponding to a markup $\mu = 1.1$. The steady state level of productivity A is set to 1. For the elasticity of the matching function, we adopt the standard value of $\sigma = 0.5$.

The labor market: In the baseline calibration, we set unemployment to be $u = 0.05$. The vacancy filling rate q is set to 0.75 and the job-finding rate p to 0.6, as in Walsh (2005). Given u and p, it is possible to determine the separation rate using the relation $\rho = up/\left((1-u)(1-p)\right)$. We obtain a value $\rho = 0.096$. The workers' relative bargaining power η is set to 0.5, as standard in the literature. The vacancy cost parameter κ is chosen such that hiring costs represent a 1 percent fraction of steady state output. The parameter $\varkappa$ on disutility of labor is determined using steady state relations.

The degree of Price rigidity ζ is set equal to 0.75, as in Galì (2002), implying an average duration of price contracts of one year. In the baseline calibration, following Campolmi and Faia (2006) and Blanchard and Galì (2006), we set the degree of real wage rigidity γ equal to 0.5.

Monetary policy: Following Campolmi and Faia (2006) and Walsh (2005), we adopt an interest rate rule for monetary policy where the central bank responds to inflation but not to the output gap. Furthermore, we assume that the degree of inertia in the policy rule ρ_m equals 0.9, a value consistent with the empirical evidence on policy rules.[13]

Shocks: There are two exogenous shocks in the model: the productivity shock and the monetary policy shock.[14] Following Walsh (2005), we set the standard deviation of the policy shock $\sigma_\varepsilon = 0.002$. The persistence and standard deviation of productivity shocks are set to $\rho_a = 0.95$ and $\sigma_a = 0.007$, as standard in the literature.

4 The Effects of Different Labor Market Institutions on The Business Cycle

How do labor market structures influence the size, shape and intensity of business cycles? In this section we use the described model to get predictions about the effect of different labor market institutions on the business cycle. We distinguish between two types of labor market imperfections: *labor market frictions*, which capture the institutions - like employment protection legislation, hiring costs and the matching technology - that limit the flows in and out of unemployment; and *real wage rigidities*, intended to capture all the institutions - including the wage bargaining mechanism and legislation - which influence the responsiveness of real wages to economic activity.

[13] See, e.g, Clarida et al. (2000).

[14] In a previous version of the model we also introduced a government shock. We decided not to put it on this version because it does not add much to the analysis.

Business cycle characteristics are illustrated by looking at three dimensions: (i) the persistence of key economic variables; (ii) their volatility; (iii) the length, average duration and intensity of recessions and expansions. For the computation of the persistence we use the estimated sum of the AR coefficients of a univariate regression.[15] Volatility is measured as the standard deviation from the mean, where we alternatively considered the raw data and the cyclical component of the HP filtered series.[16] An alternative point of view on business cycles can be obtained by trying to identify turning points in the level of economic activity. The approach, which is closely related to Burns and Mitchell's (1946) methodology, permits the measurements of durations, amplitudes and cumulative changes of the cycle. All these statistics can be computed from a single series using a version of the Bry and Boschen (1971) algorithm.[17] Regarding the parametrization, we have applied the values suggested in Harding and Pagan (2002, 2004), for which the authors show that the dating obtained with this algorithm for the US is strikingly similar to the one of the NBER reference business cycle. Once turning points are identified, we can compute the average duration from peak-to-peak ($ADPP$) as a measure for the length of the cycle as well as the average growth rate from trough-to-peak ($GRRATETP$) as a measure of the intensity of the cycle.[18]

4.1 The Role of Real Wage Rigidities

In this section we study how different degrees of real wage rigidities are likely to affect the persistence, volatility and shape of the business cycle. To this purpose, we simulate the model varying the index of real wage rigidities γ from 0 to 0.95. Notice that since all the other factors characterizing the dynamics of the economy (shocks, trend growth, monetary policy etc.) are maintained constant, we are able to perfectly isolate the effect of different degrees of real rigidities on business cycles.

Figure 1 shows the influence of real wage rigidities on the persistence (first column) and volatility (second column) of key economic variables:

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[15] In the empirical part we additionally employ an alternative measure, which gives for the model identical results and is hence not reported. We refer the reader to the empirical part of this paper for a better description of the persistence measures employed in this study.

[16] Since the model does not exhibit any growth the simulated "raw data" is stationary and the results for the effects of the labour market rigidites on the standard deviations do not change when measuring standard deviation on the raw or the HP-detrended series.

[17] The algorithm can be described as follows:

1) Smooth the reference serie y_t with a series of filters in order to eliminate outliers, high frequency or irregular variations. Call y_t^{sm} the smoothed series. 2) Use a dating rule to determine a potential set of turning points. The rule we have used is: $\triangle^2 y_t^{sm} > 0\ (< 0)$, $\triangle y_t^{sm} > 0\ (< 0)$, $\triangle y_{t+1}^{sm} < 0\ (> 0)$, $\triangle^2 y_{t+1}^{sm} < 0\ (> 0)$. 3) Use a censuring rule to ensure that peaks and throughs alternate and that the duration and the amplitude of phases is meaningful. See Canova (2007) for an explanation and a discussion of this methodology.

[18] As of the symmetric nature of the model, the average duration between trough-to-trough will be identical to the peak-to-peak duration. Similarly, does it not matter whether we measure the intensity of the cycle as the average growth rate from trough-to-peak or peak-to-trough. In the empirical part however we will distinguish between these four measures.

- *Persistence*: A higher degree of real wage rigidity amplifies the persistence of inflation and reduces the persistence of output and unemployment. This is hardly surprising, as when real wages adjust sluggishly to economic conditions, shocks tend to have longer effects on real variables and these effects are spread, through monetary policy and the endogenous response of firms, to inflation. Accordingly, $tradeoff_p$, which represent the ratio between the persistence of inflation and that of output, is decreasing in the degree of real wage rigidity.

- *Volatility*: Real wage rigidities amplify output and unemployment volatility while they reduce inflation volatility. Accordingly, the trade-off between inflation and unemployment volatility, denoted by $tradeoff_v$, gets smaller as γ rises. The reason is simple: real wage rigidities limit wage adjustments and shift the labor market adjustment from prices to quantities. A higher degree of real wage rigidities thus flattens the Phillips curve and inflation becomes less sensitive to unemployment.

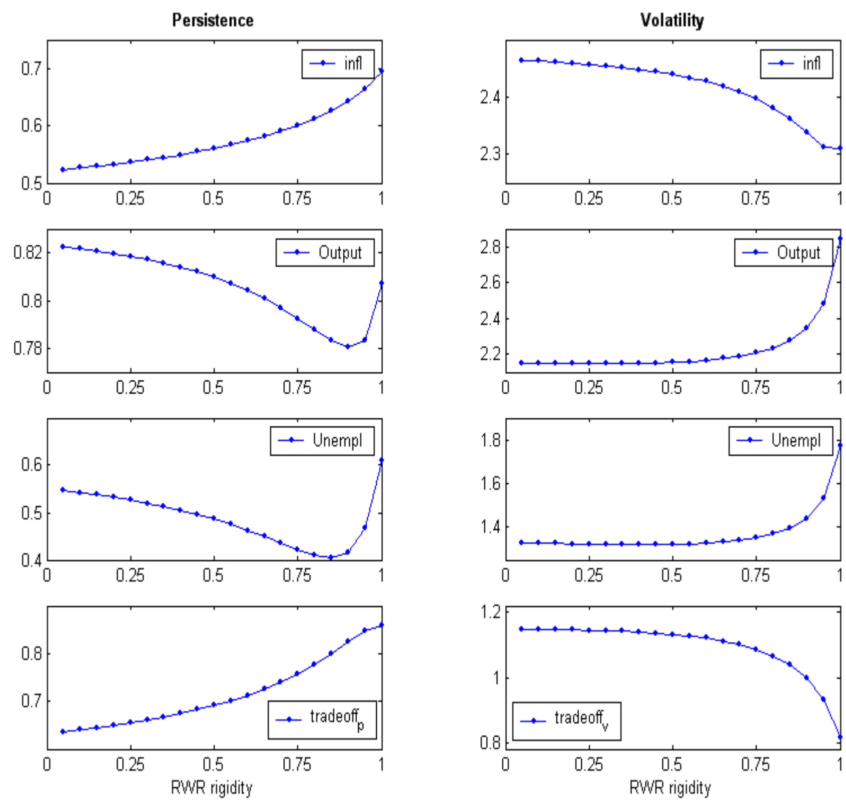


Figure 1: *The Effect of Real Wage Rigidities on the Persistence and Volatilities of Selected Variables*

- *Duration and Intensity*: Figure 2 shows how the average duration and amplitude of the business cycle changes with wage rigidities. For realistic levels of real wage rigidity, that is for $\gamma < 0.85$, a higher degree of wage rigidity shortens the average business cycle.[19] The intensity of the cycle is instead increasing in the degree of real wage rigidity (as the growth rate in expansions, gets bigger and the growth rate in recessions, more negative).

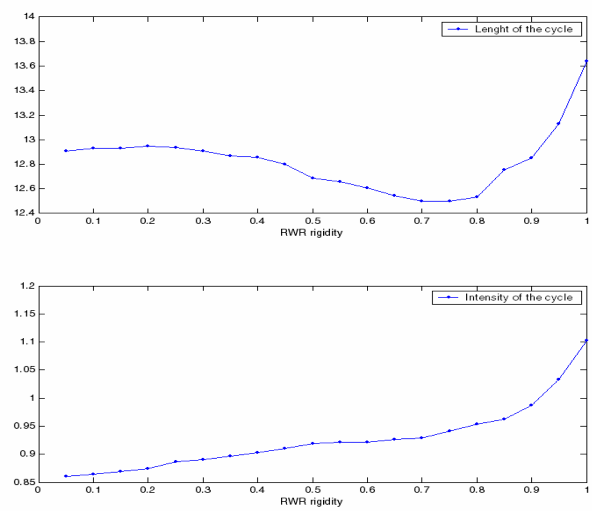


Figure 2: *The Effect of Real Wage Rigidities on the Cycle*

We conclude that sticky wages shorten the business cycle, but make the cycle more intense. The explanation may go as follows: a higher degree of real wage rigidities increases output volatility; as a consequence, it is relatively easier that a bad realization of the technology or monetary policy shocks lead the economy in a recession phase. Cycles are shorter but more severe, as the economy reacts more to shocks.[20]

4.2 The Role of Labor Market Frictions

Calibrating the degree of labor market frictions is somehow a more challenging task, as the overall degree of "rigidity" in the labor market does not depend only on one parameter but on all the configuration of the labor market, as captured by the interplay of different parameters.

[19]Though the difference in the magnitude is relatively low, it is possible to show that in a more realistic model with trend growth these dimensions take more realistic values and the difference gets amplified.

[20]For extremely high levels of RWR, that is for $\gamma > 0.85$, a higher degree of RWR actually increases the lenght of the business cycle. This is due to the fact that, when γ gets very high, the persistence of wages and output increases considerably.

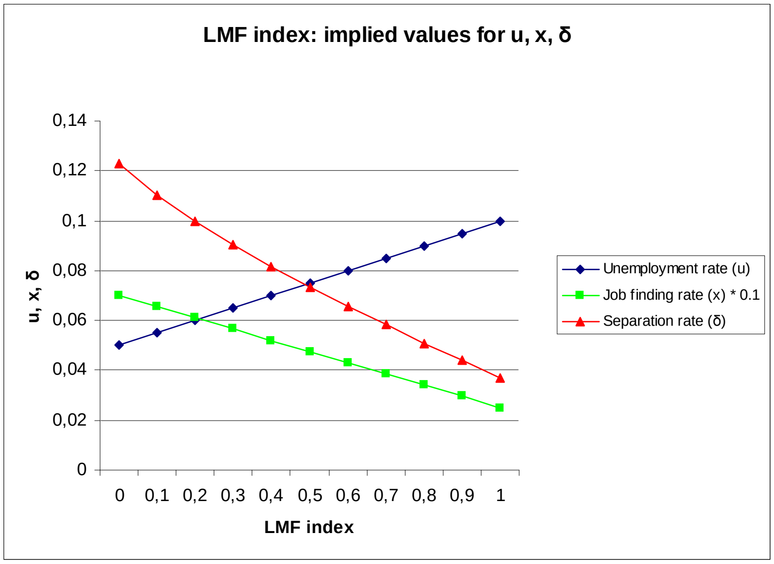


Figure 3: *The Labor Market Frictions Index*

Following Blanchard and Galì (2006), we characterize the degree of labor market frictions by calibrating the steady state unemployment and job-finding rates (u and p). We define a labor market as "flexible" when the job-finding rate is high and the unemployment rate low; the opposite holds in a "sclerotic" labor market. To perform simulations, we vary simultaneously u and p; the job-finding rate is then determined through the steady state relationship $\rho = up/\left((1-u)\left(1-p\right)\right)$. Figure 3 displays the evolution of the three parameters implied by our calibration strategy. Notice that to any particular value of labor market rigidity corresponds a different steady state and that in a rigid economy, as in real data, a low job-finding rate is associated with a low separation rate and a high unemployment rate.[21]

The results, which are shown in Figure 4 and 5, can be summarized as follows:

- *Persistence*: a higher degree of rigidity in the labor market reduces the persistence in inflation, while the persistence of unemployment and output is only slightly affected. The trade-off between inflation and output persistence is therefore decreasing in the degree of labor market rigidities
- *Volatility*: More rigid labor markets tend to increase the volatility of inflation and to decrease the volatility of real variables. The trade-off between inflation and output volatility is therefore increasing in the degree of labor market rigidities. These two results can be reconciled looking at the impulse response functions (See the appendix). When labor markets are more

[21] The unemployment rate varies between 0.05 and 0.10 and the job-finding rate between 0.7 and 0.35. The implied separation rate goes from around 0.12 to 0.06. We decided to calibrate directly the job-finding rate and the unemployment rate because these are more easily estimated than, lets say, the reservation wage or the separation rate.

rigid, monetary or productivity shocks are mainly absorbed through a large (but short-lived) increase in inflation. Intuitively, when hiring new workers becomes more costly, firms find it relatively more convenient to absorb a shock through changes in prices than through changes in the quantities produced. As a consequence, inflation reacts a lot to shocks while the response of (detrended) output and unemployment gets smaller.[22]

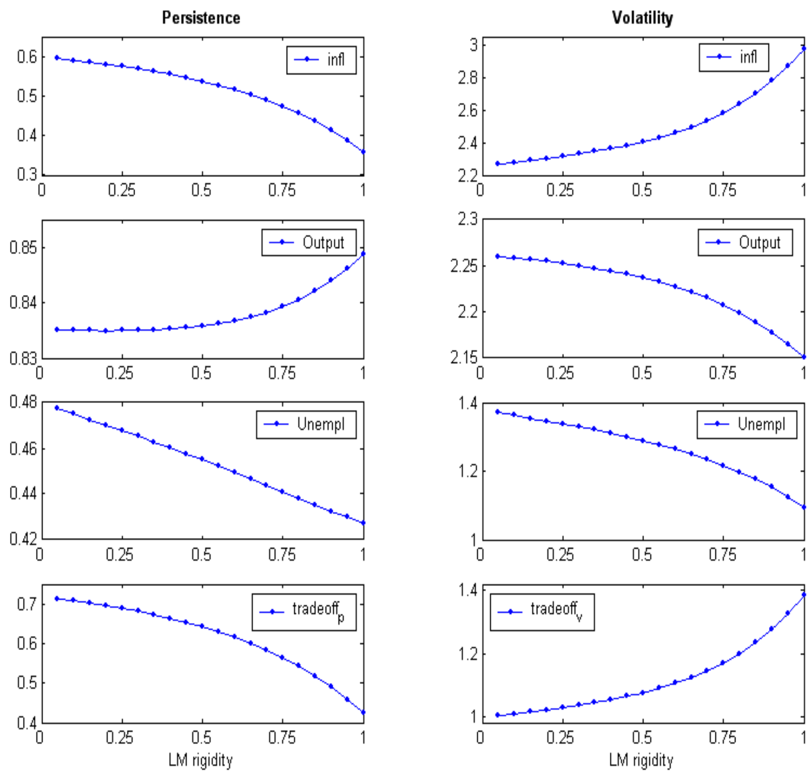


Figure 4: *The Effect of Labor Market Frictions on the Persistence and Volatilities of Selected Variables*

- *Duration and Intensity*: Labor market frictions increase the average duration of the cycle; however, the cycle gets less intense, in the sense that the growth rate of output during expansions and recessions, in absolute value,

[22]More sophisticated explanations can be given. For instance, it can be shown that - ceteris paribus - higher job-finding and separation rates both increase employment volatility. A higher job-finding rate increases the Nash bargained wage and makes workers less willing to accept a cut in real wages: inflation becomes less sensitive to unemployment changes (the Phillips curve gets flatter). Similarly, as the probability of exogenous separation gets higher, fewer matches survive from one period to the other and employment becomes more sensitive to labor market conditions. Again, this implies that inflation is less sensitive to unemployment changes.

gets smaller. Hence, when labor markets are more rigid, cycles get longer but less severe, as the real economy reacts less to shocks.

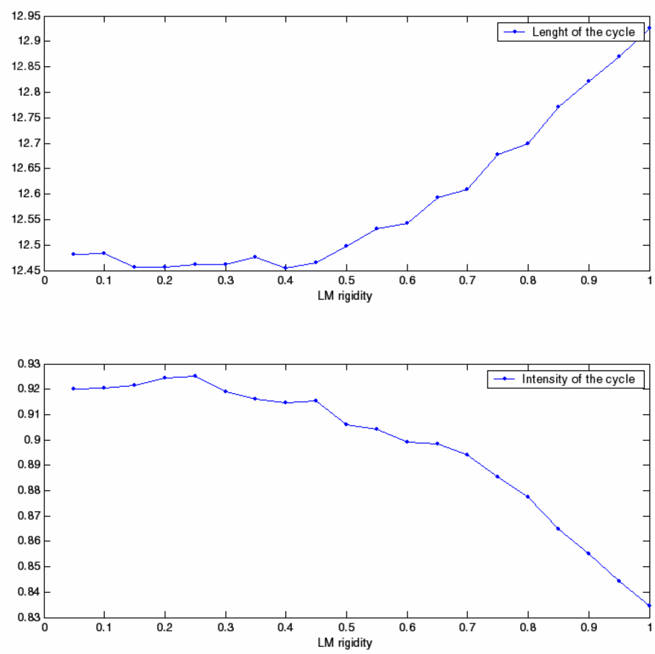


Figure 5: *The Effect of Labor Market Frictions on the Cycle*

4.3 Summing up

An important result emerges from the previous analysis: real wage rigidities and labor market frictions, while often associated in policy discussions (and often labeled under the same category of labor market rigidities) may have *opposite* effects on business cycle fluctuations. In other words, it does make a difference whether the rigidity lies in the wage determination mechanism or in the labor market structure. When the rigidity lies in the wage determination mechanism, real wages cannot fully adjust and shocks tend to be absorbed through changes in quantities - unemployment in our case. A higher degree of real wage rigidity thus amplifies the response of the real economy to shocks, shortens the duration of the business cycle but makes it more intense. When the rigidity lies in the labor market, it is more costly for firms to hire new workers and therefore unemployment does not vary as much as it would in a more flexible economy. Labor market frictions thus increase inflation volatility and smooth the responses of the real economy to shocks; the cycle gets longer but less severe. This is a very intuitive result, since (loosely speaking) in the first case the rigidity is in "prices", while in the second it is "quantities" that cannot adjust.

4.4 Interactions among "Price Constraints" and "Quantity Constraints"

Another important question arises naturally from the analysis: how do different labor market rigidities interact? Are interaction effects likely to be important or negligible?

Figure 6 shows how the volatility trade-off, i.e. the ratio between the volatility of inflation and the volatility of unemployment, changes for different combinations of real wage rigidities (*RWR*) and labor market frictions (*LMF*). Notice that the trade-off can be interpreted as the slope of the Phillips Curve, since it describes how much inflation volatility is afforded in order to reduce the volatility of unemployment by one percent.

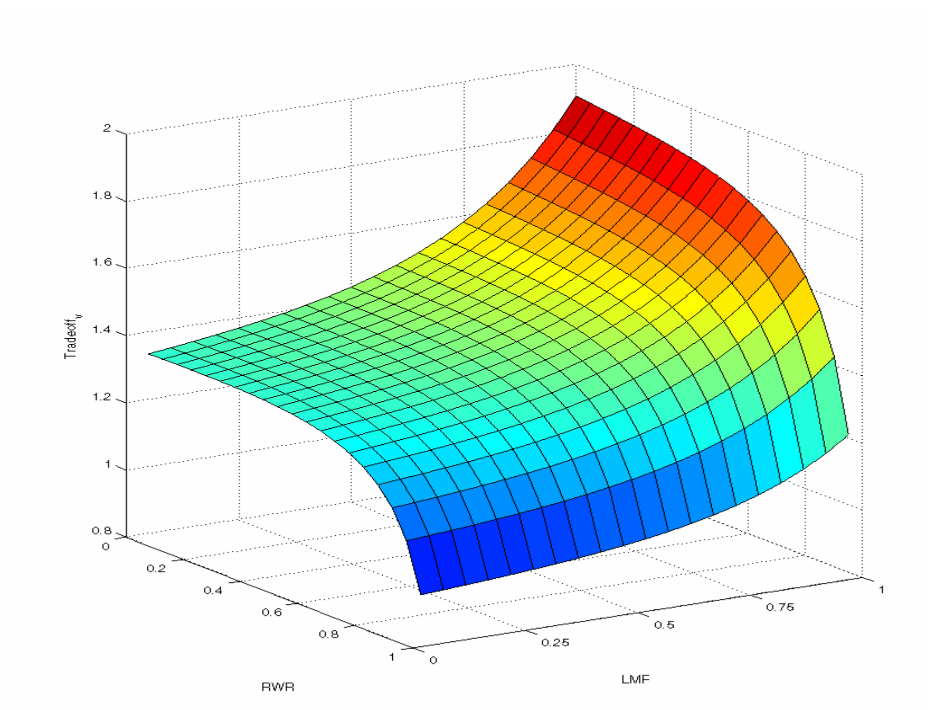


Figure 6: *Interacting Institutions and Volatility*

An important message emerges from Figure 6: though looking at the effect of one type of rigidity while maintaining the other constant is informative, it can be highly misleading, as it ignores the existence of important interactions between LMF and RWR that alter the slope of the Phillips Curve. In particular, it is crucial to determine whether different labor market institutions are *complements* or *substitutes*. If LMF and RWR are *complements*, in the sense that countries with rigid wages are the ones with rigid labor markets and, vice versa, countries that have flexible wages also have flexible labor markets, the effects of RWR and LMF tend to offset each other. In Figure 6, this situation is captured in the west (low RWR-low LMF) and in the east (high LMF-high RWR) corners. Notice that the predicted volatility trade-off, for countries that have completely opposite labor market structures, can be very similar.

If LMF and RWR are *substitutes*, in the sense that countries with rigid wages have flexible labor markets or vice versa, the effects of different types of rigidities on the trade-off tend instead to reinforce and magnify each other. The volatility trade-off is at its maximum in a country with very rigid labor markets and flexible wages (the north corner) as both elements induce firms to prefer changes in prices rather than changes in quantities; it is at its minimum instead in countries where real wage rigidities are high and labor market frictions are low (the south corner). Notice that the effects are strong (the trade-off in the north corner is more than two times bigger than in the south corner) and highly non-linear.

Figure 7 displays the same exercise when looking at the persistence trade-off. Again we find that it is crucial to take account of interactions. In the case of institutions being *complements*, the predicted values for the trade-off are very similar (note that the scale on the axis is inverted).

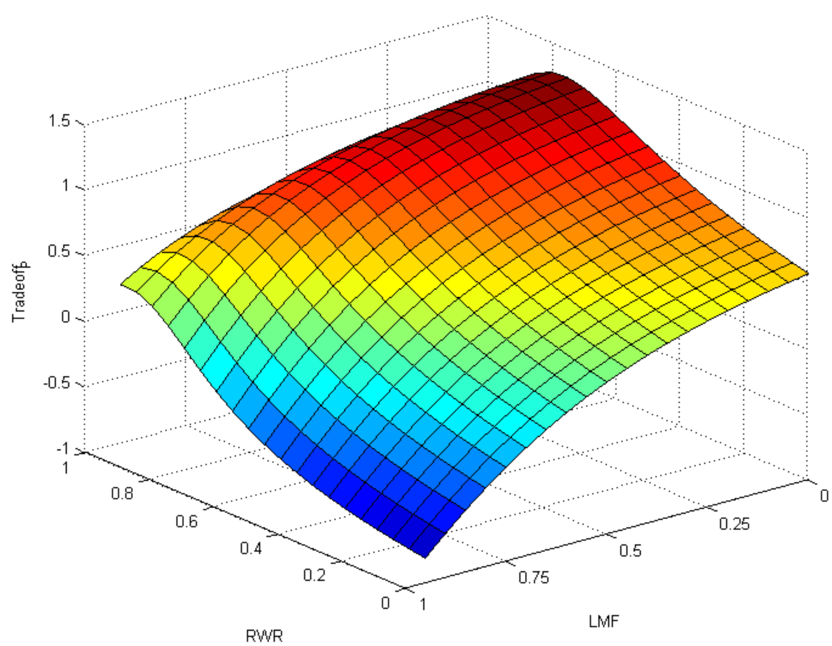


Figure 7: *Interacting Institutions and Persistence*

If LMF and RWR are *substitutes* the trade-off takes high values in the northern corner (low LMF-high RWR) and very low values in the southern corner (high

LMF-low RWR).[23] The results are again caused by the fact that RWRs have the opposite effect on inflation and unemployment compared to LMFs. Effects are, therefore, offsetting when institutions are complements and reinforcing when they are substitutes.

Are LMF and RWR likely to be complements or substitutes? A priori, there is no clear-cut answer, as good theoretical arguments can be found that go in both directions.[24] The final answer is empirical, and we defer to the second part of the paper for a discussion of the available evidence.

5 Empirical Analysis

Our simple model provides a wide range of hypothesis as to how labor market institutions (LMI) may influence the behavior of inflation and the unemployment rate over the business cycle, in terms of volatility, persistence as well as in terms of intensity and duration of the cycle. Our approach in testing these hypotheses is twofold: In a preliminary step we analyze the correlations between various institutions and the observed moments of the data for a panel of 20 OECD countries over the period 1970-1999.[25] In a second step we split the data in three equally long time periods (70-79, 80-89 and 90-99) and conduct a panel estimation of the impact of institutions on the observed volatilities.

5.1 Associating labor market institutions

Labor market institutions can lead to very different dynamic effects depending on whether they constrain the price adjustment or the quantity adjustment on the labor market. While in the theoretical part we have focused our attention on two particular types of labor market rigidities (labor market frictions and real wage rigidities), we believe this to be an intuitive and quite general result. In this section, we try to discuss informally how different institutions could be accommodated in the context of our framework, and in particular which institutions can be considered as "price restricting institutions" and which as "quantity restricting institutions".

The candidates of observable institutions are the tax wedge, the unemployment benefits/duration, the employment protection legislation (EPL), the union

[23] For extremly low values of RWR and very high values of LMF, the trade-off takes even negative values. This is due to the fact that inflation persistence turns slightly negative under this constellation, since close to all adjustement takes place over prices.

[24] For instance, a strict employment protection legislation and a generous unemployment benefit system can arguably be considered as substitutes: anectodical evidence suggests that countries with weak public finance may find it difficult to put in place an efficient unemployment benefit system and may therefore opt for firing costs as a way to defend the workers from transitory shocks. On the other side, the presence of hiring/firing costs may be considered as complement of the insider/outsider problem: hiring and firing costs, in fact, increase the rents linked to an employment relationship and thus the insiders' power. If wages are set by the insiders, this may lead to a decrease of the responsiveness of real wages to economic activity and unemployment.

[25] The time span is conditioned by the availability of the labour market indicators.

density/coverage, the extent of coordination/centralization of the wage bargaining, and any potential measure of real wage rigidity. To classify these institutions in one or the other category we resort both to the findings of the labor economics literature and to the intuition provided by our simple model. In particular, the model provides an intuitive guidance to determine the effects of "price restricting institutions" on the degree of wage rigidity, which we use extensively in the following discussion. Consider again the Nash wage equation (5):[26]

$$W_t^{Nash} = MRS_t + \frac{\eta}{1-\eta} PRE_t$$

where MRS may be understood as the reservation wage and PRE stands for the "wage premium" that accrues due to the fact that an employment relation is valuable. Notice that the bargained wage depends on two parts: a very stable part - the reservation wage - and a very volatile one - the wage premium, which is a function of the labor market tightness and of the job-finding rate. The wage equation can help us in the classification of the effects of different institutions in the following way: any institution that increase the weight of the stable part of the bargained wage - MRS - makes the wage more rigid; institutions that increase the importance of the "wage premium", instead, make the bargained wage more volatile.

Quantity restricting institutions.

1. *Employment Protection Legislation (Firing costs)*: Much debate in the literature has focused on the impact of EPL on the *level* of unemployment. Though there is no clear consensus as to whether EPL has a predictable impact on the level of unemployment, it seems clear that EPL limits the flow in and out of the labor force and thus make quantity adjustments relatively more costly compared to price adjustments. Hence, EPL promises to be capturing well the labor market friction in the model.

2. *Hiring costs and efficiency of the matching*: When hiring workers is more costly, and the matching between the workers and the firms in the labor market is less efficient, firms will find easier to absorb shocks by changing prices than by changing quantities. These are captured in the model by the parameters κ and σ_m. Unfortunately, good indicators on these dimensions are not available.

Price Restricting Institutions

1. *Unemployment Benefits Systems (Benefit Duration and Benefit Replacement Ratio)*: With respect to the unemployment insurance system, labor market theorists have repeatedly stressed the importance of its optimal design. One of the notions is that systems with high benefits (and possibly high duration) reduce the disutility from unemployment. Additionally,

[26] The single terms are given by: $MRS_t = \frac{\varkappa}{\lambda_t}$ and $PRE_t = \frac{\kappa_t}{q_t} - \beta(1-\rho)\frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}(1-p_{t+1})$.

this may increase the probability of finding an alternative employment (for separated workers) since the other unemployed's search activity is reduced (Layard et al. 2001). In such a case it might well be that unemployment fluctuates stronger and wages react less to such fluctuations. This line of argumentation suggest that systems with rather high benefit entitlements, tend to restrict price adjustments. In the model, more generous unemployment benefit systems increase the reservation wage MRS and thereby the less responsive part of wages.[27]

2. *Tax Wedge*: The labor market literature has primarily identified the tax wedge as a shift parameter in the labor market schedule and as such does not give clear guidance as to whether to associate this institution with RWR or LMF. In our setup, the tax wedge would enter the wage equation via the MRS, since a higher tax wedge requires a higher compensation for a given level of consumption. Hence, a higher tax wedge would increase the fraction of the wage that is less responsive to the labor market tightness, making the wage rate less responsive to unemployment changes. The tax wedge is therefore attributable to RWR, restricting price adjustments.

3. *Centralization*: The labor market literature suggests that the effects of the centralization of the wage bargaining process are not clear-cut. On the one side, it may be argued that under centralized bargaining real wages respond more to unemployment fluctuations than under decentralized wage bargaining. This corporatist argument is based on the notion that when wages are bargained over at more decentralized levels, unions may take a more aggressive stance in wage negotiations since there exists an outside option in working for other firms. At the centralized level this outside option does not exist anymore since wages are basically set for the entire labor force, leading the union to internalize possible adverse effects on unemployment of too high wage realizations. Hence, wage centralization may be associated with higher flexibility in price adjustments. On the other side, according to Calmfors and Driffill (1988) wage setting tends to be less aggressive at the decentralized and at the centralized level, while at intermediate levels wage settlements tend to be higher. This gives rise to the hump-shaped hypothesis. Such a pattern would imply that a simple linear relationship may be ill-suited in terms of measuring real wage rigidity. Since, most studies in the literature found stronger support for the corporatist argument,[28] we will associate in the following wage centralization with the institutions affecting the price adjustment and assume that a higher decentralization of wage settlement leads to more rigid wages. [29]

[27] This argument has been formalized by Zanetti (2007).

[28] See for example Bertola et al (2002), Blanchard and Wolfers (2000) or Nickell et al (2002).

[29] To the extent that the centralization index is a proxy of the workers' bargaining power, a higher degree of centralization is associated with a higher η in the model and thus leads to more volatile wages (as the share of the surplus captured by workers is higher). This is in line with our proposed ordering.

4. *Union Density*: The impact of unions is not incorporated easily in our framework. In particular, associating union density with RWR or LMF depends primarily on the unions preferences over tolerating rather variation in the real wage or variation in the labor force. It is hence perfectly plausible that a union with high coverage may opt for a strategy which allows for higher variation in the wage adjustment as opposed to variation in the labor force. It remains an empirical question which effect outweighs the other. In the context of the model, even though we have not explicitly modeled trade unions, we may interpret the union density/coverage as a measure of the power workers have in the bargaining process. In this sense a high level of union density corresponds to a high level of η, implying that wages are more responsive to unemployment variation. Alternatively, to the extent that unions may be willing to forgo an increase in wages today in exchange with a promise to not reducing wages in the following period (a sort of insurance mechanism), trade unions may be a reason behind the presence of a wage norm and of rigid wages, as captured by the parameter γ.

The below table summarizes the expected institutions' impact on the adjustment process over the cycle as implied by the model and the theoretical considerations:

Labor Market Institutions			
Quantities		Prices	
Institution	Parameter	Institution	Parameter
EPL (Firing)	(ρ)	Centralization	(η)
Hiring Cost	(κ)	Benefit Duration	(MRS)
Matching	(σ_m)	Benefit Replacement	(MRS)
		Tax Wedge	(MRS)
Union (?) (η,γ)			

We are not aware of empirical investigations which explore the implication of various labor market rigidities for business cycle variations across countries. However, some authors have investigated the combined effect of shocks and labor market institutions on the level of the unemployment rate.[30] Notably, Blanchard and Wolfers (2000) found in a study of 20 OECD countries and eight five-year periods starting in 1960 that shocks have larger effects on unemployment when the benefit replacement rate is higher, the benefit duration longer, employment protection stricter, union density is high and coordination low. The analysis by Bertola, Blau and Kahn (2001) roughly supports these results. Since these empirical works do not look at cyclical patterns but at the level of unemployment they give us little guidance for our work.

5.2 A model-based real wage rigidity measure

Given the indeterminacy with respect to union density/coverage as well as the missing indicators for hiring costs and the matching efficiency, we focus in our em-

[30] For a summary of the literature see for example Arpaia and Mourre (2005).

pirical approach on EPL as a measure of LMF and on Benefit Duration/Replacement, the tax wedge as well as centralization as measures for RWR. Additionally, we consider an estimated real wage rigidity measure based on the model's equation. Recalling that the change in the real wage is given by $\hat{w}_t^R = \gamma \hat{w}_{t-1}^R + (1-\gamma)\,\hat{w}_t^{Nash}$ we make use of the labor market tightness (17) and the Nash wage (5) to re-write this equation as:

$$\begin{aligned} \hat{w}_t^R &= \gamma \hat{w}_{t-1}^R + (1-\gamma)\,\hat{w}_t^{Nash} \\ &= \gamma \hat{w}_{t-1}^R + (1-\gamma)\,[\alpha_1 \hat{c}_t + \sum_{i=-1}^{1} \beta_i \hat{u}_{t+i}] \end{aligned} \tag{12}$$

Assuming expectations about the future unemployment are related to current unemployment, consumption and productivity levels, i.e. $E_t \hat{u}_{t+1} = f(\hat{u}_t, \hat{c}_t, \hat{a}_t)$ we get:

$$\hat{w}_t^R = \gamma \hat{w}_{t-1}^R + (1-\gamma)\,[f(\hat{c}_t, \hat{u}_t, \hat{u}_{t-1}, \hat{a}_t]$$

We estimate the empirical analogue:[31]

$$\hat{w}_t^R = \gamma \hat{w}_{t-1}^R + \beta_1 \hat{c}_{t-1} + \beta_2 \hat{u}_{t-1} + \beta_3 \hat{u}_{t-2} + \beta_4 \hat{a}_{t-1} + \varepsilon_t \tag{13}$$

where we control for potential endogeneity by taking the lagged values of $\hat{c}_t$, $\hat{u}_t$, and $\hat{a}_t$. ε_t is the error term and variables with hat are percentage deviations from the filtered trend series. γ corresponds to the empirical measure of real wage rigidity. The results, shown in the appendix, are quite interesting, intuitive and in line with expectations.[32]

This measure has some clear advantages and some drawbacks. The first advantage is that it corresponds exactly to the real wage rigidity index employed in the theoretical part. Second, it may capture, in a single synthetic measure, the interplay of different institutions constraining price adjustments in the labor market. Third, it may also capture the degree of real wage rigidities arising from the combination of nominal price and nominal wage stickiness, something the other institutional measures cannot capture. On the other hand, one of the drawbacks relates to data availability. Long enough series for quarterly wages only exists for 14 OECD countries, limiting our analysis when using this measure to fewer countries. The second drawback relates to the fact that our real wage rigidity measure is by its nature endogenous to the model and, to the extent that equation (13) is misspecified, it may capture elements that are not strictly related to labor market institutions constraining price adjustments. These advantages and drawbacks should be kept in mind in the following section, which relates the business cycle dynamics to the different labor market institutions.

[31] We estimated also (12) using GMM on the overall sample period. The estimates are highly correlated with the OLS estimates of (13), with a value of 0.87. As the subsample analysis does not allow the use of GMM due to the too short sample size, we remain out of consistency with the OLS estimates also for the overall sample statistics.

[32] In a previous version of this paper, we estimated a RWR measure using the Layard et al. (2001) estimation strategy, obtaining similar results.

5.3 Substitutes versus Complements

A central result of the model relates to the question whether institutions are complements or substitutes. If institutions are complements in the sense that institutions that generate rigidities in the quantity adjustment are positively correlated with institutions that generate price rigidities, effects may be offsetting, and we find ourself in the eastern and western corner of figure 6. The result would be that having a combination of a very rigid overall labor market or a very flexible labor market affects the trade-off only marginally. If however, institutions are substitutes such that RWR and LMF are negatively correlated, we should find a significant difference between the volatility trade-off of countries with high RWR and low LMF versus countries with low RWR and high LMF.

To investigate this question and to get a picture of the prevailing institutions we take a look at the underlying data for some of the countries in our sample.[33]

	Standard Deviations				Labour Market Indicators					
	GDP	UR	INFL	T.off	EPL	CO	BD	BEN	TAX	$\widehat{RWR}$
Anglo										
Australia	1.24	0.71	0.54	0.75	0.50	3.00	1.02	23.16	14.95	0.81
UK	1.37	0.53	0.71	1.33	0.34	1.70	0.65	21.01	25.37	0.57
USA	1.62	0.71	0.42	0.59	0.10	1.27	0.18	12.57	25.16	0.83
Mean	1.41	0.65	0.56	0.89	0.31	1.99	0.62	18.91	21.83	0.74
Skand.										
Denmark	1.41	0.57	0.44	0.77	1.02	4.00	0.71	50.00	33.37	na
Norway	1.09	0.38	0.59	1.55	1.51	4.74	0.45	28.16	26.97	0.55
Sweden	1.25	0.44	0.42	1.07	1.46	4.17	0.04	23.70	42.38	0.84
Mean	1.25	0.46	0.50	1.13	1.33	4.31	0.40	33.95	34.24	0.70
Cont. Eur.										
France	0.75	0.34	0.34	0.98	1.17	2.00	0.34	31.72	39.48	0.61
Italy	1.37	0.32	0.60	1.84	1.95	2.77	0.04	6.32	42.34	0.66
Spain	0.95	0.56	0.37	0.66	1.87	na	0.15	28.17	32.84	na
Mean	1.02	0.41	0.44	1.16	1.66	2.39	0.18	22.07	38.22	0.64

Table 1: Descriptive Statistics

The picture that emerges from table (1) is that Anglo-Saxon countries tend to have generally flexible labor markets with the exception of the benefit duration (BD) and the estimated RWR measure ($\widehat{RWR}$) that tend to be above the overall sample mean. Continental European countries on the other hand tend to have stricter EPL, higher taxes (TAX) but weak unemployment benefit programs. Scandinavian countries are coined by high taxes, relatively accommodating benefit systems and high levels of centralization (CO). The difference in volatilities emerges clearly from this picture. GDP and unemployment tend to be more volatile in Anglo-Saxon countries compared to Continental European countries.

[33] For a detailed description of the indicators see the Appendix. For a graphical representation in terms of scatter plots see the graphs below.

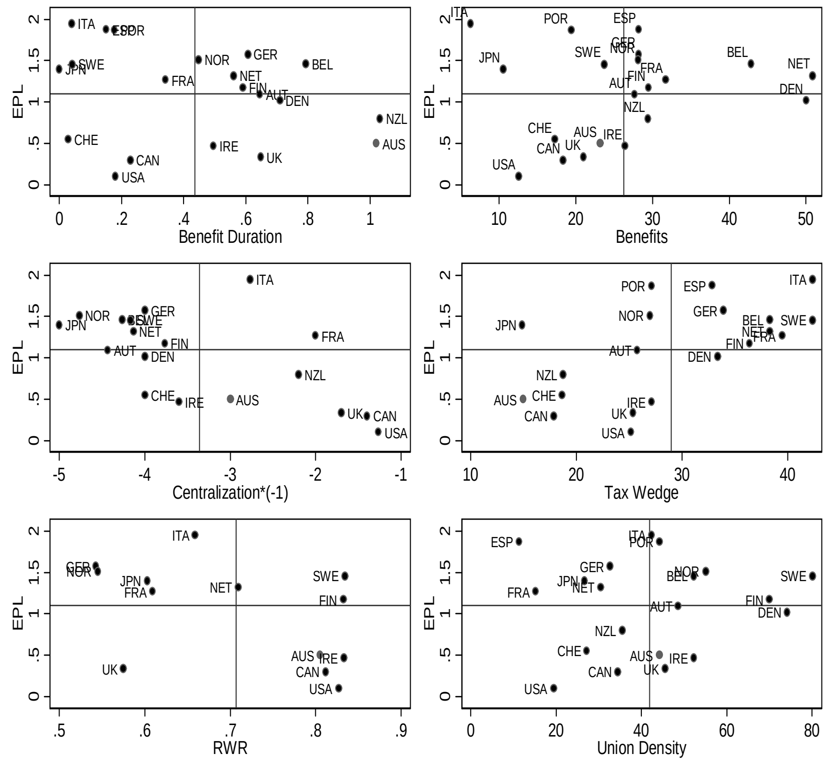
This pattern is less visible for the inflation volatility. This is hardly surprising, considering that inflation depends primarily on the policy regime and on the preferences and credibility of monetary authorities, which present large cross-country variations especially in the 80s-early 90s. The trade-off between inflation volatility and unemployment volatility takes the lowest value in the Anglo-Saxon countries, which have the least restrictive EPL and rather high RWR when measured in terms of benefit duration or the estimated RWR. On the other hand, Continental European countries and Scandinavian countries that tend to have higher EPL and lower RWR in terms of the estimated measure and the benefit duration exhibit on average higher trade-off values. However, from these statistics we may not conclude that countries' institutions are generally substitutes. To investigate this relationship further, we compute correlations between the average values of the respective indicators in our sample.[34]

Table 2	EPL			
	70-79	80-89	90-99	70-99
BD	-0.27	-0.24	-0.22	-0.26
BEN	-0.02	0.11	0.27	0.12
DEC	-0.37	-0.62	-0.58	-0.59
TAX	-	0.60	0.54	0.58*
$\widehat{RWR}$	-0.37	-0.38	-0.35	-0.48
UNION	-0.03	0.13	0.05	0.06

* Correlation for the period 80-99

Although higher levels of EPL seem to be associated with shorter benefit duration (BD) and more centralized wage setting (DEC), there is a strong positive correlation with the tax wedge and no clear correlation with the composite measure of unemployment benefits nor with union density. Our estimated measure of real wage rigidity is in all three periods negatively correlated with EPL. Hence, given the fact that the sign of the correlations depend on which institution is taken to be the measure of RWR and values are sometimes rather low, we can neither make a clear case in favor of institutions being substitutes nor can we find strong support for institutions to be complements.

[34] "DEC" stands for decentralization. This measure is nothing else than the coordintation indicator which has been premultiplied by (-1) such that the sign is to be interpreted as for the other indicators and a higher value corresponds to stronger real wage rigidity (more decentralized wage bargaining systems).



5.4 Total Sample Correlations: Volatility, Persistence and Duration

In the following we contrast the LMIs to the four dimensions of our variables of interest over the business cycle: volatility, persistence, duration and intensity. Volatilities are measured by the standard deviations computed on the Band-Pass filtered series.[35] To measure the persistence of a variable x_t, following Gadzinski and Orlandi (2004), we estimate an AR model of the form:

$$x_t = c + \varsigma x_{t-1} + \sum_{i=1}^{k} \psi_i \triangle x_{t-i} + \varepsilon_t \tag{14}$$

Given the quarterly data we set $k = 4$ for all countries in the baseline scenario and use ς as the persistence measure. Though this has been standard practice in determining inflation persistence and it may be a reasonable approach for the simulated model, this approach has many drawbacks when applied to real data. In particular results will depend on the number of lags included and persistence

[35] In this baseline setting we used the commonly used dimensions with a lower limit of 6 quarters and an upper limit of 32 quarters for the computation of the band pass filter. Employing a Hodrick-Prescott Filter does not change the main results.

tends to be overestimated in the presence of structural breaks. Clearly, for a sample period from 1970 to 1999 we may well expect structural changes in either variable. To address these issues authors have employed ARFIMA techniques or have allowed for structural breaks (see for example Dolores Gadea and Mayoral (2006) or Gadzinski and Orlandi (2004)). As argued by Marques (2004), in particular the latter does not solve the problem of wrongly estimating the persistence. Hence, we employ an alternative measure proposed by Marques (2004). Accordingly, we allow the mean to vary over time and compute the statistic:

$$\iota = 1 - \frac{n}{T} \tag{15}$$

where n stands for the number of times the series crosses the mean during a time interval with $T+1$ observations and the mean is measured by the HP trend. By construction ι will always be between zero and unity. Values of ι close to 0.5 signal the absence of any significant persistence while values above 0.5 signal positive persistence and values below 0.5 negative persistence.[36]

The duration of the cycle in the data is alternatively measured as trough-to-trough (ADTT) or peak-to-peak (ADPP), using the dating method described before. For the data we compute the average growth rate from trough-to-peak (GRRATETP) and peak-to-trough (GRRATEPT) since these are very different given the asymmetry with short recessions and long expansion in particular for employment and the GDP series.

Contrasting the volatilities with the various labor market measures we find the model's predictions to be born out fairly well.[37] In particular simple correlations for EPL, the estimated RWR and benefit duration are consistent with the model. All six measures have the right sign for the prediction with respect to the trade-off and are relatively high for EPL, the estimate RWR and, the composite benefit measure.[38] Maybe not surprisingly, the tax rate performs the worst in terms of reflecting the real wage rigidity.

Volatility	Quantity		Prices					
1970-99	Model	Data	Model	Data				
Institution	ρ	EPL	γ, MRS, η^{-1}	$\widehat{RWR}$	BD	BEN	TAX	DEC
UR	-	-0.56	+	0.72	0.34	0.19	-0.10	0.45
GDP	-	-0.32	+	0.42	0.11	-0.33	-0.48	0.32
INFL	+	0.16	-	-0.35	0.01	-0.37	-0.24	0.18
Trade-off	+	0.41	-	-0.54	-0.37	-0.47	-0.27	-0.36

Table 3: Volatility of key Variables (standard deviation)

Looking at ι as a measure of persistence we find again the sign for the results for EPL and the benefit duration to be consistent with the model's predictions,

[36] In our case values were always well above 0.5, giving strong support for positive persistence.

[37] Note that we excluded Finland and Germany from the sample due to the breaks they exhibited in the early 90s. Including the two countries affects results only marginally.

[38] This holds also when we repeat the exercise for the 3 sub-samples. See the Appendix for these statistics.

however values are rather low. The results for the other measures are mixed and give no clear indication. When measuring persistence using ς, the results do not improve for most indicators with the exception of the estimated RWR (see Appendix).

Persistence(ι)	Quantity		Prices					
1970-99	Model	Data	Model	Data				
Institution	ρ	EPL	γ,MRS, η^{-1}	$\widehat{RWR}$	BD	BEN	TAX	DEC
UR	-	-0.10	-	0.34	-0.18	0.24	0.31	-0.09
GDP	+	0.18	-	0.06	-0.47	-0.31	0.09	0.24
INFL	-	-0.24	+	0.26	0.09	-0.27	-0.10	0.48
Trade-off	-	-0.19	+	0.15	0.13	-0.29	-0.15	0.42

Table 4: Persistence of key Variables

Lastly we take a look at the correlations between the labor market indicators and the statistics for duration and intensity of the cycle. No matter whether we look at the cycle's length in terms of real GDP, employment or in terms of the unemployment rate, the duration between peaks (and the duration between troughs) is positively correlated with the labor market rigidity (EPL).[39] Also we do find, the predicted negative correlation between intensity of the cycle and EPL. Similarly we do find the results for the estimated RWR and the benefit duration to support the model's predictions. The other measures give again no conclusive results.

Cycle	Quantity		Prices					
GDP	Model	Data	Model	Data				
	ρ	EPL	γ,MRS, η^{-1}	$\widehat{RWR}$	BD	BEN	TAX	DEC
ADPP	+	0.34	-	-0.51	-0.24	-0.06	0.33	0.10
ADTT	+	0.33	-	-0.33	-0.25	-0.01	0.39	0.11
GRRATETP	-	-0.18	+	0.24	0.36	-0.03	-0.25	0.24
GRRATEPT	-	-0.20	+	-0.04	0.12	0.05	-0.15	0.46

Table 5: Cyclical Properties of GDP

Though all these statistics are based on simple correlations for only few observations, we do find results for EPL, the estimated RWR, benefit duration and to a lesser extent the composite benefit measure to be generally in line with the model's predictions.

5.5 Regression Approach for Volatility[40]

One of the reasons why results for simple correlations are imperfect, relates to the fact that the model's implications involve interactions between the institutions.

[39] For statistics with respect to the unemployment rate and the employment level see the Appendix.

[40] Since the theoretical predictions and the empirical results are more robust for the case of volatility we decided to focus on this dimension. Nevertheless, we present in the Appendix the

This would not matter if institutions were substitutes (or complements), since then only the north-south (east-west) axis in figure (6) matters, which can be roughly approximated by a linear correlation. However, as was observed in the descriptive statistics, institutions in the sample are far from being exclusively substitutes (or complements). Hence, a bivariate approach promises to detect better the pattern than a univariate approach. Furthermore, there have been structural changes over the sample period. In particular average inflation volatility has declined dramatically over the period and with it the trade-off.[41] Our former descriptive analysis on the overall sample averages was brushing away these aspects. To take account of these considerations we split the sample in three equally long periods, allowing for a maximum of 60 observations, and compute the values for the standard deviations in the subsamples and the corresponding average values for the labor market institutions.[42] Though far from being the ideal dataset, this allows us to make some meaningful empirical analysis. Given the nature of the data our strategy is to employ a fixed effect panel technique to account for nonobservable time effects which addresses to some extent the changing nature of monetary policy over the sample period and other factors that account for the general decline in the trade-off.[43] As of the small number of observations we limit ourselves to as few regressors as possible at the cost of a possible missing variable bias. To the extent that some of these variables (e.g. monetary policy stance) have taken a similar pattern for the panel of OECD countries over time, the fixed time effect approach does address this potential problem. Hence we estimate the following regression

$$Y_{i,t} = c + \alpha_t + EPL_{i,t}\beta_1 + RWR_{i,t}\beta_2 + \varepsilon_{i,t}$$

Taking the trade-off (the standard deviation of the inflation rate over the standard deviation of the unemployment rate) as dependent variable, we would expect $\beta_1 > 0$ and $\beta_2 < 0$. Regression results are reported in table 6. In the case of benefit duration and the composite benefit measure as well as for the tax rate we find the sign to be as expected negative and strongly significant. The centralization measure and the estimated real wage rigidity measure though having

estimation results for the computed persistence trade-off. Though the signs are as expected in most of the cases, significance is only given for the case of centralization. The reason for the insignificance may stem from two sources that make results less robust: (1) from a theoretical side, a richer model that generates a hump-shaped response of inflation by introducing habit in consumption is likely to give more accurate predictions than our (deliberately) simple model. Such a model would have to be implemented differently in the empirical exercise. (2) The difficulty in correctly measuring the persistence in the context of non stationary series and short samples may affect the accuracy of our computed persistence measures, leading to biases in the estimation. Since both of these issues can more or less be easily addressed, but are above the scope of this essay, we believe that this avenue may pose an interesting subject for future research on the impact of LMIs on the pattern of the business cycle.

[41] Despite a parallel decline in output volatility (measured in terms of GDP), the volatility of the unemployment rate does not show any pronounced trend pattern over the period.

[42] Effectively we have 58 observations, since we exclude Germany and Finland in the last period due to the breaks. Again results would remain unchanged, if we were to keep the two observations in the sample.

[43] Regression results for the single variables, unemployment and inflation, are reported in the Appendix.

the right sign are insignificant. EPL has always the expected sign and is in two cases significant at the 1% level and twice at the 5% level. Hence, we find the conclusions drawn from the simple correlations reaffirmed and statistically significant. The former regression approach made the importance of a bivariate approach clear in order to account for the diverse institutional landscape across countries. As a next step, we address the issue of non linearity. To this end we construct measures which are roughly in line with the model's predictions. The model predicts non linearities which may be approximated by an exponential relationship.[44]

Table 6: Dependent Variable (Trade-off)

Variable	1	2	3	4	5
EPL	0.41	0.68	0.82	0.78	0.33
	(0.05)	(0.01)	(0.01)	(0.02)	(0.18)
BD	-1.13				
	(0.02)				
BEN		-0.04			
		(0.00)			
TAX			-0.06		
			(0.00)		
$\widehat{RWR}$				-0.21	
				(0.34)	
DEC					-0.13
					(0.28)
Const.	1.35	1.58	1.58	0.63	1.38
	(0.00)	(0.00)	(0.00)	(0.10)	(0.04)
Overall R^2	0.17	0.30	0.30	0.09	0.08
Obs.	58	58	37	35	52

p-values in parenthesis, robust std.errors

A simple transformation that would allow for a non-linear structure is given by

$$y_{i,t} = \exp(X_{i,t}\beta + \varepsilon_{i,t})$$

which may be estimated by:[45]

$$\ln(y_{i,t}) = X_{i,t}\beta + \epsilon_{i,t}$$

[44] The exact non linear relationship predicted by the model may be described by: (1) $\frac{\partial Tradeoff}{\partial RWR} < 0$ (2) $\frac{\partial^2 Tradeoff}{\partial^2 RWR} < 0$ (3) $\frac{\partial Tradeoff}{\partial LMF} > 0$ (4) $\frac{\partial^2 Tradeoff}{\partial^2 LMF} > 0$. Such a structure may be modelled by estimating $Y_{it} = c + \alpha_t + \beta_1 \exp(LMF) + \beta_2 \exp(RWR)$, where we would expect $\beta_1 > 0$ and $\beta_2 < 0$. However, in practice we did not find this relationship to be the most powerful.

[45] Note that this form of estimation implies that $\frac{\partial^2 Tradeoff}{\partial^2 RWR} < 0$ does not hold for the expected sign of the coefficient on the real wage rigidity measure.

As can be seen from the table (7), significance and fit improves for the estimation involving the composite benefit measure, while most other estimations remain unaffected. A possible explanation for this, may be that all measures with the exception of the composite benefit measure are either in all periods negatively correlated with EPL or in all three periods positively correlated. Hence, for these measures a linear relationship approximates well the trade-off outcome along the respective axes. However, the composite benefit measure spreads over the whole plane of combinations of institutions such that non linearities may play a more important role. This result suggests that for certain institutions non linearities do play a role and need to be accounted for.

Table 7: Dependent Variable ln(trade-off)

Variable	6	7	8	9	10
EPL	0.25	0.40	0.60	0.34	0.23
	(0.08)	(0.00)	(0.00)	(0.02)	(0.17)
BD	-0.62				
	(0.02)				
BEN		-0.02			
		(0.00)			
TAX			-0.04		
			(0.00)		
$\widehat{RWR}$				-0.38	
				(0.51)	
DEC					-0.06
					(0.44)
Const.	0.73	0.15	0.20	-0.27	-0.13
	(0.00)	(0.41)	(0.00)	(0.55)	(0.74)
Overall R^2	0.17	0.37	0.28	0.12	0.08
Obs.	58	58	37	35	52

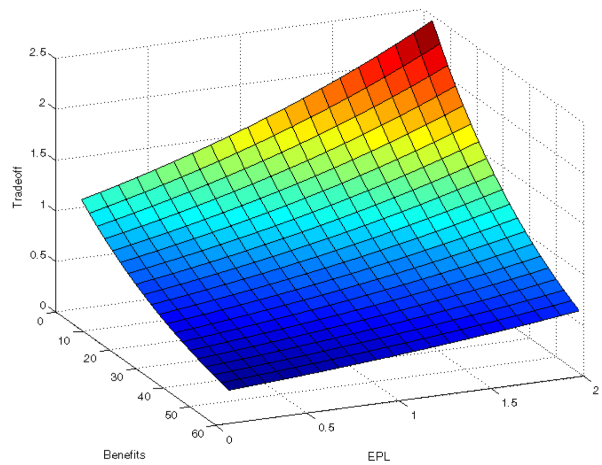
p-values in parenthesis, robust std.errors

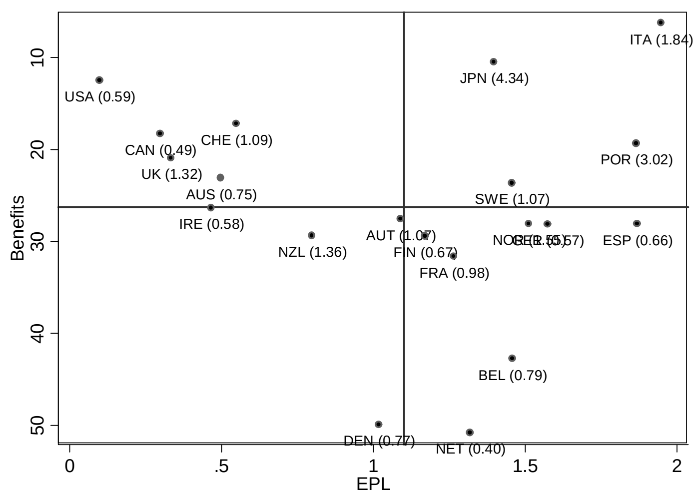
In the next graph, we show the graphical representation of the predicted values values for the estimation involving the composite benefit measure and the actual grouping of the countries when using the overall averages for the total sample period. The shape gets very close to the one predicted by our simple model in terms of ordering and magnitude.

In a last step we construct a composite measure which accounts for (weak) non linearity and the differential impact of RWR and LMF. In order to do so we normalize the values of all regressors such that they are bound between zero and unity, by simply dividing through the maximum value. Taking the exponential of each regressor we then compute the respective indices by dividing the respective exponented RWR measure with the exponented value of the EPL measure. The general formula may be described as follows:

$$indexRWR = \frac{\exp(\frac{RWR}{\max(RWR)})}{\exp(\frac{EPL}{\max(EPL)})}$$

which is by construction bound between e^{-1} and e.[46]





The regression results imply that this measure is reflecting fairly well the differential impact of RWR and LMF. In particular we do find the indices based on the benefit measures and the tax rate to be highly significant. Furthermore, now also the indices using the real wage rigidity estimates and the centralization index become significant at the 5% level. A graphical representation for the real wage rigidity measure is given in the Appendix.

[46] Note that in this case we do not have $\frac{\partial^2 Tradeoff}{\partial^2 EPL} > 0$ for the expected sign of the coefficient estimate. Furthermore, notice that we implicitly restrict the estimated coefficient.

Table 8: Dependent Variable (Trade-off)

Variable	11	12	13	14	15
Index BD	-0.83				
	(0.01)				
Index BEN		-1.87			
		(0.00)			
Index TAX			-1.42		
			(0.01)		
Index $\widehat{RWR}$				-0.76	
				(0.05)	
Index DEC.					-0.48
					(0.04)
Const.	2.12	3.09	2.54	2.16	1.81
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Overall R^2	0.11	0.25	0.22	0.09	0.07
Obs.	58	58	37	35	52

p-values in parenthesis, robust std.errors

5.6 Policy Implications

In this paper we have argued the need to distinguish between institutions constraining quantities (LMF) and institutions constraining prices (RWR). LMF and RWR in fact, while often associated in policy discussions, are found to have opposite effects on business cycle dynamics. While a higher degree of LMF makes the Phillips curve steeper, more rigid wages flatten it. When institutions on the two side of the market are complements, the effects can offset each other, but when they are substitute, they can actually reinforce and magnify each other.

In this section we argue that our findings carry strong policy implications, both with respect to the conduct of optimal monetary policy and with respect to the effects of labor market reforms.

First, our findings can explain why European countries have longer cycles and are traditionally less volatile than Anglo-Saxon countries. Second, our results suggest that macroeconomic stabilization is easier in countries with "sclerotic" labor markets and/or flexible wages. In these countries, in fact, the Phillips curve is steeper and the central bank can reduce inflation volatility incurring in a smaller increase in unemployment volatility: the trade-off of monetary policy gets less severe.[47] Third, the optimal degree of aggressiveness of monetary policy should depend on the labor market structure. Since in countries with higher real wage rigidities and lower labor market frictions inflation is less sensitive to unemployment changes (the Phillips curve is flatter), monetary authorities in such countries will have to adopt a more aggressive monetary policy stance in order to bring inflation in line with the target. On the other side, in countries where LMF are high and RWR are low, it is easier to bring inflation in line with

[47] This finding is shown more formally in Abbritti and Mueller (2007).

target, but the monetary policy tool is less effective in affecting the real side of the economy. These results may explain why the European central bank has often been less aggressive (and less expansionary) than the Federal Reserve.

The need to take account of the two types of rigidities becomes even more striking in the context of a monetary union. When countries within a union exhibit heterogeneous labor markets, the propagation mechanisms of shocks are likely to differ across member countries. This may have strong positive and normative implications. From a positive point of view, symmetric shocks (and thus monetary policy) are likely to have strong asymmetric effects and lead to large, inefficient, inflation and unemployment differentials. From a normative point of view, our results suggest the need for the common central bank to react differently to shocks originating in different regions, as the effect of shocks depends crucially on the labor market structure of the region where the shock takes place.[48]

Interestingly, our results may serve to formulate some implications of labor market reforms. Our analysis suggests that reforms that reduce the hiring and firing costs in the labor market (which are likely to have beneficial effects on the natural level of unemployment) may decrease the responsiveness of inflation to unemployment, render macroeconomic stabilization more difficult but increase the effectiveness of monetary policy on the real side of the economy. The opposite would hold if, by reducing the generosity of the unemployment benefit system, real wages become more flexible. Taking into consideration these effects is likely to be important in order to give monetary policy a role in accommodating labor market reforms in an optimal way.

6 Conclusion

This essay analyzed how different labor market institutions affect the persistence, volatility and amplitude of business cycle fluctuations. Two main results are obtained. First, real wage rigidities (RWR) and labor market frictions (LMF) are found to have opposite effects on business cycles. The reason is simple: while a higher degree of real wage rigidity flattens the Phillips curve, as the elasticity of inflation to unemployment changes gets lower, a more "sclerotic" labor market makes the Phillips curve steeper, because firms find it easier and cheaper to adjust prices than quantities. A higher degree of real wage rigidities thus amplifies the response of the real economy to shocks, shortens the duration of the business cycle but makes it more intense. When the rigidity lies in the labor market, inflation volatility increases and the response of the real economy to shocks becomes smoother, while the cycle gets longer but less severe.

Second, what really matters is the interaction among different labor market institutions. In particular, it is crucial to determine whether institutions are *complements* or *substitutes*: the effects of RWR and LMF on the slope of the Phillips curve tend to offset each other when the two types of rigidities are *complements* (in the sense that high RWR are associated with high LMF, or vice versa) while

[48] See, e.g, Abbritti and Mueller (2007) for an analysis of the positive and normative implications of asymmetric labor market institutions in a monetary union.

they tend to reinforce and magnify each other when they are *substitutes* (in the sense that countries with high LMF have flexible real wages or vice versa). The slope of the Phillips Curve is maximal when LMF are high and real wages are flexible, while it is minimal when LMF are low and RWR high. Intermediate cases can be determined by different combinations of LMF and RWR.

Using employment protection legislation as a measure of labor market frictions and an estimated value of real wage rigidity we compute simple correlations for a set of OECD countries and find the results to be consistent with these predictions. Accounting for the differential impact of LMF and alternative measures of RWR on the volatility trade-off, we estimate a panel model with time-varying volatility measures for three sub-periods and find also here the estimates in line with the model's predictions. Though the main point of our paper is with regards to the theoretical analysis, our simple empirical exercise underpins the importance in distinguishing the two types of institutions and the relevance of their interaction for policy evaluations.

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A Nash Bargained Wages

Let Ω_t^F be the value function of the firm at time t:

$$\Omega_t^F = \varphi_t A_t^\alpha (N_t)^\alpha K_t^{1-\alpha} - W_t N_t - \kappa_t v_t - (I_t + T(I_t, K_t)) + E_t \beta \frac{\lambda_{t+1}}{\lambda_t} \Omega_{t+1}^F$$

The marginal value of an employment relationship for the firm is:

$$\begin{aligned} \frac{\partial \Omega_t^F}{\partial N_t} &= \varphi_t f_{N_t} - W_t + \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Omega_{t+1}^F}{\partial N_{t+1}} \frac{\partial N_{t+1}}{\partial N_t} \\ &= \varphi_t A_t - W_t + \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \Omega_{t+1}^F}{\partial N_{t+1}} (1-\rho) \end{aligned}$$

Notice that from the first order condition with respect to vacancies:

$$\frac{\partial \Omega_t^F}{\partial N_t} = \frac{\kappa_t}{q_t}$$

Let Ω_t^H be the value function of the household in period t. The household's expected return from a job is given by the marginal value of employment[49]:

$$\begin{aligned} \frac{\partial \Omega_t^H}{\partial N_t} &= \lambda_t W_t - \varkappa + \beta \frac{\partial \Omega_{t+1}^H}{\partial N_{t+1}} \frac{\partial N_{t+1}}{\partial N_t} \\ &= \lambda_t W_t - \varkappa + \beta \frac{\partial \Omega_{t+1}^H}{\partial N_{t+1}} (1-\rho)(1-p_{t+1}) \end{aligned}$$

A realised job match yields a rent equal to the sum of the expected search costs of the firm and the worker. Let η denote the relative bargaining power of workers. The Nash real wage W_t is determined according to the maximization of the following Nash criterion where the surplus of each agent is given by the marginal value of unemployment (measured in terms of consumption goods):

$$w_t^n = \arg\max_{\{w_t\}} \left(\frac{\partial \Omega_t^H}{\lambda_t \partial N_t} \right)^\eta \left(\frac{\partial \Omega_t^F}{\partial N_t} \right)^{1-\eta}$$

The first order condition gives the following surplus sharing rule:

$$\eta \frac{\partial \Omega_t^F}{\partial N_t} = \eta \frac{\kappa_t}{q_t} = (1-\eta) \frac{\partial \Omega_t^H}{\lambda_t \partial N_t}$$

Iterating and multiplyng by $\frac{1}{\lambda_t}$, we get:

$$\frac{\lambda_{t+1} \partial \Omega_{t+1}^F}{\lambda_t \partial N_{t+1}} = \frac{\lambda_{t+1}}{\lambda_t} \frac{\kappa_{t+1}}{q_{t+1}} = \frac{(1-\eta)}{\eta} \left(\frac{\partial \Omega_{t+1}^H}{\lambda_t \partial N_{t+1}} \right)$$

[49] A worker that is employed at time t, has a probability $(1-\delta)$ of remaining employed the following period. Even if she loses the job, she has a probability p_t of immediately finding the job.

By combining this last expression with the expressions of the surpluses and the sharing rules we can derive the wage expression:

$$W_t = \frac{\varkappa}{\lambda_t} + \frac{\eta}{1-\eta}\frac{\kappa_t}{q_t} - \beta\left(1-\rho\right)\frac{\eta}{1-\eta}\frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}\left(1-p_{t+1}\right) \tag{16}$$

Notice that combining this expression with the optimal condition for vacancy posting (4), we get the equation pinning down the *equilibrium under Nash bargaining*:

$$\frac{\kappa_t}{q_t} = \left(1-\eta\right)\left(\varphi_t A_t - \frac{\varkappa}{\lambda_t}\right) + \beta\left(1-\rho\right)\frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}\left(1-\eta p_{t+1}\right)$$

Substituting back in the wage equation, we find the *equilibrium wage under flexible wages*:

$$W_t = \left(1-\eta\right)\frac{\varkappa}{\lambda_t} + \eta\varphi_t A_t + \eta\beta\left(1-\rho\right)\frac{\lambda_{t+1}}{\lambda_t}\frac{\kappa_{t+1}}{q_{t+1}}p_{t+1}$$

B The model in log-linearized form

The complete log-linearized model is described below, where variables with "hat" denote log-deviations from steady state variables, while variables without a time subscript denote steady state values.

- Euler equation:

$$\hat{c}_t - E_t\hat{c}_{t+1} = -\left[\hat{\imath}_t - E_t\hat{\pi}_{t+1}\right]$$

- Phillips curve:

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \lambda\hat{\varphi}_t$$

- Aggregate constraint:

$$-\frac{1}{N}\hat{u}_t = \frac{\bar{C}}{\bar{Y}}\left(1+\kappa v\right)\hat{c}_t + \frac{\kappa v\bar{C}}{\bar{Y}}\left(\hat{\theta}_t + \frac{(1-s)}{s}\frac{1}{N}\hat{u}_{t-1}\right) - \hat{a}_t$$

- Labor market tightness

$$\hat{\theta}_t = -\frac{1}{N}\frac{1}{\rho\left(1-\sigma\right)}\left\{\hat{u}_t - \left[(1-\rho)\frac{U}{s}\right]\hat{u}_{t-1}\right\} \tag{17}$$

- Marginal costs

$$\hat{\varphi}_t = \frac{W}{\varphi}\hat{w}_t^R + \left(1-\frac{W}{\varphi}\right)\hat{c}_t - \sigma\varpi\hat{\theta}_t + \beta\left(1-\rho\right)\sigma\varpi E_t\hat{\theta}_{t+1}$$

where $\varpi = \frac{\kappa}{q}\frac{\bar{C}}{\varphi}$ and $\varrho = (1-\beta\left(1-\rho\right))$.

- Nash Wages

$$\hat{w}_t^n = \hat{c}_t + \frac{\eta}{1-\eta}\frac{\varpi\varphi}{W}\left\{\sigma\hat{\theta}_t - \beta\left(1-\rho\right)\left[\sigma-p\right]\hat{\theta}_{t+1}\right\}$$

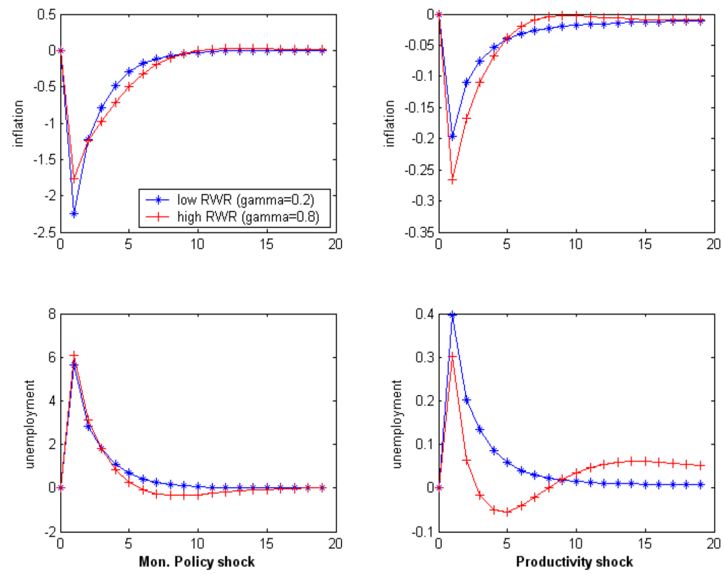
- Real wages

$$\hat{w}_t^R = \left(1-\gamma\right)\hat{w}_t^n + \gamma\hat{w}_{t-1}^R$$

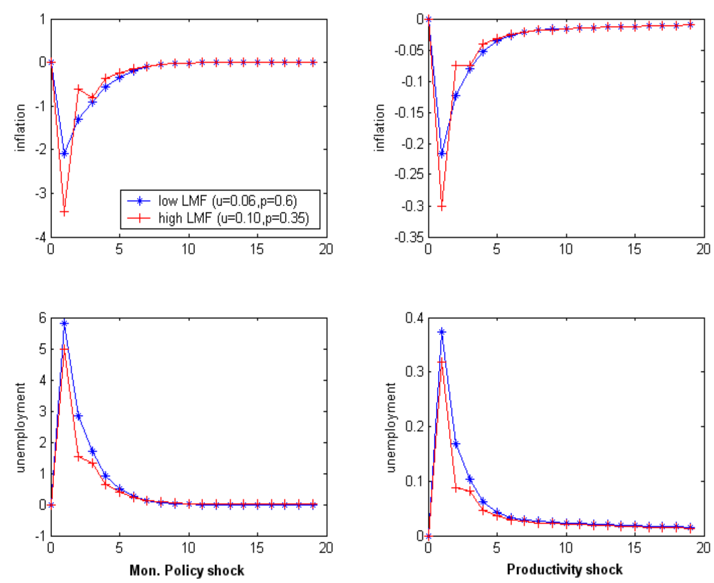
- Interest rate rule:

$$\hat{\imath}_t = \rho_m\hat{\imath}_{t-1} + \phi_\pi\left(1-\rho_m\right)\hat{\pi}_t + \phi_z\left(1-\rho_m\right)\left(\hat{y}_t - \hat{y}_t^n\right) + \varepsilon_t^m$$

C Impulse Responses



Monetary and productivity shocks for different degrees of real wage rigidities



Monetary and productivity shocks for different degrees of labor market frictions

D Data Description

Macroeconomic variables are all taken from the OECD Economic Outlook with the exception of the inflation rate which is computed using the consumer price index taken form the OECD Main Economic Indicators. Labour market indicators are taken from various sources. While the benefit duration measure and the measure of employment protection legislation are taken from Nickel et al (2001) and the updated values from Nickell (2003), the tax wedge and the composite benefit measure are taken from the OECD. The measure of centralization/coordination is taken from Kenworthy (2001). The composite benefit measure is defined as the average of the gross unemployment benefit replacement rates for two earnings levels, three family situations and three durations of unemployment. For further details, see The OECD Jobs Study (1994).

Data Sources and Definitions

Variable	Source	Unit	Description
Macro Account			
Real GDP	OECD Eco. Out.	Real value	-
Unempl. Rate	OECD Eco. Out.	Percent	-
Inflation	OECD MEI	Percent	CPI q-to-q change
Labor Prod.	OECD STAN	Index	-
Compensation Rate	OECD Eco. Out.	Value	private sector
Consumption	OECD Eco. Out.	Real value	-
Labor Mkt. Inst.			
EPL	Nickell (2001,2003)	Index	Range: 0-2
Benefit Duration	Nickell (2001)	Index	Range: 0-1
Benefits	OECD	Index	-
Centrlization	Kenworthy (2001)	Index	Range: 1-6
Taxes	OECD	Rate	For married, 2 children

The following table lists the estimated real wage rigidities. The real wage is measured by the deflated nominal compensation rate, using the CPI index.[50]

[50] Due to a lack of data we used in the case of Italy and Norway the wage rate instead of the compensation rate. This is unlikely to affect the comparison across estimate results since wage and compensation measure are nearly perfectly correleted, for those countries where data is available for both series.

	70-99	70-79	80-89	90-99
Australia	0.805	0.833	0.821	0.674
Canada	0.812	0.772	0.777	0.790
Finland	0.832	0.357	0.812	0.695
France	0.609	0.591	0.292	0.575
Germany	0.543	0.424	0.585	0.509
Ireland	0.832	n.a.	0.833	0.811
Italy	0.658	0.704	0.347	0.643
Japan	0.603	0.453	0.290	0.501
Netherlands	0.709	0.574	0.386	0.426
Norway	0.545	n.a.	0.308*	0.746
Sweden	0.834	0.904	0.903	0.676
UK	0.547	0.551	0.262	0.549
USA	0.826	0.747	0.853	0.654

* Not significant

Using rolling regression techniques we singled out outliers and adjusted the respective countries' series by accounting for these outliers in the estimation.

E Correlations

E.1 Volatilities in the sub-periods

Volatility	Quantity		Prices					
1970-79	Model	Data	Model	Data				
Institution	ρ	EPL	MRS, η	RWR	BD	BEN	TAX	DEC
UR	-	-0.51	+	0.11	0.21	0.08	-	0.27
GDP	-	-0.05	+	-0.26	-0.07	-0.26	-	0.13
INFL	+	0.17	-	-0.07	-0.25	-0.47	-	0.02
Trade-off	+	0.36	-	-0.25	-0.43	-0.45	-	-0.30

Volatility	Quantity		Prices					
1980-89	Model	Data	Model	Data				
Institution	ρ	EPL	MRS, η	RWR	BD	BEN	TAX	DEC
UR	-	-0.45	+	0.39	0.47	0.37	-0.01	0.33
GDP	-	-0.39	+	0.36	0.38	0.04	-0.25	0.01
INFL	+	-0.04	-	0.13	0.20	-0.14	-0.30	0.23
Trade-off	+	0.24	-	-0.36	-0.39	-0.41	-0.33	-0.28

Volatility	Quantity		Prices					
1990-99	Model	Data	Model	Data				
Institution	ρ	EPL	MRS, η	RWR	BD	BEN	TAX	DEC
UR	-	-0.44	+	0.59	0.33	-0.06	-0.09	0.43
GDP	-	-0.27	+	0.54	-0.06	-0.58	-0.40	0.23
INFL	+	-0.14	-	0.38	-0.06	-0.38	-0.17	0.29
Trade-off	+	0.35	-	-0.29	-0.45	-0.43	-0.26	-0.31

E.2 Persistence

Persistence(ς)	Quantity		Prices					
1970-99	Model	Data	Model	Data				
Institution	ρ	EPL	MRS, η	RWR	BD	BEN	TAX	DEC
UR	-	0.04	-	-0.41	0.18	0.31	0.25	-0.43
GDP*	+	0.05	-	0.02	-0.27	-0.09	0.07	0.04
INFL	-	0.03	+	0.01	0.07	0.22	0.36	0.46
Trade-off	-	0.01	+	0.11	0.02	0.13	0.29	0.54

*Measured using the HP filtered series using 4 lags and no dummies.

E.3 Cyclical Measures

Cycle	Quantity		Prices					
UR	Model	Data	Model	Data				
	ρ	EPL	MRS, η	RWR	BD	BEN	TAX	DEC
ADPP	+	0.25	-	-0.10	-0.25	0.18	0.68	0.40
ADTT	+	0.16	-	-0.14	-0.19	0.20	0.53	0.47
GRRATETP	-	-0.32	+	0.41	-0.04	-0.05	-0.34	-0.10
GRRATEPT	-	-0.35	+	0.27	0.18	0.13	-0.28	0.03

Cycle	Quantity		Prices					
Employment	Model	Data	Model	Data				
	ρ	EPL	MRS, η	RWR	BD	BEN	TAX	DEC
ADPP	+	0.19	-	-0.14	-0.15	0.32	0.13	-0.17
ADTT	+	0.01	-	-0.14	-0.17	0.14	-0.09	-0.18
GRRATETP	-	-0.24	+	0.59	0.01	-0.11	-0.34	0.52
GRRATEPT	-	-0.48	+	-0.57	0.02	-0.01	-0.35	0.54

E.4 Estimation Results

E.4.1 Regression Approach for Persistence (ι)

Dependent Variable (Trade-off_P)

Variable	1	2	3	4	5
EPL	-0.04	-0.04	-0.02	0.01	0.04
	(0.38)	(0.34)	(0.69)	(0.87)	(0.39)
BD	0.03				
	(0.61)				
BEN		-0.01			
		(0.45)			
TAX			-0.00		
			(0.91)		
$\widehat{RWR}$				0.20	
				(0.17)	
DEC					0.05
					(0.01)
Const.	0.6	0.68	0.61	0.48	0.40
	(0.00)	(0.00)	(0.00)	(0.10)	(0.00)
Overall R^2	0.02	0.05	0.01	0.05	0.05
Obs.	58	58	37	35	52

p-values in parenthesis

E.4.2 Regression Approach for Volatility

Dependent Variable (Unempl. Rate)

Variable	A1	A2	A3	A4	A5
EPL	-0.19	-0.23	-0.24	-0.24	-0.22
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
BD	0.17				
	(0.08)				
BEN		0.01			
		(0.05)			
TAX			0.01		
			(0.09)		
RWR				0.16	
				(0.46)	
DEC					0.02
					(0.53)
Const.	0.63	0.63	0.54	0.67	0.64
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Overall R^2	0.26	0.25	0.26	0.36	0.22
Obs.	58	58	37	35	52

p-values in parenthesis

Dependent Variable (Unempl. Rate)

Variable	A6	A7	A8	A9	A10
Index BD	0.27				
	(0.00)				
Index BEN		0.45			
		(0.00)			
Index TAX			0.40		
			(0.00)		
Index RWR				0.28	
				(0.00)	
Index DEC					0.21
					(0.00)
Const.	0.23	0.06	0.04	0.17	0.24
	(0.00)	(0.53)	(0.73)	(0.11)	(0.00)
Overall R^2	0.21	0.23	0.21	0.35	0.18
Obs.	58	58	37	35	52

p-values in parenthesis

Dependent Variable (Inflation)

Variable	B1	B2	B3	B4	B5
EPL	0.01	0.03	0.05	-0.05	-0.02
	(0.83)	(0.61)	(0.60)	(0.49)	(0.70)
BD	-0.03				
	(0.78)				
BEN		-0.01			
		(0.02)			
TAX			-0.01		
			(0.15)		
RWR				0.00	
				(0.98)	
DEC					0.02
					(0.47)
Const.	0.47	0.60	0.52	0.49	0.41
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Overall R^2	0.01	0.17	0.06	0.01	0.00
Obs.	58	58	37	35	52

p-values in parenthesis

E.5 Predicted Value Representation for RWR