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Asymmetric Labor Market Institutions in the EMU: Positive and Normative Implications

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Asymmetric Labor Market Institutions in the EMU: Positive and Normative Implications*

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1 Introduction

Inflation and output growth differentials are a big concern for policy-makers. Recent empirical evidence shows that inflation and output growth differentials among Euro Area countries - even when compared with the ones arising among different States in the US - are rather sizeable and very persistent over time. This evidence has attracted substantial public attention, because it suggests that the adjustment mechanism in the single currency area may not be working efficiently. Indeed, as emphasized by Angeloni and Ehrmann (2004), the importance of these issues "can hardly be overemphasized, given the frequently voiced concern that heterogeneity dents the solidity of the monetary union itself"[1].

Labor market rigidities are often blamed as one of the potential causes behind the inefficient and asymmetric adjustment of member countries to economic shocks. The received wisdom is that there is a "need for more flexible labor markets in the context of the EU, particularly at the national and regional levels" (ECB Monthly Bullettin, May 2005, p. 71) without specifying what labor market flexibility means. Moreover, little work has been done, in the context of DSGE models, to analyze how asymmetric labor market institutions affect the functioning of the currency area.

The aim of the present paper is to analyze how asymmetric labor market institutions affect the volatility of inflation and unemployment differentials in a currency union and to determine the implications of these asymmetries for optimal monetary policy. For this purpose, we set up a DSGE currency union model that combines three key ingredients: (i) monopolistic competition and nominal rigidities in the goods market, which serve to give a role to monetary policy; (ii) hiring frictions in the labor market, which generate involuntary unemployment; (iii) real wage rigidities, which hinder wage adjustments and shift the labor market adjustment from prices to quantities.

Table 1 shows labor market indicators for selected countries. On average, Euro Area countries are characterized by heavily regulated labor markets, generous unemployment benefit systems and high unemployment. Looking only at the averages, however, can be misleading. Labor market institutions vary considerably across member countries. In 2006, the unemployment rate was 4% in Ireland compared to around 9% in France and Spain. Employment protection legislation is extremely tight in countries like Italy, Portugal, France and Spain, but very loose in Ireland.

[1] Angeloni and Ehrmann (2004), p. 6. See, e.g., ECB (2003, 2005), Angeloni and Ehrmann (2004), Benalal et al. (2006) for some evidence on inflation and output differentials and for analyses of the potential causes and policy implications.

Table 1. Labor Market Characteristics of Selected Euro Area Countries

	EPL	Wage Flexibility	Union Density	Benefit repl. rate	Unempl. rate
Austria	1.10	1.43	36.5	32.2	5.7
Belgium	1.00	0.65	55.6	38.7	8.5
France	1.40	2.22	9.7	40.2	9.4
Germany	1.30	0.55	25.0	28.2	8.4
Ireland	0.50	0.8	37.8	32.5	4.4
Italy	1.50	2.07	34.9	34.3	7.2
Netherlands	1.10	0.66	23.2	52.5	4.8
Portugal	1.70	n.a.	23.5	42.9	7.8
Spain	1.40	0.17	13.9	37.1	8.7
Av. Euro Area	*1.22*	*1.07*	*28.9*	*37.6*	*8.2*
UK	0.35	0.98	31.2	16.6	5.2
USA	0.10	0.32	12.8	13.5	4.7
Japan	1.40	n.a.	21.5	10.7	4.2
Av. Others	*0.62*	*0.65*	*21.8*	*13.6*	*4.7*

Notes: Labor market indicators are taken from various sources. EPL refers to the employment protection legislation measure (0,2) as constructed by Nickell et al. (2001). Wage flexibility represents the percentage increase in wages in response to a one percentage point fall in the unemployment rate (source: Nickell 1997). Union density, benefit replacement rates and unemployment rates are taken from the OECD. The benefit replacement rate is defined as the average of the gross replacement rates over two earnings levels, three family types and three unemployment durations. The unemployment rate refers to 2006Q1. The other data refers to the last date available in the datasets of Nickell 2001 or the OECD (1998 for EPL, 2000 for union density and the benefit measure).

Wage flexibility (measured as the percentage increase in wages in response to a 1 percent decrease in the unemployment rate) in France and Italy is much higher than in Spain and in Germany[2]. Large heterogeneity is also present in the degree of unionization and in the generosity of the unemployment benefit system.

A few currency union models have been proposed in recent years (see, among others, Benigno, 2004, Galí and Monacelli, 2008, Benigno and Lopez-Salido, 2002, Altissimo, Benigno and Palenzuela, 2005). The literature has focused on the implications of different degrees of nominal rigidities in member countries. The main result is that, when asymmetries in the degree of price stickiness are present, an inflation targeting strategy that gives higher weight to inflation in the "sticky price" region is nearly optimal (Benigno, 2004). Most of these works assume perfectly competitive labor markets and thus ignore a fundamental source of asymmetry among member

[2] The fact that some countries like Italy and France show large degrees of real wage flexibility might be surprising, but one should keep in mind that the link between nominal and real wage rigidity is non-trivial and depends on the underlying wage setting mechanism. For example, in countries with high degrees of price indexation, real wages are relatively sticky.

countries, namely the wide heterogeneity in European labor market institutions.

Campolmi and Faia (2008) are the first to integrate labor markets frictions "à la Mortensen-Pissarides" into a DSGE currency union model. Their paper, which studies the link between inflation volatility differentials and different unemployment insurance coverage, represents an important first step towards an understanding of how the transmission mechanism of monetary policy works in the presence of asymmetries in the structure of labor markets[3].

Following Blanchard and Galí (2008), we model labor market frictions by assuming the presence of hiring costs, which increase in the degree of labor market tightness. Real wage rigidities are introduced, following much of the literature, by employing a version of Hall's (2005) notion of the wage norm. The model provides a rigorous framework for the analysis of the functioning of a currency union characterized by asymmetric labor market institutions. We use the model for three different purposes.

First, we analyze how different labor market structures influence the Phillips curves of member countries. We distinguish among two types of labor market imperfections: unemployment rigidities (UR), which capture the institutions - such as employment protection legislation, hiring costs and the matching technology - that limit the flows in and out of unemployment; and real wage rigidities (RWR), intended to capture the institutions which influence the responsiveness of real wages to economic activity. These two types of labor market rigidities are found to have very different effects on the incentives for firms to reset prices and thus on the Phillips curve. Unemployment rigidities make the Phillips curve steeper. This effect is strong and non-linear. Real wage rigidities make the Phillips curve flatter, as inflation becomes less sensitive to unemployment changes[4]. Moreover, as in Blanchard and Galí (2007, 2008) real wage rigidities create a trade-off for monetary policy between inflation stabilization and unemployment stabilization.

Second, we study how different labor market structures affect the adjustment of member countries to monetary and productivity shocks. The main focus is on

[3] Other contributions related to our paper include Andersen and Seneca (2007), Poilly and Sahuc (2007), Dellas and Tavlas (2004) and Fahr and Smets (2008). Andersen and Seneca (2007) discuss the effects of asymmetric size, market power and nominal wage rigidities for aggregate volatilities. Dellas and Tavlas (2004) and Poilly and Sahuc (2007) study respectively the implications of asymmetries for the costs of membership in a currency union and the implications of labor market reforms on the welfare of member countries in the presence of labor market asymmetries. Fahr and Smets (2008) analyse the implications of downward wage rigidities for optimal monetary policy in a currency area.

[4] In a related paper, Abbritti and Weber (2008) find empirical support for these findings.

the evolution of inflation and unemployment differentials, as these reflect the way in which economic disturbances are absorbed in the currency union. We find that labor market rigidities have a strong impact on the functioning of the currency union. Unemployment rigidities make it more costly for firms to hire new workers and shift the adjustment from quantities to prices. A higher degree of UR thus increases the volatility of inflation differentials but reduces the volatility of unemployment differentials. Real wage rigidities, which shift the adjustment from labor prices to labor quantities, substantially increase the volatility of unemployment differentials whereas they have little impact on the volatility of inflation differentials.

We also find that labor market asymmetries matter: asymmetries in UR and RWR increase both the volatility of inflation and unemployment differentials. This suggests that asymmetric labor market structures worsen the adjustment mechanism of a currency union to symmetric and asymmetric shocks.

Third, we investigate the implications of asymmetric labor market structures for monetary policy and welfare. First, we find that monetary policy should give a negligible weight to unemployment. Then we ask whether in the presence of labor market asymmetries the central bank should respond to inflation differentials and find that the central bank should give a higher weight to inflation in the region with *more sclerotic* labor markets but with *more flexible* real wages.

The remainder of the paper is organized as follows. Sections 2-5 describe the model. Section 6 studies how the New Keynesian Phillips curve changes with the labor market structure. Section 7 studies the positive behavior of the model under different calibrations. Section 8 carries out the normative analysis and Section 9 concludes.

2 The Model

A currency union is a group of regions or countries sharing the same currency, with a single central bank entitled to conduct monetary policy. To keep things simple, we consider a currency union consisting of two regions, Home and Foreign, of the same size (normalized to 1). Each economy, which is populated by identical, infinitively lived households, is specialized in the production of a bundle of differentiated goods. Production of these goods takes place in two sectors. Wholesale firms produce intermediate goods in competitive markets and sell their output to monopolistic retailers. Retailers transform the intermediate goods into final goods and sell them to the households. The labor market is characterized by hiring costs, leading to involuntary unemployment in equilibrium. Price rigidities arise at the retail level, while hiring frictions in the intermediate goods sector. There is no migration across regions. Capital markets are complete. Wages are set in individual bargaining between the employer and the employee. Countries are symmetric for everything apart from labor market institutions[5].

2.1 Households

The representative household within a country is thought of as a large extended family with names on the unit interval. In equilibrium, some members will be employed and others not; to abstract from distributional issues, we assume that households pool their income and consumption.

The representative household in country i ($i = H$ or F) maximizes a standard lifetime utility, which depends on the household's consumption and disutility of work:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log C_t - \chi \frac{\left(N_t^H\right)^{1+\phi}}{1+\phi} \right\}, \quad E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log C_t^* - \chi^* \frac{\left(N_t^F\right)^{1+\phi}}{1+\phi} \right\} \tag{1}$$

where variables with star refer to the foreign country. N_t^i denotes the number of employed individuals in the representative household of country i while C_t and C_t^* are the composite consumption indexes for the home and foreign country respectively, defined as:

$$C_t = \frac{\left(C_t^H\right)^{1-\alpha} \left(C_t^F\right)^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}, \quad C_t^* = \frac{\left(C_t^{F,*}\right)^{1-\alpha} \left(C_t^{H,*}\right)^{\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \tag{2}$$

$C_t^{j,i}$, the quantity of the good produced in country j and consumed by residents of country i, is given by the usual CES aggregator. The parameter $\epsilon > 1$ denotes the elasticity of substitution between varieties produced within a given country. $\alpha \in [0, 1]$ is the weight on the imported goods in the utility of private consumption; a value for α strictly less than $\frac{1}{2}$ reflects the presence of home bias in consumption.

Utility maximization for the Home household is subject to a sequence of budget constraints which, conditional on optimal allocation of expenditures across varieties,

[5] The basic framework of the currency union is inspired by the work of Benigno (2004) and Galí and Monacelli (2008). The structure of the labor market builds on Blanchard and Galí (2008). The complete derivation of the model is described in Appendix A and B, which are available on the authors' webpage.

is given by[6]:

$$P_t C_t + E_t Q_{t,t+1} V_{t+1}^H \leq V_t^H + W_t^H N_t^H + \Pi_t^H - T_t^H$$

where $P_t = \left(P_t^H\right)^{1-\alpha} \left(P_t^F\right)^{\alpha}$ is the home CPI index, V_t^H is the nominal payoff in period t of the portfolio held at the end of period $t-1$ and $Q_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs, which is common across countries. W_t^H is the nominal wage, T_t^H denotes lump-sum taxes and Π_t^H the profits received by the Home household, which are the sum of the dividends derived from retailers. P_t^H and P_t^F are the Dixit-Stiglitz domestic price indexes of the Home and Foreign countries. Since the law of one price holds, P_t^H represents both the domestic price index at Home as well as the price index of the Home goods imported by Foreign.

Similar conditions hold for the Foreign country.

2.2 The Terms of Trade and the Real Exchange Rate

We define the bilateral terms of trade between the Home and Foreign country as:

$$S_t = \frac{P_t^F}{P_t^H} \tag{3}$$

The terms of trade, which represent an index of competitiveness, play a central role in our model. Movements in the terms of trade are crucial for understanding the response of the economy to asymmetric shocks and the transmission mechanism of monetary policy.

As the law of one price holds for all goods - which implies $P_t^F = P_t^{F,*}$ and $P_t^H = P_t^{H,*}$ - the *CPI* and the *domestic* price indexes in the two regions are related according to:

$$P_t = P_t^H \left(S_t\right)^{\alpha}, \quad P_t^* = P_t^F \left(S_t\right)^{-\alpha}$$

The real exchange rate RER_t is defined as the ratio between foreign and home CPIs and is related to the terms of trade according to:

$$RER_t = \frac{P_t^*}{P_t} = \left(S_t\right)^{1-2\alpha}$$

[6]Implicit in the budget constraint is the assumption that the law of one price holds across the union.

2.3 International Risk Sharing

Capital markets are complete: each household has access to a complete set of contingent claims, traded internationally. Combining the first order conditions relative to state contingent securities in the two countries, we obtain the usual result:

$$RER_t = \psi \frac{u'(C_t^*)}{u'(C_t)} = \psi \frac{C_t}{C_t^*} \tag{4}$$

where $\psi = RER_0 \frac{u'(C_0^*)}{u'(C_0)}$ is a constant, reflecting initial conditions regarding relative net asset positions. If PPP holds - i.e. for $\alpha = 1/2$ -, the real exchange rate $RER_t = 1$ and the marginal utilities of consumption are equated up to a constant ψ. On the contrary, when home bias is present, $\alpha < 1/2$ and movements in the real exchange rate are reflected in different consumption rates. Henceforth, to keep the analysis as simple as possible, we assume initial conditions are such that $\psi = 1$.

2.4 Supply Side

The setup of the supply side of the two countries follows Blanchard and Galí (2008). There are two sectors of production in each economy. Firms in the wholesale sector are perfectly competitive and produce a homogeneous intermediate good using labor as the only input. This output is sold to retailers who are monopolistically competitive. Retailers then transform the homogeneous goods one for one into differentiated goods at no cost.

2.4.1 Wholesale Firms and the Labor Market

The wholesale sector in each country is composed of a continuum of firms, indexed by $j \in [0, 1]$. Each firm produces a homogeneous intermediate good $X_t^i(j)$ with an identical CRS technology:

$$X_t^i(j) = A_t^i N_t^i(j), \ for \ i = H, F(^*)$$

where the variables A_t^i represent the state of technology in country i.

In each period a fraction δ^i of the employed loses their job and joins the unemployment pool. Employment in firm j evolves according to

$$N_t^i(j) = (1 - \delta^i) N_{t-1}^i(j) + h_t^i(j), \ for \ i = H, F(^*)$$

where $h_t^i(j)$ is the number of new hires for firm j in country i.

At the aggregate level, employment $N_t^i \equiv \int_0^1 N_t^i(j)dj$ is given by:

$$N_t^i = (1-\delta^i)N_{t-1}^i + h_t^i$$

where $h_t^i \equiv \int_0^1 h_t^i(j)dj$ denotes the aggregate hiring level.

We assume all unemployed in the family look for a job. The analysis thus abstracts from any transition of people in and out the labor force, which we assume to be constant and equal to 1. The number of searching workers who are available for hire in country i, U_t^i, is defined as

$$U_t^i = 1-(1-\delta^i)N_{t-1}^i, \ \ for \ i = H, F(^*)$$

while we define unemployment as the fraction of the population who are left without a job after hiring takes place, $u_t^i = 1 - N_t^i$.

Labor market frictions are introduced by assuming that hiring labor is costly. Total hiring costs for a firm in country i are given by $G_t^i h_t^i(j)$ where G_t^i, the cost per hire in country i, is taken as given by the individual firm[7].

Following Blanchard and Galí (2008), we define the labor market tightness index as the ratio of aggregate hires to the number of searching individuals, $x_t^i \equiv \frac{h_t^i}{U_t^i}$, and we assume that recruitment costs are an increasing function of the labor market tightness index:

$$G_t^i = A_t^i B^i \left(x_t^i\right)^{\varphi}, \ \ for \ i = H, F(^*)$$

where $\varphi > 0$ and B^i is a positive constant. This specification of hiring costs leads to labor market frictions which are very similar to the ones obtained in the standard search and matching model[8].

The labor market tightness index will be a crucial variable in our analysis. Since by assumption firms can hire workers only from the pool of unemployed, $x_t^i \in [0, 1]$. Note that, while from the viewpoint of firms the tightness index captures the conditions of the labor market, from the viewpoint of the unemployed it can be interpreted as the probability of finding a new job in period t, i.e. as the job-finding rate. In the following we use the terms labor market tightness and job-finding rate interchangeably.

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[7] G_t^i is expressed in terms of the domestic CES bundle of goods.

[8] See Blanchard and Galí (2008), p.7. In the standard Diamond-Mortensen-Pissarides model the expected hiring cost is equal to the cost of posting a vacancy times the expected time to fill it. This expected time is an increasing function of the ratio of vacancy to unemployment, which can also be expressed as a function of labor market tightness.

The intermediate good produced at Home is sold to Home retailers at relative price $\mu_t^H = \frac{P_{I,t}}{P_t^H}$, with $P_{I,t}$ being the nominal price of the intermediate good. Profit maximization gives the first order condition:

$$\mu_t^H A_t^H = W_t^{H,R} (S_t)^\alpha + G_t^H - (1-\delta) E_t \left\{ \beta_{t,t+1} G_{t+1}^H \right\} \tag{5}$$

where $\beta_{t,t+1} = \beta \frac{C_t (S_t)^\alpha}{C_{t+1}(S_{t+1})^\alpha}$ and where $W_t^{H,R} = \frac{W_t^H}{P_t}$ is the real wage expressed in terms of the consumption good. Equation (5) states that the real marginal revenue product of labor (the left-hand side) has to equal its real marginal cost, that now includes not only real wages but also a component associated with hiring costs. This new component is composed of two terms. The first, G_t^H, represents the additional cost the firm faces to hire a new worker; the second - the last term in (5) - reflects the savings in future hiring costs resulting from increasing the number of employees today. Given the presence of these two additional terms, the cyclical behavior of marginal costs in a model with labor market frictions can depart substantially from that of real wages[9].

2.4.2 Wage Determination

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

Let η denote the relative weight of workers in the Nash bargaining for the home country[10]. It can be shown (see the Appendix A for details) that the *Nash wage schedule for home* is given by:

$$W_t^{H,Nash} (S_t)^\alpha = MRS_t + \eta \left\{ G_t^H - (1-\delta) E_t \left\{ \beta_{t,t+1} \left[(1 - x_{t+1}^H) G_{t+1}^H \right] \right\} \right\} \tag{6}$$

where $W_t^{H,Nash}$ denotes the Nash bargained wage (in real terms) and $MRS_t = \chi C_t (S_t)^\alpha \left(N_t^H\right)^\phi$ denotes the marginal rates of substitution between consumption

[9] See Krause and Lubik (2007).

[10] If we denote by ζ the relative bargaining power of workers, it is easy to show that

$$\eta = \frac{\zeta}{1-\zeta}$$

and leisure[11].

Intuitively, the Nash wage depends on the reservation wage (here given by the the marginal rate of substitution between leisure and consumption, MRS_t) plus a "wage premium", which depends on the size of the rents for existing employment relationships (the term in curled brackets) and on the workers' relative share of the surplus, η.

2.4.3 Introducing Real Wage Rigidities

As first emphasized by Hall (2005) and Shimer (2005), the introduction of real wage rigidities considerably improves the performance of the matching models in terms of the dynamics of the labor market. The Nash bargained wage implies in fact a real wage volatility which is too high relative to empirical evidence. As a consequence, the standard matching model finds it difficult to replicate the response of labor market variables - and in particular unemployment - to productivity shocks. This issue is especially important for the euro area, which is characterized by a considerable degree of wage rigidity[12].

To solve this problem, we follow much of the literature and 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 $W_t^{H,R}$ is a weighted average of the desired wage (the Nash bargained wage $W_t^{H,Nash}$) and a wage norm $\bar{W}^H$, which is assumed to be the wage prevailing in steady state. Specifically, we assume the real wage is determined as follows:

$$W_t^{H,R} = \left(W_t^{H,Nash}\right)^{1-\gamma} \left(\bar{W}^H\right)^{\gamma}, \quad W_t^{F,R} = \left(W_t^{F,Nash}\right)^{1-\gamma^*} \left(\bar{W}^F\right)^{\gamma^*} \qquad (7)$$

where γ^i is an index of the real wage rigidities present in the economy, with $0 \leq \gamma^i \leq 1$. As shown by Hall (2005), this wage rule remains within the range defined by the bargaining set and thus is robust to the Barro (1977) critique.

[11] The terms of trade appear in the expression for MRS_t because here everything is expressed in units of the domestic price index P_t^H.

[12] See e.g. Dickens et al. (2007) and Du Caju et al. (2008) for some evidence on nominal and real wage rigidity in the euro area.

2.4.4 Final Goods Sector

In each country 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:

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

Retailers share the same technology, which transforms one unit of wholesale goods into one unit of retail goods, so that $Y_t(z) = X_t(z)$. Firms in the retail sector purchase intermediate goods from wholesale producers at price μ_t^H and convert it into a differentiated final good sold to households and wholesale firms. Notice that the relative price of the intermediate goods μ_t^H represents the marginal cost for the final good's producers.

We introduce nominal price rigidity using the formalism à la Calvo (1983). Each period, firms may reset their prices with a probability $1-\theta$ (independent of the time elapsed since the last revision of prices). Log-linearizing around a zero inflation steady state the optimal price setting rule and the price index equation $P_t^H = \left[(1-\theta)(\tilde{P}_t^H)^{1-\epsilon} + \theta(P_{t-1}^H)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$, we get the New Keynesian Phillips curve:

$$\hat{\pi}_t^H = \beta E_t \hat{\pi}_{t+1}^H + \lambda \widehat{mc}_t^H \tag{8}$$

where $\hat{\pi}_t^H$ is domestic (i.e. producer prices') inflation, $\widehat{mc}_t^H = \hat{\mu}_t^H$ represents the log deviation of real marginal cost from its steady state value and $\lambda = (1-\beta\theta)(1-\theta)/\theta$. 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 equation (5) we can rewrite marginal costs as:

$$\widehat{mc}_t^H = \frac{W(S)^\alpha}{\mu}\left(\hat{w}_t^{H,R} + \alpha\hat{s}_t - \hat{a}_t^H\right) + \frac{g\varphi}{\mu}\hat{x}_t^H - \beta(1-\delta)\frac{g}{\mu}E_t\left\{\hat{\beta}_{t,t+1} + \Delta a_{t+1}^H + \varphi\hat{x}_{t+1}^H\right\} \tag{9}$$

where variables with hat denote log-deviations from steady state, variables without subscript steady state values, $\mu = \frac{\epsilon-1}{\epsilon}$ is equal to the inverse of the mark-up of retailers and g is the steady state value of unit hiring costs G_t^H. Marginal costs depend not only on the evolution of real wages, terms of trade and productivity, as in the standard New Keynesian model; they also depend on current labor market conditions (x_t^H) and on the future labor market conditions, as captured by the last term on the right-hand side.

Moreover, the dynamics of real wages depend on the degree of rigidity γ and on the evolution of Nash wages:

$$\hat{w}_t^{H,R} = (1-\gamma)\,\hat{w}_t^{H,Nash} \tag{10}$$

where, as shown in equation (6), the Nash wage depends on the marginal rate of substitution between leisure and consumption, on the workers' bargaining power and on labor market tightness.

Through these two channels, the introduction of hiring costs and real wage rigidities substantially changes the dynamics of the marginal costs, which in turn influence the firms' optimal price setting and the inflation dynamics.

2.4.5 Market Clearing

Final output may either be transformed in the composite consumption good or used in hiring. The clearing of all markets implies, for the home and foreign country respectively,

$$Y_t - G_t^H h_t^H = C_t (S_t)^{\alpha} D_t^H; \quad Y_t^* - G_t^F h_t^F = C_t^* (S_t)^{-\alpha} D_t^F$$

where $D_t^H \equiv \int_0^1 \left(\frac{P_t^H(z)}{P_t^H}\right)^{-\epsilon} dz$ and $D_t^F \equiv \int_0^1 \left(\frac{P_t^F(z)}{P_t^F}\right)^{-\epsilon} dz$. Notice that the assumption of Cobb-Douglas preferences over the home and foreign goods allows us to derive a simple relation between the terms of trade and relative output:

$$S_t = \frac{P_t^F}{P_t^H} = \frac{Y_t - G_t^H h_t^H}{Y_t^* - G_t^F h_t^F} \frac{D_t^F}{D_t^H} \tag{11}$$

3 The Efficient and the Flexible Price Equilibria

In this section we briefly characterize the constrained efficient allocation and the decentralized equilibrium arising when prices are flexible. This will permit to get further intuition on the functioning of the currency union and on the role played by each market imperfection in shaping our equilibrium dynamics.

3.1 The Constrained Efficient Allocation

The constrained efficient allocation, which is the benchmark relative to which monetary outcomes will be evaluated, is found by assuming that the social planner maximizes the welfare of the union, taking as given the technological constraints and the labor market frictions that are present in the decentralized economy. The solution of the social planner's problem leads to the following result, which is further explained in the appendix.

Proposition 1 *Employment is invariant to productivity shocks under the constrained efficient allocation.*

Proof. See Appendix A2. ■

As in Blanchard and Galí (2008), this invariance is a consequence of the assumption of a log utility function, which implies offsetting income and substitution effects on the labor supply. The fact that employment is constant is a useful result, as it implies that all fluctuations in employment are inefficient.

3.2 Equilibrium under Flexible Prices

Under flexible prices, profit maximization by final goods firms requires $P_t^H = \frac{\epsilon}{\epsilon-1} P_{I,t}$ for all t, where $\frac{\epsilon}{\epsilon-1}$ is the optimal gross mark-up. Solving the model under this condition, we need to distinguish two cases. First, consider the case in which there are no real wage rigidities (i.e. $\gamma = \gamma^* = 0$). In this case, the following proposition holds:

Proposition 2 *Under flexible prices and no real wage rigidities, employment is invariant to productivity shocks. The decentralized equilibrium corresponds to the constrained efficient equilibrium only if two conditions are satisfied: 1. The Hosios condition holds, i.e. $\varphi = \eta$; 2. Monopolistic distortions in the final goods market are eliminated through a production subsidy.*

Proof. See Appendix A3. ■

Blanchard and Galí (2008) obtain the same result in a closed economy model. This invariance is again a consequence of the log utility assumption, which implies that the wage at home moves one for one with $A_t^H (S_t)^{-\alpha}$. Notice also that since the employment level is constant at home and abroad, the terms of trade S_t vary proportionally to $\frac{A_t^H}{A_t^F}$. Under flexible prices and wages, asymmetric productivity shocks at home or at foreign are neutralized by changes in the wage rates and thus do not affect the firms' incentives to hire people; as a result, unemployment and labor market tightness are unchanged.[13]

On the contrary, when real wage rigidities are present wages do not move enough to absorb the impact of technology shocks. As a result, in a decentralized equilibrium with sticky wages, employment and the labor market tightness will *not* be constant.

4 Equilibrium under Sticky Prices

If prices are sticky, monetary policy matters. In a closed economy model, the presence of staggered price setting leads to an inefficient dispersion of output across varieties. In an open economy model, price stickiness creates an additional source of distortion: as prices are not free to adjust, the terms of trade follow an inefficient path in response to asymmetric disturbances[14]. In this model, two new elements deeply affect the economy: hiring frictions and real wage rigidities. In the following we show that these elements matter substantially for the dynamic behavior of the economy and, in particular, for the transmission mechanism of monetary policy.

The model is rich, but still relatively tractable, as it can be closed in eight equations. Let denote with $\hat{X}$ the deviation of a variable X from its steady state value, and let us define union-wide variables as $\hat{x}_t^U = \frac{\hat{x}_t^H + \hat{x}_t^F}{2}$. The demand side of the model is standard. The evolution of aggregate consumption at the union level is captured by the union-wide IS equation:

$$\hat{c}_t^U = E_t(\hat{c}_{t+1}^U) - (\hat{\imath}_t - E_t \hat{\pi}_{t+1}^U) \tag{12}$$

where $\hat{\pi}_t^U$ is union-wide inflation and $\hat{\imath}_t$ the common nominal interest rate. While the real interest rate affects aggregate consumption, terms of trade movements distribute production among the two countries and explain consumption differentials:

$$\hat{c}_t - \hat{c}_t^* = (1 - 2\alpha)\, \hat{s}_t \tag{13}$$

[13]It is interesting to note that inflation is not constant under the efficient allocation. Indeed, it can be shown that inflation differentials evolve according to

$$\bar{\pi}_t^F - \bar{\pi}_t^H = \Delta \hat{a}_t^H - \Delta \hat{a}_t^F$$

Notice, however, that relative price adjustments are not necessarily desirable under sticky prices, since inflation creates an inefficient dispersion of output across varieties.

[14]In an open economy model, this problem has typically a (at least partial) solution: the exchange rate. Movements in the exchange rate in fact may provide some additional flexibility to the terms of trade. This instrument, however, is absent in a monetary union. See, for instance, Benigno (2004) and Pappa (2004) for a discussion of the welfare properties of monetary unions.

Denoting with $\hat{u}_t^i = u_t^i - u^i$ the deviations of unemploment from its steady state level u^i and using the approximation $\hat{u}_t^i = -(1-u^i)\,\hat{n}_t^i$, the market clearing conditions can be expressed as:

$$\hat{c}_t = \hat{a}_t^H - \frac{\tau_0}{1-u^H}\hat{u}_t^H - \frac{\tau_1}{1-u^H}\hat{u}_{t-1}^H - \alpha\hat{s}_t \tag{14}$$

$$\hat{c}_t^* = \hat{a}_t^F - \frac{\tau_0^*}{1-u^F}\hat{u}_t^F - \frac{\tau_1^*}{1-u^F}\hat{u}_{t-1}^F + \alpha\hat{s}_t \tag{15}$$

where $\tau_0^i = \frac{1-g^i\left(1+\varphi^i\right)}{1-\delta^i g^i}$ and $\tau_1^i = \frac{g^i\left(1-\delta^i\right)\left(1+\varphi^i(1-x)\right)}{1-\delta^i g^i}$.

The supply block of the model contains the aggregate supply equations for home:

$$\hat{\pi}_t^H = \beta E_t \hat{\pi}_{t+1}^H - h_0 \hat{u}_t^H + h_L \hat{u}_{t-1}^H + h_F E_t \hat{u}_{t+1}^H - \gamma h_T\left(\hat{a}_t^H - \alpha\hat{s}_t\right) \tag{16}$$

and foreign:

$$\hat{\pi}_t^F = \beta E_t \hat{\pi}_{t+1}^F - h_0^* \hat{u}_t^F + h_L^* \hat{u}_{t-1}^F + h_F^* E_t \hat{u}_{t+1}^F - \gamma^* h_T^*\left(\hat{a}_t^F + \alpha\hat{s}_t\right) \tag{17}$$

where the coefficients h_j^i are functions of the structural parameters characterizing the two economies: workers' bargaining power, hiring costs, separation rates, markups, degree of nominal stickiness or of real wage rigidity, and so on[15].

Finally, from the definition of the terms of trade $S_t = \frac{P_t^F}{P_t^H}$ we get the following relationship between the terms of trade and the domestic inflation rates:

$$\hat{s}_t - \hat{s}_{t-1} = \hat{\pi}_t^F - \hat{\pi}_t^H \tag{18}$$

Equations (12), (13), (14), (15), (16), (17) and (18), together with a specification of monetary policy, completely characterize our equilibrium dynamics.

5 Baseline Calibration

In our baseline calibration, we assume that Home and Foreign are perfectly symmetric. The parameters are chosen to be largely consistent with those standard in the New Keynesian literature. The following table summarizes the values for the key parameters of our model (for $i = H$ or F):

[15] The expression for the parameters is given in Appendix A.

Preferences	β	ϕ^i	ϵ^i	μ^i	α
	0.992	0	6	1.2	0.25
Technology	A^i	φ^i			
	1	1			
Labor market	u^i	x^i	δ^i	η^i	
	0.08	0.45	0.071	1	
Price and Real Wage rigidities	θ^i	γ^i			
	0.66	0.5			
Shocks' Persistence and Volatility	ρ_a^i	σ_a^i	ρ_{σ_a}	σ_ε	
	0.95	0.007	0.258	0.0015	

Preferences: Time is taken as quarters. The discount factor β is set equal to 0.992, which implies a riskless annual return of about 3.3 percent. We assume the labor supply elasticity to be $\phi^i = 0$. This is consistent with our model if the members of the household have homogenous tastes for leisure. The elasticity of substitution between differentiated goods ϵ^i is set equal to 6, corresponding to a markup $\mu^i = 1.2$. The home bias parameter α, representing the share of imported goods on total consumption, is set to 0.25.

Technology: Following Blanchard and Galí (2008) we set the parameter φ^i in the hiring cost function, representing the sensitivity of hiring costs to labor market conditions, to be $\varphi^i = 1$[16]. The steady state level of productivity A^i is normalized to 1.

The labor market: In the baseline calibration, we set unemployment in country i to be $u^i = 0.08$, which is roughly consistent with the average unemployment in Europe. The job-finding rate x^i is set to 0.45, which corresponds approximately to a monthly rate of 0.18. Given u^i and x^i, it is possible to determine the separation rate using the relation $\delta^i = u^i x^i / \left(\left(1 - u^i\right) \left(1 - x^i\right) \right)$. We obtain a value $\delta^i = 0.071$. The relative bargaining power η^i is set to 1, which implies that firms and workers have the same bargaining power. The scaling parameter B^i is chosen such that hiring costs represent a 1 percent fraction of steady state output, as in Walsh (2005)[17]. The parameters χ^i can then be determined using steady state identities.

The degree of Price rigidity θ^i is set equal to 0.66, consistent with data on price duration. In the baseline calibration, following Campolmi and Faia (2008) and Blan-

[16] In order to calibrate φ^i, Blanchard and Galí exploit a simple mapping between their model and the standard search and matching model.

[17] To pin down B^i, we use the fact that in steady state hiring costs represent a fraction $\delta^i g^i = \delta^i B^i \left(x^i\right)^{\varphi^i}$ of GDP.

chard and Galí (2008), we set the degree of real wage rigidity γ^i equal to 0.5.

Shocks: We follow the literature and set the standard deviation of the productivity shocks σ_a^i to 0.007 and the standard deviation of the policy shock σ_ε to 0.0015. Following Backus, Kehoe and Kydland (1992) we set the correlation between the productivity shocks ρ_{σ_a} to 0.258.

Simulations of the model with this baseline calibration show that the volatilities of the model are close to the data. The standard deviation of output, inflation and unemployment of the euro area are 0.85, 0.5 and 4.59, compared to 0.84, 0.57 and 4.68 in our model[18].

6 The Transmission Mechanism

How do labor market structures influence the transmission mechanism of member countries to shocks? To answer this question, we distinguish between two types of labor market imperfections: *Unemployment Rigidities (UR)*, which capture the institutions - such as employment protection legislation, hiring costs and the matching technology - that limit the flows in and out of unemployment; and *Real Wage Rigidities (RWR)*, intended to capture all the institutions - including wage indexation and the wage bargaining mechanism and legislation - which influence the responsiveness of real wages to economic activity. These two types of labor market rigidities, while often associated, are likely to have different effects on the dynamics of the economy: in the first case, the rigidity is in "labor quantities", while in the second case it is "labor prices" that cannot adjust.

Before proceeding, some details on the calibration strategy are needed. To study the role of different degrees of RWR, we simulate the model varying the index of RWR (γ^i) from 0.1 to 0.9. Calibrating the degree of UR is a more challenging task, as the overall degree of "rigidity" in the labor market does not depend only on one parameter but on the entire configuration of the labor market. Following Blanchard and Galí (2008), we characterize the degree of labor market frictions by calibrating the steady state unemployment and job-finding rates (u^i and x^i); the job-separation rate is then determined through the steady state relationship $\delta^i = u^i x^i / ((1-u^i)(1-x^i))$. We define a labor market as "flexible" when the job-

[18] The standard deviations of actual euro area data are taken from Christoffel, Kuester and Linzert (2009), who use quarterly data for the euro area from 1984Q1 to 2006Q4. Both data and model are detrended with an HP filter ($\lambda = 1600$). In order to facilitate the comparison, inflation is computed in a year to year base ($\hat{\pi}_t^{yoy} = \log P_t - \log P_{t-4}$) and the volatility of unemployment is calculated in percentage terms.

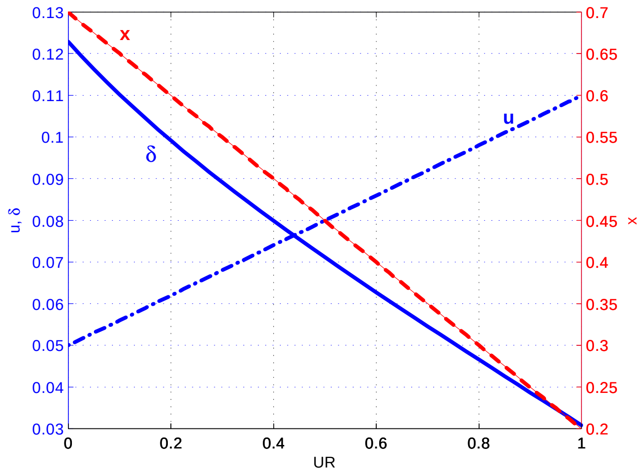


Figure 1: *The Unemployment Rigiditiy (UR) Index*

finding and the separation rate are high; the opposite holds in a "sclerotic" labor market. Figure 1 displays the evolution of the three parameters implied by our calibration strategy. As our UR index increases from 0 to 1, the unemployment rate increases from 0.05 to 0.11, the job-finding rate decreases from 0.7 to 0.2 and the separation rate decreases from 0.12 to 0.03[19]. We calibrate directly the job-finding rate and the unemployment rate because these are more easily observable than the reservation wage or the separation rate. Note also that we keep constant total hiring costs in steady state as percentage of GDP. This implies that marginal hiring costs are higher in labor markets with low hiring rates (i.e. high UR). This is consistent with a view of "sclerotic" economies characterized by institutional constraints on the hiring process.

To see how labor market structures influence the transmission mechanism of member countries to shocks, let's consider the Phillips curve of the home country, which we rewrite here for convenience:

$$\hat{\pi}_t^H = \beta E_t \hat{\pi}_{t+1}^H - h_0 \hat{u}_t^H + h_L \hat{u}_{t-1}^H + h_F E_t \hat{u}_{t+1}^H - \gamma h_T \left(\hat{a}_t^H - \alpha \hat{s}_t \right) \tag{19}$$

Labor market rigidities affect the supply side of member countries through their impact on the parameters h_i. In order to facilitate intuition, we concentrate our attention on the two key parameters:

[19]Notice that the two extremes of our UR index roughly correspond to the "EU calibration" and to the "US calibration" in Blanchard and Galí (2008).

- The "slope coefficient" h_0, which captures the elasticity of inflation to unemployment changes.[20]
- The "trade-off coefficient" γh_T, which determines to what extent productivity shocks and terms of trade movements enter as cost push shocks in the Phillips curve.

Figure 2 shows how the slope coefficient changes for varying degrees of UR and RWR. A higher degree of UR has a strong, positive and non-linear effect on the slope of the PC. The reason is that with lower job-finding rates and separations employment adjusts less easily to changing labor market conditions. This in turn implies that marginal costs and hence inflation become more sensitive to unemployment changes[21].

RWR have the opposite effect on h_0: higher degrees of RWR lower the sensitivity of real wages and inflation to unemployment changes. Note also that the sensitivity of the slope to RWR is much smaller than to UR, and becomes sizeable only when UR are high. This suggests that there may be important interaction effects between different types of labor market rigidities.

While UR have a dominant role in explaining the size of the slope coefficient h_0, RWR are the main determinant of the trade-off coefficient γh_T[22]. In particular, note that when real wage rigidities are present, $\gamma \neq 0$, productivity shocks enter directly as a negative cost push shock in the Phillips curve, leading to large and persistent unemployment fluctuations.

7 Positive Analysis: The Adjustment Mechanism

A key issue in the debate about the currency union concerns how individual countries adjust to common or country-specific shocks (see, e.g., EEAG report 2007). Indeed, after ten years of the Euro, the marked and persistent divergence of growth and inflation among euro-area economies seems to suggest that the adjustment process inside the currency area may not be working efficiently.

[20] In our calibrations, the parameters on lagged (h_L) and future unemployment (h_F) are small relative to h_0. Therefore, we follow Ravenna and Walsh (2007) and refer to h_0 as the slope of the Phillips curve. While this is clearly an approximation, we believe it to be useful to develop intuition that will hold throughout the paper.

[21] See Ravenna and Walsh (2007) for a similar argument in the context of a closed-economy DSGE model with search in the labor market.

[22] The effect of URs on γh_T is found to be negligeable.

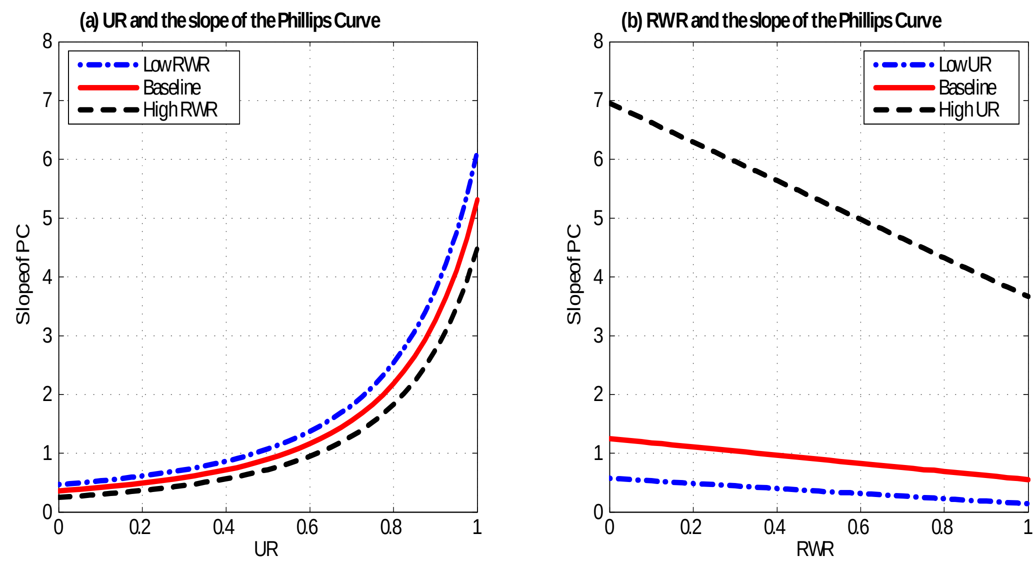


Figure 2: *Labor Market Rigidities and the Slope of the Phillips Curve*

In this positive analysis we study how different labor market structures are likely to affect the functioning of a currency union. The main focus is on the evolution of inflation and unemployment differentials because they show how shocks are absorbed in the monetary area.

Labor market rigidities can affect inflation and unemployment differentials in two main ways. First, the presence of labor market rigidities may affect the size and persistence of unemployment and inflation differentials following asymmetric shocks. Second, symmetric shocks may have asymmetric effects when the two regions have different labor market structures. How do these effects operate? Are they likely to be important or negligible? These are the questions we try to adress next.

7.1 The Dynamics of the Currency Union

In this section we describe the dynamic behavior of the model in response to two types of shocks: productivity shocks (symmetric and asymmetric) and monetary policy shocks. The monetary authority is assumed to follow a Taylor-type interest rate rule:

$$\hat{\imath}_t = \rho_m \hat{\imath}_{t-1} + (1 - \rho_m)\left(1.5\hat{\pi}_t^U - 0.25\hat{u}_t^U\right) + \varepsilon_t \tag{20}$$

and where $\rho_m = 0.85$, a value consistent with the empirical evidence on policy rules.[23]

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

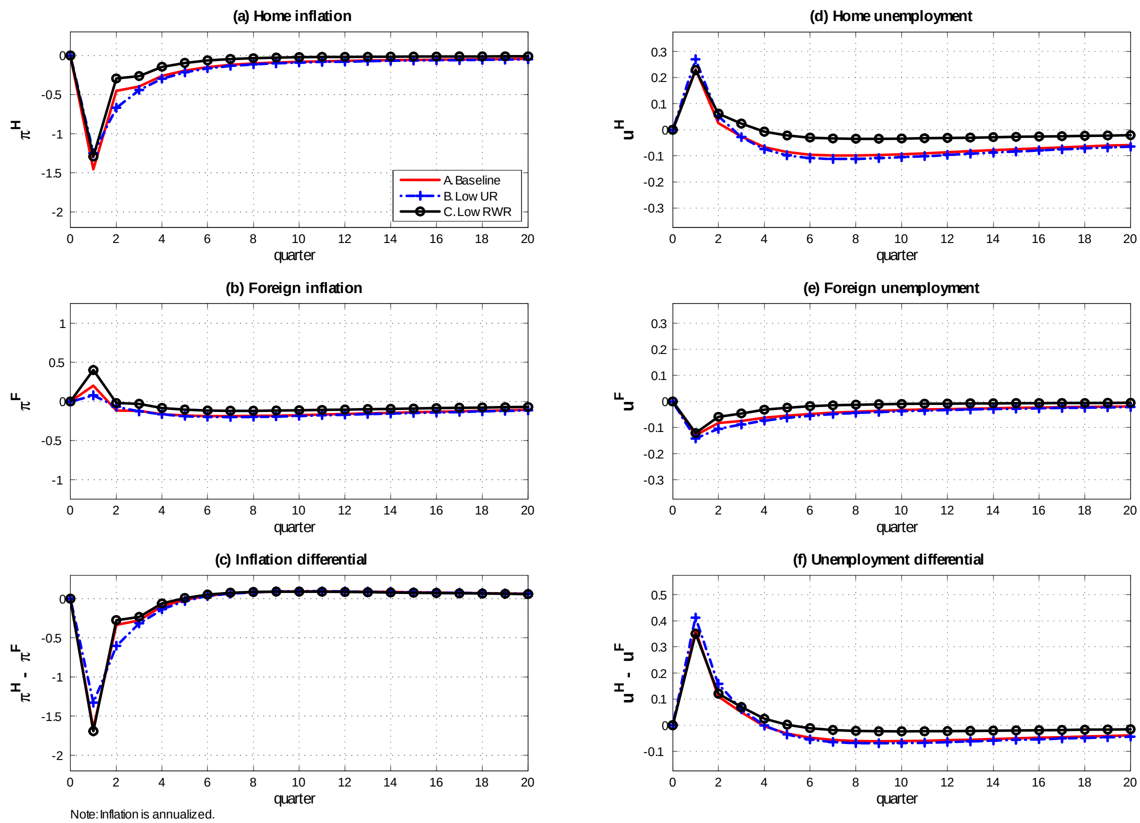
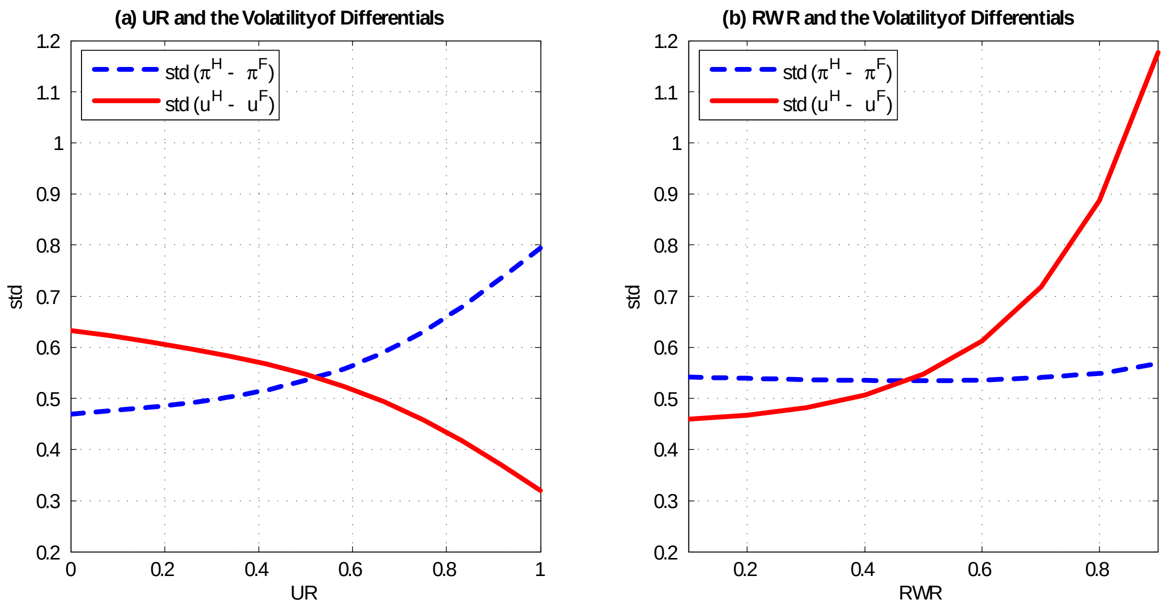


Figure 3: *Impulse Responses to an Asymmetric Productivity Shock (Home)*

7.1.1 Asymmetric Shocks and Labor Market Rigidities

First, we look at asymmetric productivity shocks, and consider how the transmission mechanism of the union changes when both the countries have less rigid labor markets or less rigid wages. Figure 3 displays the responses of inflation and unemployment to a positive technology shock in the home country for three different calibrations: the baseline calibration (A), a currency union with low UR (B) and a currency union with low RWR (C).[24] On impact, the three economies react in the same direction: home inflation ($\hat{\pi}^H$) decreases while home unemployment ($\hat{u}^H$) increases. The latter is due to the presence of price rigidity. The productivity increase allows firms that cannot reset prices to produce the same amount with fewer workers; consequently, unemployment rises on impact. This unemployment increase is short-lived, as over time more firms can reset their prices and the effect of the productivity shock fades away.

[24] The parameters for calibration B are $x = 0.7$, $\delta = 0.12$ whereas for calibration C we use $\gamma = 0.25$.



Note: we report the std of the unfiltered time series of quarterly inflation and unemployment (in deviation from steady state).

Figure 4: *Labor Market Rigidities and the Volatility of Differentials*

The home productivity shock is transmitted to the foreign country through movements of the terms of trade and through monetary policy. On the one hand, the reduction in the prices of the home goods exerts deflationary pressure abroad as consumers in both countries shift their consumption towards the home good. On the other hand, the central bank lowers the interest rate, which has a stimulating effect on the foreign economy. The overall effect is an increase of foreign inflation and a decrease of foreign unemployment.

Putting the impulse responses of the country specific variables together, a positive technology shock at home leads to a negative inflation differential and a positive unemployment differential (at least on impact).

The labor market structure has an important influence on the size and persistence of these differentials. First, consider the case where both countries are characterized by a lower degree of UR (B): the inflation differential decreases by 0.4 percentage points less and the unemployment differential increases slightly more when UR are low. When hiring new workers is less costly, firms find it relatively more convenient to absorb a shock through changes in quantities rather than through changes in prices.

Second, compare the baseline economy (A) to the economy with a lower degree of RWR (C). A lower degree of RWR has little impact on the inflation differential, but it substantially reduces the persistence of the response of the unemployment differential to the productivity shock. As in Hall (2005), when real wages are rigid, the firms' share of the match surplus increases strongly with productivity and hence hiring and unemployment is strongly related to movements in productivity.

In Figure 4 we further assess how the volatility of differentials depends on RWR and UR[25]. A higher degree of UR increases the volatility of the inflation differential, but reduces the volatility of the unemployment differential. A higher degree of RWR increases the volatility of the unemployment differential, while the effect on the inflation differential is small and the slope is sensitive to calibration choices.

Labor market rigidities are often blamed as one of the possible causes of large and long-lasting inflation and unemployment differentials in the European Monetary Union. Our results, however, suggest that it is crucial to distinguish among the institutions that constrain the "quantity" adjustment (UR) from the ones that constrain the "price" adjustment (RWR) in the labor market, as these may have very different, and sometimes opposite, dynamic implications.

Result 1 (Labor Market Rigidities and the Volatility of Differentials): *UR and RWR have different effects on the volatility of inflation and unemployment differentials: UR increase the volatility of the inflation differential but reduce the volatility of the unemployment differential, while RWR increase the volatility of the unemployment differential but have little effect on the volatility of the inflation differential.*

As shown in Figure 1 in the Appendix, a similar intuition applies for the volatility of union variables.

7.1.2 Symmetric Shocks and Asymmetric Labor Markets

In this section we analyze the dynamic behavior of the currency union in the presence of asymmetric labor market structures. We distinguish three cases:

1. Baseline: the member countries share the same economic structures.

2. Asymmetric UR: the home country has more rigid labor markets than the foreign country. Following Blanchard and Galí (2008), we calibrate the job finding rates at $x^H = 0.2$ and $x^F = 0.7$ and the separation rates at $\delta^H = 0.03$ and $\delta^F = 0.12$.

3. Asymmetric RWR: in the home country real wages are more sticky than in the foreign country. Specifically, we choose $\gamma = 0.75$ and $\gamma^* = 0.25$.

[25] We simulate the model for different calibrations of the labor market and show the standard deviation of the unfiltered time series of the inflation and unemployment differential. We include both monetary and productivity shocks.

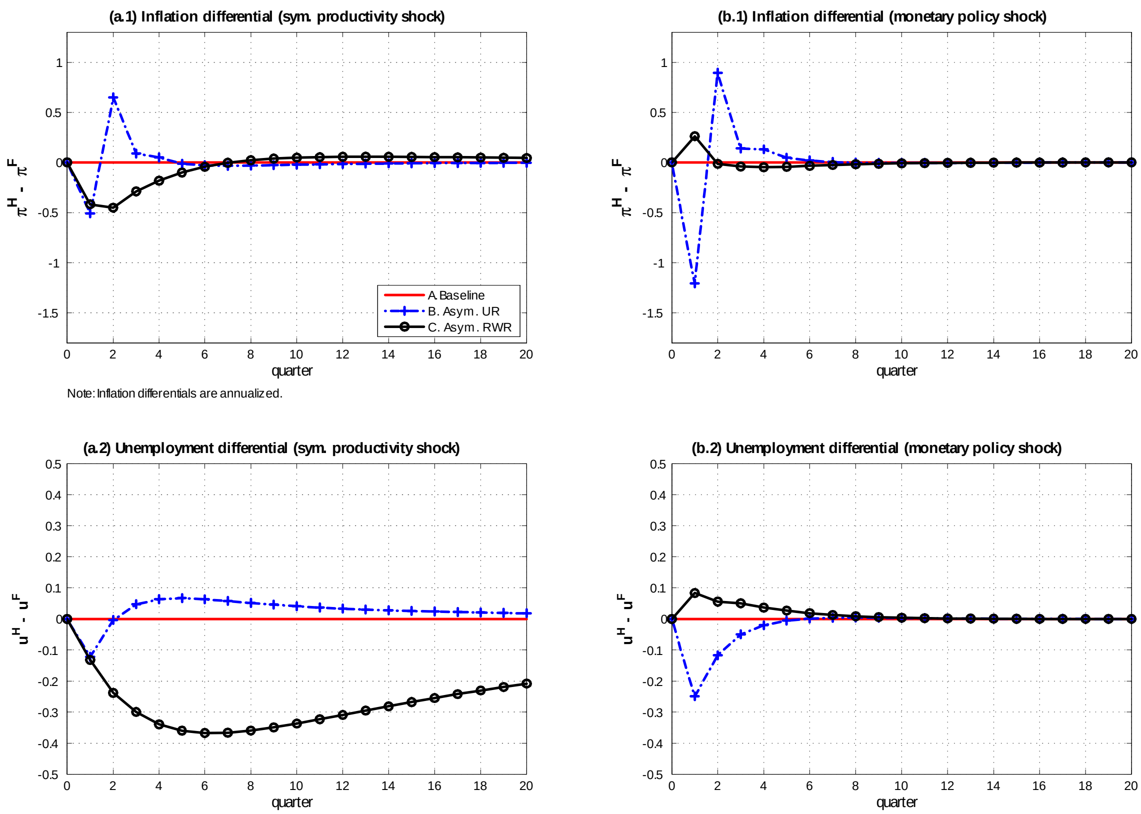


Figure 5: *Impulse Responses to a Symmetric Productivity shock (a) and a Monetary Policy shock (b).*

Figure 5 shows the impulse responses of the inflation and unemployment differential following a symmetric productivity shock (a) and a monetary policy shock (b). In the symmetric currency union, symmetric shocks do not affect differentials as the response in the home and foreign country are the same. On the contrary, in the presence of asymmetries, substantial differentials arise in response to symmetric shocks. In particular, in the presence of asymmetric UR the inflation differential shows a very strong response on impact and then is reversed in the second quarter. The reason for this pattern is that in the country with lower UR, inflation decreases less on impact but then is more persistent (see also Figure 3). Asymmetric UR are also a source of unemployment differentials as unemployment increases more in the country with lower UR.

Sizeable inflation and unemployment differentials also arise in the presence of asymmetric RWR. Most noteworthy is the substantial decrease in the unemployment differential in the response to a symmetric productivity shock. The reason is that unemployment responds more strongly in the country with rigid real wages.

Interestingly, asymmetries in the degree of RWR seem to have a bigger effect on the adjustment mechanism to productivity shocks, while UR have a bigger impact on the adjustment mechanism to monetary policy shocks. This is because RWR mainly determine the extent to which productivity shocks enter as negative "cost push shock" in the Phillips curve, while UR only affect the slope of the Phillips curve, which plays a key role in the transmission mechanism of demand shocks.

We further analyze how labor market asymmetries affect the volatility of differentials, holding the average degree of UR and RWR constant. For this purpose, we construct an index of asymmetry that starts out at 0 where both countries are perfectly symmetric (the baseline calibration). As the index increases towards 1, the two countries become increasingly different but the average degree of UR and RWR does not change. The following tabulation shows the values of the underlying parameters:[26]

	Complete Symmetry: Index=0	Strong Asymmetry: Index=1
Asymmetric UR	$x^H = x^F = 0.45$ $\delta^H = \delta^F = 0.07$	$x^H = 0.2$ / $x^F = 0.7$ $\delta^H = 0.03$ / $\delta^F = 0.12$
Asymmetric RWR	$\gamma = \gamma^* = 0.5$	$\gamma = 0.9$ / $\gamma^* = 0.1$

Figure 6 shows that the volatility of inflation and unemployment differentials is increasing in asymmetries in both UR and RWR. The reason is simple and intuitive: when asymmetries are present, symmetric shocks are transmitted differently across member countries and, as a consequence, inflation and unemployment differentials arise. Asymmetries in the degree of RWR are found to increase substantially the volatility of the unemployment differential (note that we would have to rescale Figure 6 (b)). Asymmetric UR have instead a stronger effect on the volatility of the inflation differential, which is related to the fact that in the presence of high UR firms adjust to shocks by adjusting prices rather than quantities.[27]

Overall, these results suggest that asymmetries in labor market structures worsen

[26] See Benigno (2004) and Andersen and Seneca (2007) for similar assumptions.

[27] In the Appendix Figures 3 and 4, we carry out a sensitivity analysis with respect to the correlation of productivity shocks. When the correlation of productivity shocks across the two countries is perfect ($\rho_{\sigma_a} = 1$), the volatility of differentials is strongly increasing in asymmetries. This shows that in the presence of asymmetric labor market rigidities it is the symmetric shocks that drive the differentials. When the correlation of productivity shocks is equal to zero, the volatility of differentials is still increasing except the volatility of the unemployment differential, which is slightly decreasing in the degree of asymmetry. Note, however, it is likely that productivity shocks are more strongly correlated across members of the EMU than in our baseline calibration ($\rho_{\sigma_a} = 0.258$) because our baseline calibration is based on an estimate of ρ_{σ_a} between the U.S. and a European aggregate (see Backus, Kehoe and Kydland, 1992).

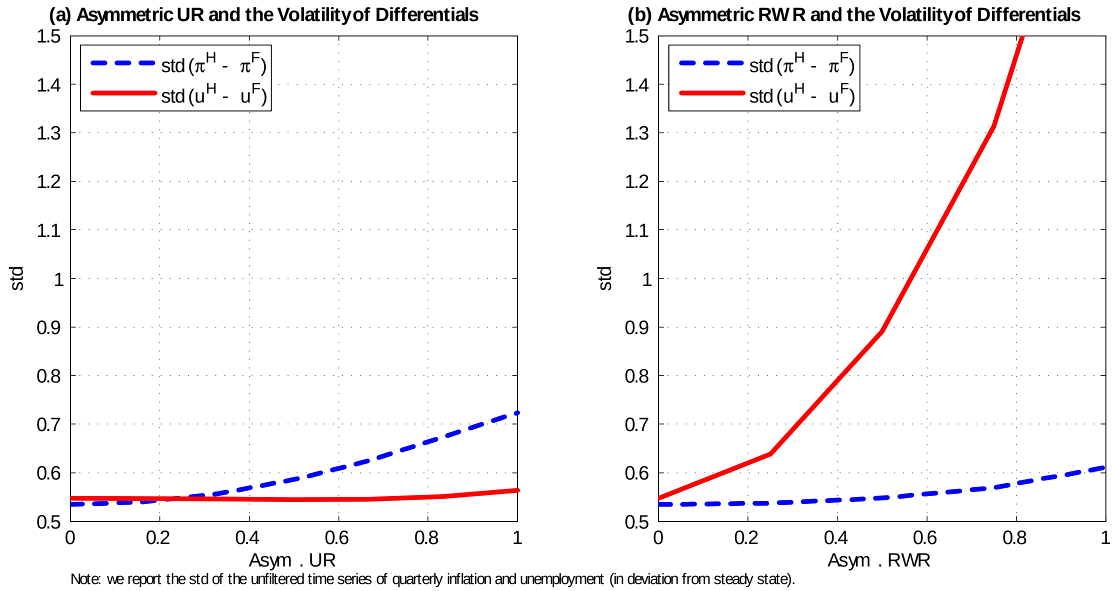


Figure 6: *Asymmetric Labor Market Rigidities and the Volatility of Differentials*

the adjustment mechanism of a currency union to symmetric and asymmetric shocks. It is important to note, however, that in the presence of asymmetric labor market structures, monetary policy shocks themselves create terms of trade movements and are a source of differentials. Can then the central bank exploit these asymmetries and gain from responding *systematically* to differentials? We try to address this question in the next section.

Result 2 (Asymmetric Labor Market Rigidities and the Volatility of Differentials):

Asymmetries in UR and RWR increase the volatility of inflation and unemployment differentials. This suggests that asymmetries in labor markets worsen the adjustment mechanism of a currency union to shocks.

Figure 2 in the Appendix shows how the volatility of union variables is affected by asymmetries in labor market rigidities. In general, the volatility of union variables is increasing in the degree of asymmetry. The only exception is the volatility of union unemployment, which is slightly decreasing with asymmetries in UR.

8 Optimal Monetary Policy

What is the optimal monetary policy in a currency union characterized by asymmetric labor market rigidities?[28] What are the optimal targets for the central bank? Should monetary policy respond to differentials? To answer these questions, we derive a loss function from the welfare criterion of the currency union, which we define as the utilitarian social welfare function. A second order approximation to the welfare criterion delivers the utility loss from steady state utility[29]

$$\begin{aligned} L_0 \;\simeq\; & E_0 \sum_{t=0}^{\infty} \beta^t [\frac{\omega_\pi}{2}\left(\hat{\pi}_t^H\right)^2 + \frac{\omega_\pi^*}{2}\left(\hat{\pi}_t^F\right)^2 + \frac{\omega_u}{2}\left(\hat{u}_t^H\right)^2 + \frac{\omega_u^*}{2}\left(\hat{u}_t^F\right) \\ & -\frac{\omega_{u_L}}{2}\hat{u}_t^H \hat{u}_{t-1}^H - \frac{\omega_{u_L}^*}{2}\hat{u}_t^F \hat{u}_{t-1}^F] + t.i.p. \end{aligned} \tag{21}$$

where t.i.p. refers to “terms independent of policy”. The derivation for the micro-founded loss function and the expression for the weights ω_π^i, ω_u^i and $\omega_{u_L}^i$ are given in the Appendix B. Because of log utility in consumption, welfare losses in each country are in percentage deviation from steady state consumption. To simplify the analysis, the approximation of the welfare criterion has been derived under the assumption that the steady state allocation of the decentralized economy corresponds to the constrained efficient allocation. This is true if two conditions are met: 1. The Hosios condition holds, i.e. $\varphi = \eta$; 2. Monopolistic distortions in the final goods market are eliminated through a production subsidy.

Our micro-founded loss function shows that the central bank of the currency union should care about (in both countries):

1. The variance of inflation: in the presence of price rigidity, inflation leads to inefficient dispersion of output across varieties, just like in a standard New Keynesian model.

2. The variance of unemployment, for two reasons. First, with concave utility over consumption and employment, fluctuations in employment around the steady state are undesirable per se. Moreover, in our model hiring is a wasteful activity in the sense that it consumes output. Since aggregate hiring costs

[28] See also Benigno (2004) and Galí and Monacelli (2008) for optimal monetary policy in a currency union in the presence of price rigidities and Thomas (2008) for optimal monetary policy in an economy with search and matching frictions.

[29] We deviate from Blanchard and Galí (2008) who eliminate some of the terms arguing that $g\hat{n}_t^i$ are of "second order". With our calibration strategy, this approximation would work well only for low URs.

$G(\frac{h_t^i}{U_t^i})h_t^i$ are increasing and convex in aggregate hiring, fluctuations in hiring (and unemployment) around the steady state lead to higher aggregate hiring costs and thus higher welfare losses.

3. The autocovariance of unemployment: since hiring is equal to $N_t - (1-\delta)N_{t-1}$, one can *reduce* the volatility of hiring, and thus aggregate hiring costs, by smoothing employment (and unemployment) across time.

Note also that one can express $\omega_u^i E_t\left(\hat{u}_t^i\right)^2 - \omega_{u_L}^i E_t\left(\hat{u}_t^i \hat{u}_{t-1}^i\right)$ as $\left(\omega_u^i - \rho_u^i \omega_{u_L}^i\right) E_t\left(\hat{u}_t^i\right)^2$ where ρ_u^i is the autocorrelation of unemployment. Then for high values of ρ_u^i the "effective" weight on the variance of unemployment is rather small as ω_u^i and $\rho_u^i \omega_{u_L}^i$ tend to cancel out each other.[30] This suggests that policies that aim at reducing the volatility of unemployment are unlikely to yield large welfare gains even in the presence of high UR.

The weights on inflation do not depend on the labor market rigidities but only on the degree of price rigidity. For this reason, the weights on inflation are the same in both countries[31] and welfare losses arising from the volatility of inflation can be expressed as

$$\begin{aligned}
\omega_\pi E_t\left(\hat{\pi}_t^H\right)^2 + \omega_\pi E_t\left(\hat{\pi}_t^F\right)^2 &= \omega_\pi\left[2E_t\left(\frac{1}{2}\hat{\pi}_t^H + \frac{1}{2}\hat{\pi}_t^F\right)^2 + \frac{1}{2}E_t\left(\hat{\pi}_t^H - \hat{\pi}_t^F\right)^2\right] \\
&= \omega_\pi\left[2E_t\left(\hat{\pi}_t^U\right)^2 + \frac{1}{2}E_t\left(\hat{\pi}_t^d\right)^2\right] \qquad (22)
\end{aligned}$$

This implies that - holding the variance of union inflation constant - welfare losses are increasing in the variance of inflation differentials, which reflects adjustment costs to shocks in a currency union. When the weights on home and foreign unemployment are the same, a similar relationship also holds for unemployment differentials.

8.1 The Policy Frontier

Before evaluating optimal rules and their welfare losses, we illustrate the trade-offs that monetary policy faces by calculating the policy frontier (i.e. the set of feasible monetary policy choices). In particular, we focus on the trade-off between stabilizing

[30] Note that ρ_u^i depends on monetary policy and thus the "effective" weight might depend on monetary policy itself. We find, however, that ρ_u^i varies very little with monetary policy and the "effective" weight is almost identical across all policies considered in this section.

[31] See Benigno (2004) for an analysis of optimal monetary policy in a currency union with asymmetric price rigidity.

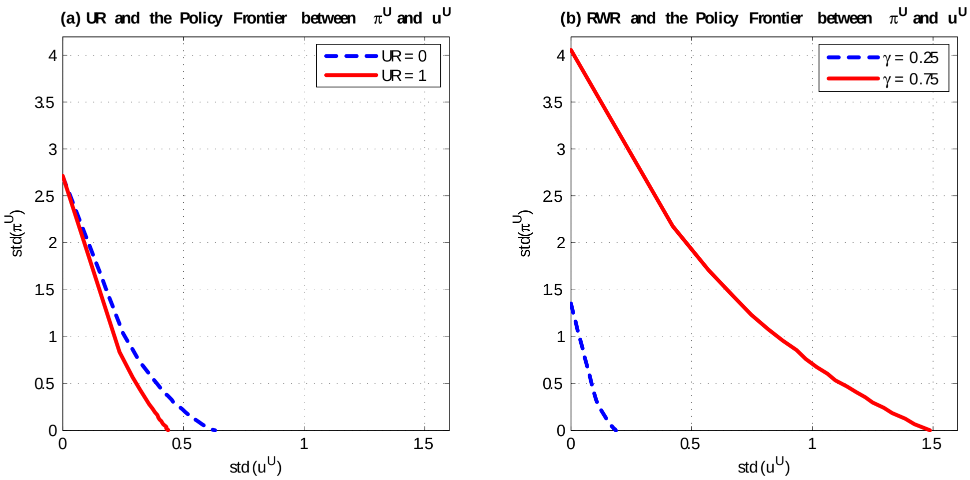


Figure 7: *The Policy Frontier between Inflation and Unemployment at the Union Level*

inflation and unemployment at the union level for different labor market rigidities and on the trade-off between home and foreign inflation in the presence of labor market asymmetries.

Figure 7 shows how the policy frontier between union inflation and unemployment varies with different degrees of UR and RWR. An increase in UR changes the slope of the policy frontier, which shifts inside. Intuitively, when labor market are more sclerotic, inflation becomes more sensitive to labor market conditions and the Phillips curve becomes steeper. For monetary policy this implies that the trade-off gets less severe and the central bank can reduce inflation volatility incurring a smaller increase in unemployment volatility. To put it in simple words, macroeconomic stabilization is easier in a more sclerotic currency union. An increase in RWR, on the contrary, shifts outside the policy frontier (as it increases the trade-off of monetary policy in face of productivity shocks) and flattens its slope (as the Phillips curve gets flatter). Both effects tend to increase the costs in terms of union inflation and unemployment volatilities: RWR make macroeconomic stabilization much more difficult.

Figure 8 shows the policy frontier between the volatility of home and foreign inflation. The slope of the policy frontier is in favor of the rigid country (home) in the presence of asymmetric UR, but in favor of the flexible country (foreign) with asymmetric RWR. The same intuition as in the symmetric case applies: inflation is more sensitive to labor market conditions when UR are high and when real wages are flexible and, therefore, macroeconomic stabilization is easier in the country with high UR and low RWR.

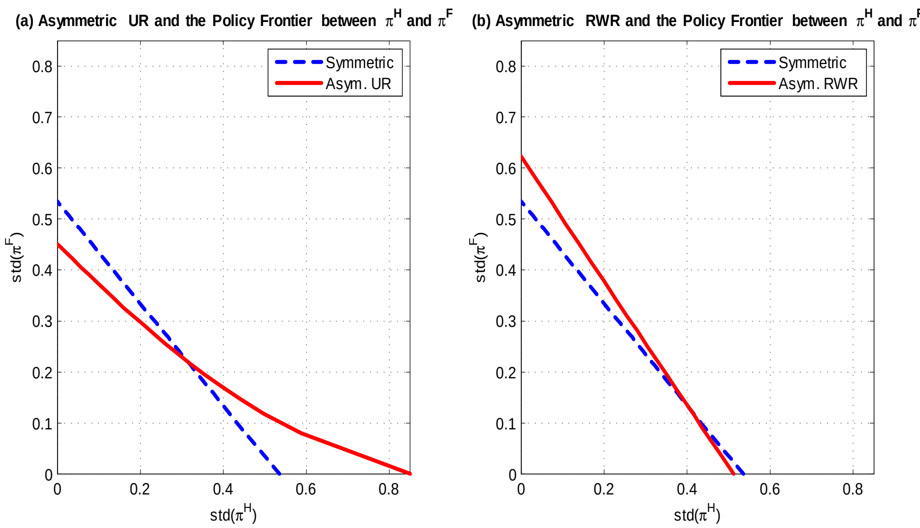


Figure 8: *The Policy Frontier between Home and Foreign Inflation*

8.2 Should Monetary Policy Target Unemployment?

The European Central Bank has often been criticized for not giving enough weight to unemployment stabilization. Indeed, in our model in the presence of RWR, monetary policy faces a trade-off between stabilizing inflation and stabilizing unemployment. How much weight should the central bank give to unemployment stabilization as opposed to inflation stabilization? To answer this question, we consider a symmetric currency union and evaluate the welfare losses of the following two targeting rules:

1. Symmetric Inflation Targeting (IT): $\hat{\pi}_t^U = 0$

2. Optimized Mixed Targeting (MTopt): $\hat{\pi}_t^U - \alpha_u \hat{u}_t^U = 0$

where α_u is found by optimizing over a grid spanning the interval $[0, 2]$.

Perhaps surprisingly, we find that the optimal weight α_u is close to zero (< 0.1) and, except for large degrees of RWR (that is, except for $\gamma > 0.8$), the welfare gains of $MTopt$ over the symmetric IT are small (less than 0.001% of steady state consumption). This result is a consequence of the fact that, under plausible calibrations, the *"effective" utility cost* of unemployment fluctuations is much lower than the utility cost of inflation dispersion.[32] To make this point clearer, we evaluate the

[32] Thomas (2008) and Ravenna and Walsh (2008) find similar results in closed economy models with search frictions: real wage rigidities do not provide a rationale for deviating from price stability. The result that the optimal weight on inflation stabilization is much larger than on employment stabilization is standard also in New Keynesian models without search frictions (see, e.g., Woodford, 2003).

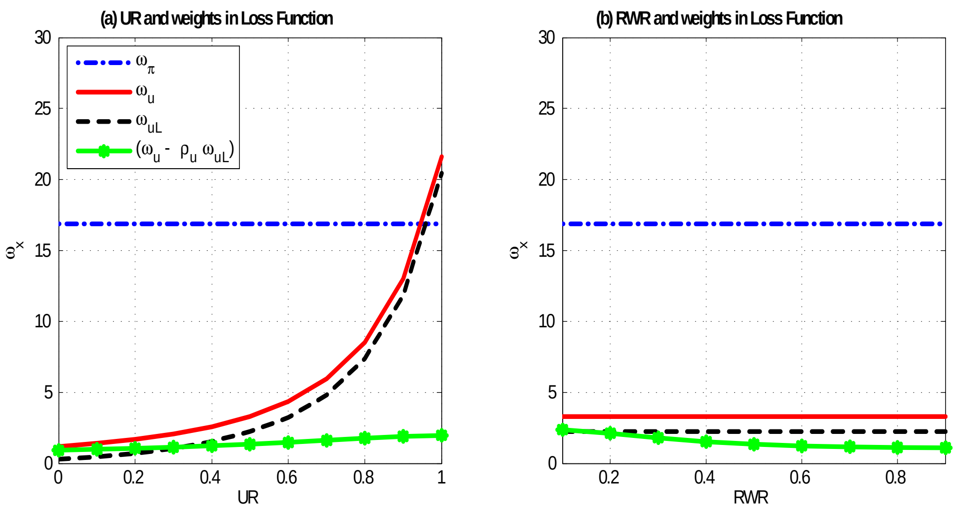


Figure 9: *Labor Market Rigidities and the Weights in the Loss Function*

weights $\omega_\pi^i, \omega_u^i, \omega_{u_L}^i$ in the loss function as well as the "effective" weight $\left(\omega_u^i - \rho_u^i \omega_{u_L}^i\right)$ for different calibrations of the labor market. Figure 9 shows that while RWR do not affect the weights in the loss function, a higher degree of UR strongly increases the impact of the variance and autocovariance of unemployment on welfare. These latter two terms, however, tend to offset each other and, for all our calibrations, the "effective" weight on the volatility of unemployment is below 2.5 compared to a weight on the volatility of inflation of almost 17. That is to say, the utility cost of unemployment fluctuations remains much lower than the utility cost of inflation dispersion. For this reason, in our model higher UR or RWR do not provide a good justification for unemployment stabilization.[33]

Result 3 (Optimized Mixed Targeting rule)

The optimized Mixed Targeting rule gives little weight to unemployment stabilization and, except for large degrees of RWR, the welfare gains relative to a symmetric Inflation Targeting rule are small.

[33] One may argue that the central bank doesn't want to stabilize unemployment but rather changes in unemployment in order to reduce aggregate hiring costs. To assess this claim we evaluate the welfare losses of the following mixed targeting rule: $\hat{\pi}_t^U + \alpha_h \hat{h}_t^U = 0$ where we replaced unemployment with hiring. We find that the optimal weight on hiring is close to zero (< 0.1) and, except for large degrees of RWR (that is, except for $\gamma > 0.8$), the welfare gains of this mixed targeting rule over the symmetric IT are small (less than 0.003% of steady state consumption).

8.3 Should Monetary Policy Respond to Inflation Differentials?

In our positive analysis we found that inflation differentials strongly depend on the underlying labor market structures. Moreover, our loss function indicates that the volatility of inflation differentials yields welfare losses. Should monetary policy therefore target inflation differentials? It is important to point out that in a symmetric currency union inflation differentials are independent of monetary policy (see Benigno, 2004). In a symmetric currency union, differentials can arise in response to asymmetric shocks, but by its nature monetary policy has only symmetric effects. Therefore, targeting inflation differentials does not yield any welfare improvement. On the contrary, in the presence of asymmetries in labor market rigidities, monetary policy creates terms of trade movements and directly affects differentials (see the impulse responses in Figure 5). Should monetary policy then *systematically* respond to inflation differentials? To answer this question, we evaluate the welfare losses of the following two targeting rules:

1. Symmetric Inflation Targeting (IT): $\hat{\pi}_t^U = 0$
2. Optimized Inflation Targeting (ITopt): $\alpha_\pi \hat{\pi}_t^H + (1 - \alpha_\pi)\hat{\pi}_t^F = 0$

where α_π is found by optimizing over a grid spanning the interval $[0, 1]$.[34] Note that one can reformulate ITopt as $\hat{\pi}_t^U + (\alpha_\pi - \frac{1}{2})\hat{\pi}_t^d = 0$, which implies that for any $\alpha_\pi \neq 0.5$ monetary policy responds to inflation differentials.

We use the same index of asymmetry as in the previous section and compute the optimal weight in the ITopt rule as we go from 0 (complete symmetry) to 1 (strong asymmetry). We also compute the percentage dead weight loss (PDWL) of the ITopt rule relative to the symmetric IT rule. Similar to Benigno (2004), the PDWL is computed as:

$$PDWL = 100 * \frac{L_{ITopt} - L_{opt}}{L_{IT} - L_{opt}} \tag{23}$$

where L_{ITopt}, L_{IT} and L_{opt} are welfare losses under ITopt, IT and the optimal monetary policy under commitment.

The results, shown in Figure 10, suggest that the reduction in dead weight losses by following the ITopt rule can be substantial and that the ITopt rule should give a

[34] We compute optimal monetary policy under commitment (the "timeless perspective" as in Woodford, 2003). Note that the optimal monetary policy cannot replicate the efficient allocation in this model and thus the losses are always larger than zero.

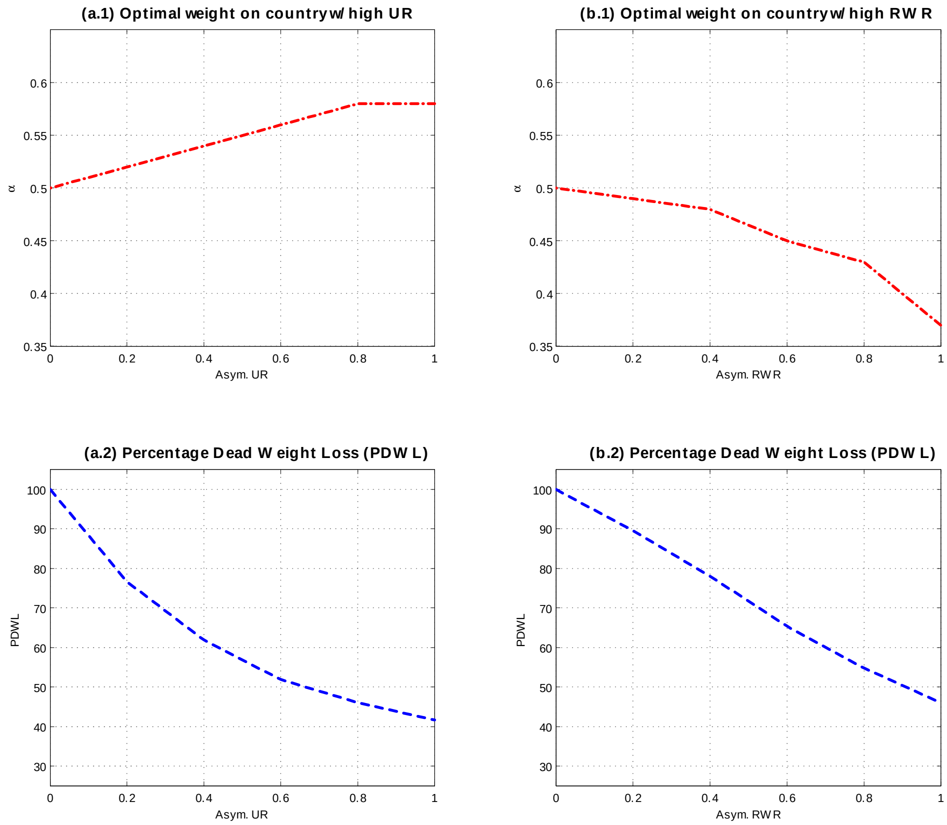


Figure 10: *Asymmetric Labor Market Rigidities, the Optimized Inflation Targeting Rule and % Reduction in Dead Weight Loss (RDWL)*

higher weight to the country with *higher* UR but *lower* RWR. The reason for this result is related to the slope of the Phillips curve: it is optimal to reduce inflation volatility in the country where inflation is more sensitive to labor market conditions (i.e. where the Phillips curve is steeper). This will increase the volatility of inflation in the country where inflation is less sensitive to labor market conditions, but by less than one to one. The fact that the trade-off in the Phillips curve depends on the real wage rigidity, gives an additional motive for targeting the flexible real wage country. Targeting the inflation of the country with more sticky real wages - i.e. the country with a larger trade-off - creates much more volatility in unemployment and thus higher welfare losses.

The result that it is optimal to target the region with flexible real wages seems to stand in contrast with the literature on sticky prices and sticky nominal wages (see, e.g., Erceg et al., 1999). In this literature, welfare losses arise because in the presence of price and nominal wage staggering, inflation leads to an inefficient dispersion of output across firms and/or inefficient labor supply across households. As a consequence, the weights in the loss function are larger for sticky price countries and thus it is optimal to put more weight on that country. On the contrary, in our framework, inflation bears the same costs in both countries because countries are symmetric in terms of price rigidities. Moreover, real wages are the same across firms, even though institutional barriers limit the extent to which real wages can adjust and hence determine how responsive inflation is to labor market conditions. As a consequence, real wage rigidities do not affect the weights on inflation or unemployment in the loss function, but only the way in which shocks are transmitted in member states (as captured by the Phillips curve of the member states).

UR and RWR are thus found to lead to opposite prescriptions for monetary policy. Do the effects of asymmetries cancel each other out when the home country has both high UR and high RWR? More generally, are there interaction effects between asymmetric unemployment and real wage rigidities? To answer this question, we evalute the welfare losses of IT and ITopt for different combinations of labor market rigidities. In particular, we find the optimal weight and dead weight losses for the following two economies:

	$UR = 1$ / $UR^* = 0$	$UR = 0$ / $UR^* = 1$
$\gamma = 0.9$ / $\gamma^* = 0.1$	$\alpha_\pi = 0.51$ $PDWL = 98.5$ (C)	$\alpha_\pi = 0.31$ $PDWL = 17.2$ (S)

The results show that when rigidities are complements, in the sense that countries with high (low) UR also have high (low) RWR (economy (C) in the table above), the effects on the optimal weight offset each other, and a symmetric inflation target is close to optimal. On the other hand, when rigidities are substitutes, that is low (high) real wage rigidities side with high (low) unemployment rigidities (economy (S) in the table), the effects reinforce each other, so that countries with low RWR but high UR receive a larger weight in the optimal inflation target and the reduction in dead weight loss from following the ITopt rule is larger than 80%.

Result 4 (Optimized Inflation Targeting rule)

The optimized Inflation Targeting rule gives more weight to countries with higher Unemployment Rigidities and lower Real Wage Rigidities. Moreover, when the rigidities are complements the effects of asymmetries offset each other, whereas when the rigidities are substitutes the effects of asymmetries reinforce each other.

9 Conclusion

In this paper we introduce unemployment, hiring frictions and real wage rigidities in a standard DSGE currency union model. Our model provides a rigorous but tractable framework for the analysis of the functioning of a currency union characterized by asymmetric labor market rigidities. In our analysis we focus on two types of labor market rigidities: Unemployment Rigidities (UR), which capture the institutions - such as employment protection legislation, hiring costs and the matching technology - that limit the flows in and out of unemployment; and Real Wage Rigidities (RWR), intended to capture all the institutions - including wage indexation and the wage bargaining mechanism and legislation - which influence the responsiveness of real wages to economic activity. Three main conclusions emerge from our analysis:

First, the two types of labor market rigidities are found to have very different effects on the incentives for firms to reset prices and thus on the Phillips curve. A higher degree of UR makes the Phillips curve steeper whereas RWR make the Phillips curve flatter. The basic intuition is that inflation is more sensitive to labor market conditions when firms adjust prices rather than quantities in response to shocks.

Second, labor market rigidities have a deep impact on the adjustment mechanism of the currency union to productivity and monetary policy shocks. We focus our analysis on the volatility of inflation and unemployment differentials, because they directly reflect the adjustment costs of the currency union to those shocks. We find that UR increase the volatility of the inflation differential but reduce the volatility of the unemployment differential, while RWR increase the volatility of the unemployment differential and have little effect on the volatility of the inflation differential. Moreover, asymmetries in UR and RWR increase both the volatility of inflation and unemployment differentials. This suggests that asymmetric labor market structures worsen the adjustment mechanism of a currency union to symmetric and asymmetric shocks.

Finally, in our normative part we find that, except for large degrees of RWR, monetary policy should give a negligible weight to unemployment. We then probe whether in the presence of labor market asymmetries monetary policy should respond to inflation differentials. Indeed, when labor market structures differ among member countries, the optimal inflation index should give a higher weight to the country with higher unemployment rigidities but more flexible real wages. We further show that it is crucial to take into consideration the interactions between institutions at the two sides of the labor market. When labor market institutions are "complements", in the sense that countries with high (low) UR also have rigid (flexible) wages, the effect of asymmetries tends to offset each other and a symmetric inflation target is close to optimal. When labor market institutions are "substitutes", that is countries with low UR tend to have high RWR or viceversa, the effects of rigidities tend to reinforce each other and welfare losses increase considerably if the central bank ignores asymmetries in the labor market.

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Appendix

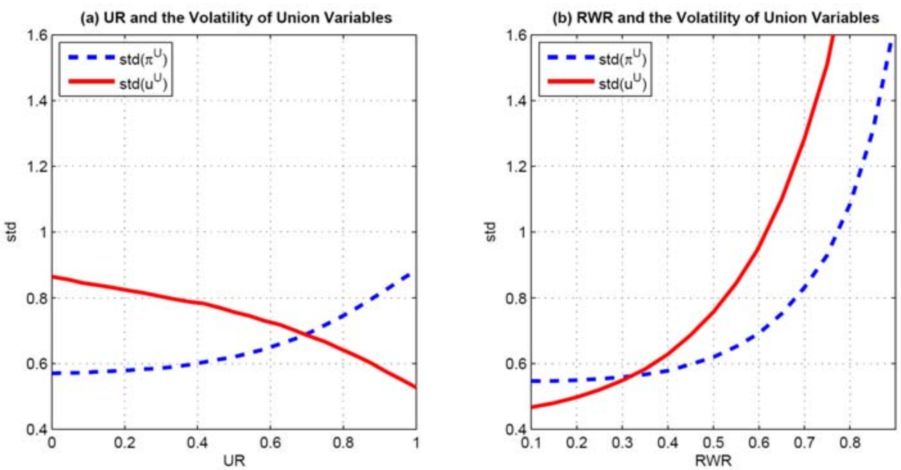

Figure 1 : *Labor Market Rigidities and the Volatility of Union Variables*

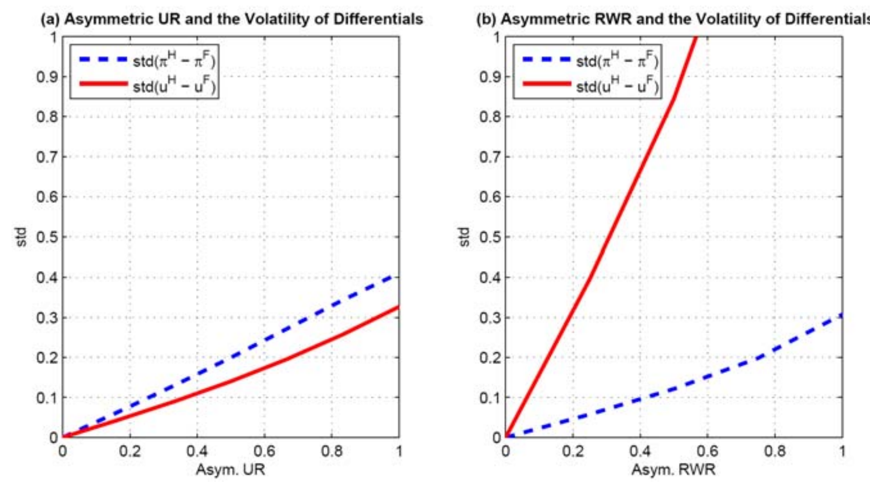

Figure 3 : *Correlation of Productivity Shocks across Countries* $\rho_{\sigma_a} = 1$.

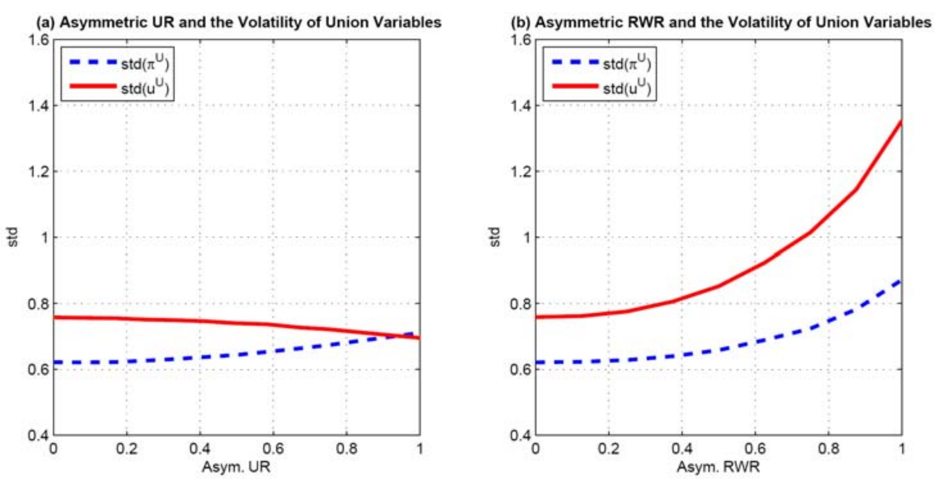

Figure 2 : *Asymmetric Labor Market Rigidities and the Volatility of Union Variables*

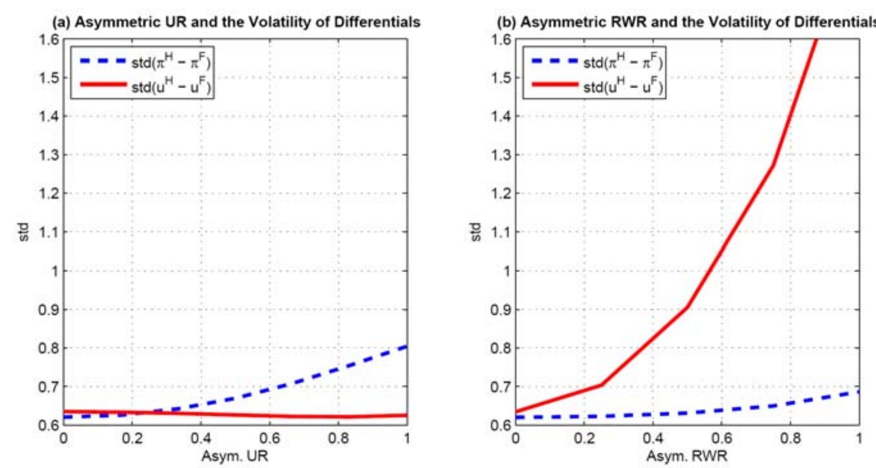

Figure 4 : *Correlation of Productivity Shocks across Countries* $\rho_{\sigma_a} = 0$.