Labor Market Institutions and Inflation Volatility in the Euro Area *

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Abstract

Despite having had the same currency for many years, EMU countries still have quite different inflation rates. In this paper we explore one possible reason: country specific labor market institutions, giving rise to different inflation volatilities. When unemployment insurance schemes differ, as they do in EMU, reservation wages react differently in each country to area-wide shocks. This implies that real marginal costs and inflation also react differently. We report evidence for EMU countries supporting the existence of a cross-country link over the cycle between labor market structures on the one side and real wages, real marginal costs and inflation on the other. We then build a DSGE model that replicates the data evidence.

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1 Introduction

Inflation differentials are still pronounced among euro area countries despite the existence, for many years, of a common currency, a single market for products, capital and labor (though with low labor mobility) and tightly harmonized fiscal policies. Why is it so? Research to date has concentrated on differentials in inflation levels, explaining their size and persistence on the basis of convergence mechanisms such as the "Balassa Samuelson", or asymmetric national shocks (in aggregate demand, or supply, or in the degree of exposure to area-wide external shocks), whose effect are typically exacerbated by high inflation persistence[1]. Here we look instead at inflation volatility differentials and study their link with labor market institutions – specifically, the degree of coverage of unemployment insurance.

We think that the properties of euro area inflation we document and the explanation we offer may be deeper and more long-lasting than those studied by other authors. While convergence phenomena are by nature transient, and inflation persistence in the eurozone can be expected to decline as a result of product market reforms and enhanced central bank credibility, labor market structures (unemployment insurance in particular) are deeply entrenched in national preferences[2] and hence should be expected to vary little over time. Linking them to inflation volatility differentials hence means pointing at features of inflation asymmetry in the EMU that will be very difficult to remove, even at much higher levels of economic and financial integration than that prevailing at present.

Labor market characteristics influence the dynamics of real wages and of the marginal cost of firms, which, in the standard New-Keynesian model, are a main driver of inflation. Hence it seems natural to assess the quantitative relevance of such institutions in determining differentials in inflation behavior. Specifically, the intuition behind our reasoning is the following. Consider e.g. a shock that reduces real wages in a given country in EMU. If the replacement rate (ratio between unemployment benefit and wage) is lower, workers face a worse outside option and therefore are willing to accept a bigger reduction in wage in order to keep their jobs. Assuming little or no labor mobility, in the country with low replacement rate we should observe in equilibrium a higher

[1] See European Central Bank (2003) for a non-technical survey and Honohan and Lane (2003) and Angeloni and Ehrmann (2007), and the references therein, for some interpretations of the evidence.

[2] André Sapir, Globalisation and the Reform of European Social Models, Breugel Policy Brief, (2005).

reduction in real wage, marginal costs as well as inflation, since inflation is linked to marginal costs via the Phillips curve. In general, the volatility of real wages, marginal costs and inflation is inversely related to the replacement rate. The shape of the relation depends not only on labor market characteristics but on the whole shock and propagation mechanisms, including (since EMU countries are highly integrated in trade and capital markets) the cross-country spillovers.

Our analysis proceeds as follows. We first document the negative empirical relation between volatilities of de-trended real wages, marginal costs and inflation and replacement rates[3] during the EMU period. Secondly, we build a DSGE model with two countries sharing the same currency, characterized by matching frictions and wage rigidity in the labor market[4], monopolistic competition and adjustment cost on pricing. The two-country model accounts for the rich structure of propagation mechanisms and international spillovers existing in a monetary union. We use this laboratory economy, calibrated on the euro area, to analyze the effect of shocks under different values of the replacement rates, and find that the model also gives rise to a negative relation. Finally, we match the model results with the empirical ones, and find that the model replicates well the relations found in the data.

In section 2 we present our empirical stylized facts; in section 3 we present the model and its calibration, in section 4 we show the model results and we match them with the data. Section 5 concludes.

2 Stylized Facts

Table (1) shows averages over 1985 to 1995 of replacement rates for a series of euro area countries. Data are taken from Nickell and Nunziata (2001). As a measure of unemployment insurance coverage they use the benefit replacement rate (BBR, benefit as a ratio to average earnings before taxes) provided by OECD, which is a measure of the monetary loss incurred by the worker when moving from the employed to the unemployed status. To proxy a dynamic concept of unemployment insurance benefit, Nickell and Nunziata calculate a weighted average of the BRR over the first 5 years of unemployment; for example, the first entry in the table means that an Austrian worker in

[3] As calculated by Nickell and Nunziata, 2001.

[4] The tradition of introducing matching frictions in DSGE closed economy model is well established. Ssee Merz (1995), Andolfatto (1996), Cooley and Quadrini (2000), Shimer (2004), Hall (2004) and Krause and Lubik (2005) among many others.

the first 5 years of unemployment earns on average 75 percent of her last wage when employed.

Several features of the data are worth noting. First, there is considerable cross-country variation, from a minimum of 0.09 to a maximum of 0.77; this seems a large enough span to have an observable macroeconomic impact. It is remarkable how this parameter varies little over time[5], suggesting that indeed the BRR incorporates deeply entrenched features of the national systems. In the literature this parameter is often use as a catch-all measure of unemployment insurance, and is assumed to be a key determinant in the worker's decision to keep a job. A further advantage of this measure is that it is easily comparable across countries.

In our analysis we consider the euro area countries during the period 1998Q1-2004Q4. 1998 is included in the sample because during most of that year exchange rates were virtually constant and EMU was expected with certainty to start at the beginning of the following year (in fact, the ECB as created in mid-1998, not in 1999 as often assumed). Among the original EMU members, we exclude Luxembourg because there are no data on replacement rates, hence making a total of 10 countries[6].

In figure (1) (panels a, b and c) we plot on the vertical axis the volatilities of wage, of unit labor costs and inflation, all measured relative to the volatility of output in the corresponding countries[7], and on the horizontal axis the replacement rates[8].

Inflation rates are measured by the GDP deflator. As measure of real wages we use the compensation per employee divided by the CPI and as a measure of marginal cost the unit labor cost. Data for compensation per employee and unit labour cost are taken by EUROSTAT, while data for CPI and GDP deflator are taken from OECD. The standard deviations have been computed on Hodrick-Prescott filtered series. In all three charts we drew two interpolating lines, a linear and an exponential one. All lines shows a negative relation, and the exponential is convex relative to the origin. Though there is large variation around the lines, the evidence of a negative and convex relation seems quite clear and robust across the three measures of volatility.

Figure (2) (panels a, b and c) shows the same variables, but this time as ratios between pairs

[5] Standard deviations of the replacement rates over the period considered for each country range from a value of 0 for the Netherlands to a value of 0.15 for Italy.

[6] For the real wage, also Portugal is missing.

[7] We divided by the volatility of output to have a standardized measure.

[8] For the replacement rates, we picked the 1995 value instead of the 1985-1995 average shown in Table 1, in order to be closer to our sample for inflation.

of countries[9]. Hence each dot shows, for a given pair of countries, the ratio between the standard deviations (relative to that of output) of real wages, marginal costs and inflation, respectively, plotted against the corresponding ratios of the replacement rates. We show these transformations of the original data because this is the appropriate way to match the model results with the data, as explained below. The negative relation, linear and non-linear, is again clear.

3 A Model for A Currency Area with Labor Market Frictions

There are two countries of equal size. Each economy is populated by households who consume different varieties of domestically produced and imported goods, save and work. Households save in both domestic and internationally traded bonds. Each agent can be either employed or unemployed. In the first case he receives a wage that is determined according to a Nash bargaining, in the second case he receives an unemployment benefit. The labor market is characterized by matching frictions and endogenous job separation. The production sector acts as a monopolistic competitive sector which produces a differentiated good using capital and labor as inputs and faces adjustment costs a' la Rotemberg (1982).

3.1 Households in the Domestic and Foreign Country

Let's denote[10] by $c_t \equiv [(1-\gamma)^{\frac{1}{\eta}} c_{h,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{f,t}^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}}$ a composite consumption index of domestic and imported bundles of goods, where γ is the balanced-trade steady state share of imported goods (i.e., an inverse measure of home bias in consumption preferences), and $\eta > 0$ is the elasticity of substitution between domestic and foreign goods. Optimal allocation of expenditure between domestic and foreign bundles yields:

$$c_{h,t} = (1-\gamma)\left(\frac{p_{h,t}}{p_t}\right)^{-\eta} c_t;\; c_{f,t} = \gamma\left(\frac{p_{f,t}}{p_t}\right)^{-\eta} c_t \qquad (1)$$

Each bundle is then composed of imperfectly substitutable varieties (with elasticity of substitution $\varepsilon > 1$).There is continuum of agents who maximize the expected lifetime utility.

[9] Using differences instead of ratios would not materially change the results.

[10] Let $s^t = \{s_0, ...s_t\}$ denote the history of events up to date t, where s_t denotes the event realization at date t. The date 0 probability of observing history s^t is given by ρ_t. The initial state s^0 is given so that $\rho_0 = 1$. Henceforth, and for the sake of simplifying the notation, let's define the operator $E_t\{.\} \equiv \sum_{s_{t+1}} \rho(s^{t+1}|s^t)$ as the mathematical expectations over all possible states of nature conditional on history s^t.

$$E_t \left\{ \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma} \right\} \tag{2}$$

where c denotes aggregate consumption in final goods. Households supply labor hours inelastically h (which we normalize to 1). Total real labor income is given by w_t and is specified below. Unemployed households members, u_t, receive an unemployment benefit, b. The contract signed between the worker and the firm specifies the wage and is obtained through a Nash bargaining process. In order to finance consumption at time t each agent also invests in non-state contingent nominal bonds b_t which pay a gross nominal interest rate $(1+r_t^n)$ one period later and in non-state contingent nominal bonds which are internationally traded, b_t^*, and which pay a gross nominal interest rate, $(1+r_t^{n,f})$, one period later. As in Andolfatto (1996) and Merz (1995) it is assumed that workers can insure themselves against earning uncertainty and unemployment. For this reason the wage earnings have to be interpreted as net of insurance costs. Finally agents receive profits from the monopolistic sector which they own, Θ_t, and pay lump sum taxes, τ_t. The sequence of budget constraints in terms of domestic CPI consumption goods reads as follows:

$$c_t + \frac{b_t}{p_t} + e_t^r \frac{b_t^*}{p_t^*} \leq w_t(1-u_t) + bu_t + \frac{\Theta_t}{p_t} - \frac{\tau_t}{p_t} + (1+r_{t-1}^n)\frac{b_{t-1}}{p_t} + (1+r_{t-1}^{n,f})e_t^r \frac{b_{t-1}^*}{p_t^*} \tag{3}$$

where e_t^r is the real exchange rate which in the currency area is given by $e_t^r = \frac{p_t^*}{p_t}$.Households choose the set of processes $\{c_t, b_t, b_t^*\}_{t=0}^{\infty}$ taking as given the set of processes $\{p_t, w_t, r_t^n, r_t^{n,f}\}_{t=0}^{\infty}$ and the initial wealth b_0, b_0^* so as to maximize (2) subject to (3). The following optimality conditions must hold:

$$c_t^{-\sigma} = \beta(1+r_t^n)E_t \left\{ c_{t+1}^{-\sigma} \frac{p_t}{p_{t+1}} \right\} \tag{4}$$

$$c_t^{-\sigma} = \beta(1+r_t^{n,f})E_t \left\{ c_{t+1}^{-\sigma} \frac{p_t^*}{p_{t+1}^*} \frac{e_{t+1}^r}{e_t^r} \right\} \tag{5}$$

$$c_t^{-\sigma} = \lambda_t \tag{6}$$

Equation (4) is the Euler condition with respect to domestic bonds. Equation (5) is the optimality condition with respect to internationally traded bonds. Equations (6) is the marginal utility of consumption. Optimality requires that No-Ponzi condition on wealth is also satisfied.

Arbitrage condition and accumulation of assets. Due to imperfect capital mobility and/or in order to capture the existence of intermediation costs in foreign asset markets workers pay a spread between the interest rate on the foreign currency portfolio and the interest rate of the foreign country. This spread is proportional to the (real) value of the country's net foreign asset position:

$$\frac{(1+r_t^{n,f})}{(1+r_t^{n,*})} = \zeta\left(e_t^r \frac{b_t^*}{p_t^*}\right) \tag{7}$$

where $\zeta > 0$[11], $\zeta' > 0$. In addition we assume that the initial distribution of wealth between the two countries is symmetric.

Workers in the Foreign Region. We assume throughout that all goods are traded, that both countries face the same composition of consumption bundle and that the *law of one price* holds. This implies that $p_{h,t} = e_t p_{h,t}^*, p_{f,t} = e_t p_{f,t}^*$. Under the currency union assumption the nominal exchange rate is equal one. Foreign workers face an allocation of expenditure and wealth similar to the one of workers in the domestic region except for the fact that they do not pay an additional spread for investing in the international portfolio. The efficiency condition for bonds' holdings will read as follow:

$$(c_t^*)^{-\sigma} = \beta(1+r_t^{n,*})E_t\left\{(c_{t+1}^*)^{-\sigma}\frac{p_t^*}{p_{t+1}^*}\right\} \tag{8}$$

All other optimality conditions are like in the home region. After substituting equation (7) into equation (5) and after merging with (5) we obtain the following relation:

$$E_t\left\{\frac{\lambda_{t+1}^*}{\lambda_t^*}\right\} = E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\frac{e_{t+1}^r}{e_t^r}\zeta\left(e_t^r\frac{b_t^*}{p_t^*}\right)\right\} \tag{9}$$

which states that marginal utilities across countries are equalized up to the spread for the country risk.

[11] As shown in Schmitt-Grohe and Uribe (2003) and Benigno (2002) this assumption is needed in order to maintain the stationarity in the model. Schmitt-Grohe and Uribe (2001) also show that adding this spread - i.e. whose size has been shown negligible in Lane and Milesi-Ferretti (2003) - does not change significantly the behavior of the economy as compared to the one observed under the complete asset market assumption or under the introduction of other inducing stationarity elements - see Mendoza (1991), Senhadji (2003), Ghironi (2001). The last observation applies in our case as well. We have decided to employ the incomplete structure with intermediation costs for international markets since this suits better with the structure of the financial markets used in Andolfatto (1996) which we use for workers' insurance.

3.2 The Production Sector In the Domestic and the Foreign Region

The maximization problems which characterize the production sector are symmetric across the two economies[12]. In the next section we show only the ones for the home region. Firms in the production sector sell their output in a monopolistic competitive market and meet workers on a matching market. The labor relations are determined according to a standard Mortensen and Pissarides (1999) framework.

3.2.1 Search and Matching in the Labor Market of the Home Region

The search for a worker involves a fixed cost κ and the probability of finding a worker depends on a constant return to scale matching technology which converts unemployed workers u and vacancies v into matches, m:

$$m(u_t, v_t) = m u_t^{\xi} v_t^{1-\xi} \tag{10}$$

where $v_t = \int_0^1 v_{i,t} di$. Defining labor market tightness as $\theta_t \equiv \frac{v_t}{u_t}$, the firm meets unemployed workers at rate $q(\theta) = \frac{m(u_t,v_t)}{v_t} = m\theta_t^{-\xi}$, while the unemployed workers meet vacancies at rate $\theta_t q(\theta_t) = m\theta_t^{1-\xi}$. If the search process is successful, the firm in the monopolistic good sector operates the following technology:

$$y_{i,t} = z_t n_{i,t} \int_{\tilde{a}_{i,t}}^{\infty} a \frac{f(a)}{1 - F(\tilde{a}_{i,t})} da = z_t n_{i,t} H(\tilde{a}_{i,t}) \tag{11}$$

where z_t is the aggregate productivity shock which follows a first order autoregressive process, $n_{i,t}$ is the number of workers hired by each firm, and $a_{i,t}$ is an idiosyncratic shock to firms which is assumed to be identically and independently distributed across firms and times with cumulative distribution function $F : [0, \infty] \to [0, 1]$. It is assumed that the idiosyncratic shock is observed before the firm starts production. The firm will endogenously discontinue the match if the realized shock, $a_{i,t}$, is below a certain cut-off value, $\tilde{a}_{i,t}$. The threshold for endogenous separation is determined as a function of the state of the economy using firms' optimality conditions. Matches are destroyed at varying rate $\rho(\tilde{a}_{i,t})$ given by the following expression:

$$\rho(\tilde{a}_{i,t}) = \rho^x + \rho^n(\tilde{a}_{i,t})(1 - \rho^x) \tag{12}$$

[12] We follow Krause and Lubik (2005).

where ρ^x is the exogenous break-up rate and $\rho^n(\tilde{a}_{i,t}) = F(\tilde{a}_{i,t})$ is the endogenous break-up rate.

We are now in the position to determine the law of motion for the workers employed and the ones seeking for a job. Labor force is normalized to unity. The number of employed people at time t in each firm i is given by the number of employed people at time $t-1$ plus the flow of new matches concluded in period $t-1$ who did not discontinue the match:

$$n_{i,t} = (1 - \rho(\tilde{a}_{i,t}))(n_{i,t-1} + v_{i,t-1}q(\theta_{t-1})) \tag{13}$$

Finally we define the gross job destruction and job creation rates as follows:

$$jd_t = \rho(\tilde{a}_{i,t}) - \rho^x \tag{14}$$

$$jc_t = \frac{(1 - \rho(\tilde{a}_{i,t}))v_{t-1}q(\theta_{t-1})}{n_{t-1}} - \rho^x \tag{15}$$

3.2.2 Monopolistic Firms

Firms in the monopolistic sector (of the home region) use labor to produce different varieties of consumption good and face a quadratic cost of adjusting prices. Hours worked and wages are determined through the bargaining problem analyzed in the next section. Here we develop the dynamic optimization decision of firms choosing prices, $p^i_{h,t}$, number of employees, $n_{i,t}$, number of vacancies, $v_{i,t}$, and the endogenous separation threshold, $\tilde{a}_{i,t}$, to maximize the discounted value of future profits and taking as given the wage schedule. Let's denote the total real wage bill of firm i (measured in CPI goods) by:

$$W_{i,t} = n_{i,t} \int_{\tilde{a}_{i,t}}^{\infty} w(a) \frac{f(a)}{1 - F(\tilde{a}_{i,t})} da \tag{16}$$

where $w(a)$ denotes the fact that the bargained wage might depend on idiosyncratic shock and other time varying factors. Given the definition of the terms of trade, $s_t \equiv \frac{p_{f,t}}{p_{h,t}}$, let's define:

$$\phi_t \equiv \frac{p_t}{p_{h,t}} = [(1-\gamma) + \gamma s_t^{1-\eta}]^{\frac{1}{1-\eta}} \tag{17}$$

The representative firm in the domestic region chooses $\left\{p^i_{h,t}, n_{i,t}, v_{i,t}, \tilde{a_{i,t}}\right\}$ to solve the following maximization problem (in real terms):

$$Max\Pi_{i,t} = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{p^i_{h,t}}{p_{h,t}} y^i_t - \phi_t W_{i,t} - \kappa v_{i,t} - \frac{\psi}{2} \left(\frac{p^i_{h,t}}{p^i_{h,t-1}} - 1 \right)^2 y^i_t \right\} \tag{18}$$

subject to

$$\text{s.to:} \qquad y^i_t = \left(\frac{p^i_{h,t}}{p_{h,t}} \right)^{-\epsilon} (c_{w,t}) = z_t n_{i,t} H(\tilde{a_{i,t}}) \tag{19}$$

$$\text{and: } n_{i,t} = (1 - \rho(\tilde{a_{i,t}}))(n_{i,t-1} + v_{i,t-1} q(\theta_{t-1})) \tag{20}$$

where $c_{w,t} = c_{h,t} + c^*_{h,t}$, where $\frac{\psi}{2} \left(\frac{p^i_{h,t}}{p^i_{h,t-1}} - 1 \right)^2 y^i_t$ represents the cost of adjusting prices and ψ can be thought as the sluggishness in the price adjustment process and κ as the cost of posting vacancies. Let's define mc_t, the lagrange multiplier on constraint (19), as the marginal cost of firms and μ_t, the lagrange multiplier on constraint (20), as the marginal value of one worker. Since all firms will chose in equilibrium the same price and allocation we can now assume symmetry and drop the index i. First order conditions for the above problem read as follows:

- n_t :

$$\mu_t = mc_t z_t H(\tilde{a_t}) - \phi_t \frac{\partial W_t}{\partial n_t} + \beta E_t (\frac{\lambda_{t+1}}{\lambda_t})((1 - \rho(\tilde{a_{t+1}}))\mu_{t+1}) \tag{21}$$

- v_t :

$$\frac{\kappa}{q(\theta_t)} = \beta E_t (\frac{\lambda_{t+1}}{\lambda_t})((1 - \rho(\tilde{a_{t+1}}))\mu_{t+1}) \tag{22}$$

- $p_{h,t}$:

$$\frac{c_{w,t}}{y_t}[1 - (1 - mc_t)\varepsilon] - \psi(\pi_{h,t} - 1)\pi_{h,t} + \beta E_t (\frac{\lambda_{t+1}}{\lambda_t})[\psi(\pi_{h,t+1} - 1)\pi_{h,t+1} \frac{y_{t+1}}{y_t}] = 0 \tag{23}$$

- $\tilde{a_t}$:

$$\mu_t \rho'(\tilde{a_t})(n_{t-1} + v_{t-1} q(\theta_{t-1})) + \phi_t \frac{\partial W_t}{\partial \tilde{a_t}} = mc_t z_t n_t H'(\tilde{a_t}) \tag{24}$$

Merging equations (21) and (22) gives the marginal value of an extra worker, μ_t, which is obtained by trading-off the cost of maintaining the match with an existing worker with the cost of posting a new vacancy:

$$\mu_t = mc_t z_t H(\tilde{a_t}) - \phi_t \frac{\partial W_t}{\partial n_t} + \frac{\kappa}{q(\theta_t)} \tag{25}$$

After substituting the marginal value of an extra worker, μ_t,into the optimality condition, (24), using the constraint which describes the evolution of employment, (20), and simplifying we obtain a relation between the threshold value and the real wage schedule:

$$mc_t z_t \tilde{a}_t - w(\tilde{a}_t)\phi_t + \frac{\kappa}{q(\theta_t)} = 0 \tag{26}$$

3.2.3 Bellman Equations, Wage Setting and Nash Bargaining

The wage schedule is obtained through the solution to an individual Nash bargaining process. To solve for it we need first to derive the marginal values of a match for both, firms and workers. Those values will indeed enter the sharing rule of the bargaining process. Let's denote by $V_t^J(a_t)$ the marginal discounted value of a match for a domestic firm measured in terms of domestic prices:

$$V_t^J(a_t) = mc_t z_t a_t - \phi_t w(a_t) + E_t\{(\beta\frac{\lambda_{t+1}}{\lambda_t})[(1-\rho(\tilde{a}_{t+1}))\int_{\tilde{a}_{t+1}}^{\infty} V_{t+1}^J(a_{t+1})\frac{f(a)}{1-F(\tilde{a}_{t+1})}da]\} \tag{27}$$

The marginal value of a match depends on real revenues minus the real wage plus the discounted continuation value. With probability $(1-\rho(\tilde{a}_{t+1}))$ the job remains filled and earns the expected value and with probability, $\rho(\tilde{a}_{t+1})$, the job is destroyed and has zero value. For each worker, the values of being employed and unemployed are given by V_t^E and V_t^U (expressed in terms of CPI):

$$V_t^E(a_t) = [w_t + E_t\{(\beta\frac{\lambda_{t+1}}{\lambda_t})[(1-\rho(\tilde{a}_{t+1}))\int_{\tilde{a}_{t+1}}^{\infty} V_{t+1}^E(a_{t+1})\frac{f(a)}{1-F(\tilde{a}_{t+1})}da + \rho(\tilde{a}_{t+1})V_{t+1}^U]\} \tag{28}$$

$$V_t^U = [b+E_t\{(\beta\frac{\lambda_{t+1}}{\lambda_t})[\theta_t q(\theta_t)(1-\rho(\tilde{a}_{t+1}))\int_{\tilde{a}_{t+1}}^{\infty} V_{t+1}^E(a_{t+1})\frac{f(a)}{1-F(\tilde{a}_{t+1})}da+(1-\theta_t q(\theta_t)(1-\rho(\tilde{a}_{t+1})))V_{t+1}^U]\} \tag{29}$$

where b denotes real unemployment benefits.

Nash bargaining. Workers and firms are engaged in a Nash bargaining process to determine wages. The standard Nash bargaining problem is given by:

$$\max_w \left(\phi_t(V_t^E(a_t) - V_t^U)\right)^{\varsigma} \left(V_t^J(a_t)\right)^{1-\varsigma} \tag{30}$$

where ς stands for the bargaining weight of the workers. After substituting the previously defined value functions in the optimal sharing rule it is possible derive the following wage schedule:

$$w_t(a_t) = \varsigma(mc_t z_t a_t + \theta_t\kappa)\frac{1}{\phi_t} + (1-\varsigma)b \tag{31}$$

Total real wage is obtained by aggregating across employees: $w_t = \int_{\tilde{a}_t}^{\infty} w(a) \frac{f(a)}{1-F(\tilde{a}_t)} da$. Equation (31) shows how the replacement rate affects the real wage which in turn has an impact on the threshold value of the idiosyncratic shock, as shown by equation (26), and on the marginal cost. From equation (25) indeed we can derive a measure of the marginal cost in our model which reads as follows:

$$mc_t = \frac{1}{z_t H(\tilde{a}_t)} [\phi_t \frac{\partial W_t}{\partial n_t} + \mu_t - \frac{\kappa}{q(\theta_t)}]$$

The first component of this measure is given by the marginal wage bargained divided by the labor productivity. This relation shows that the dynamic of the real wage has an impact on the dynamic of the marginal cost which in turn has an impact on the dynamic of inflation via equation (23).

Real wage rigidity. As shown in Shimer (2003), Hall (2003) and Krause and Lubik (2005) introducing real wage rigidity improves the performance of the matching model in terms of the dynamic of labor market variables. We borrow from Hall (2003) and assume a simple form of wage rigidity which serves well our purposes. In particular we assume that the individual real wage is weighted average of the one obtained through the Nash bargaining process and the one obtained as solution to the steady state[13]:

$$w_t(a) = \lambda[\varsigma(mc_t z_t a_t + \theta_t \kappa)\frac{1}{\phi_t} + (1-\varsigma)b] + (1-\lambda)w(a) \tag{32}$$

3.3 The Monetary Policy Rule in the Currency Area

An active monetary policy sets the short term nominal interest rate by reacting to an average of the inflation levels in the area. This rule rationalizes the behavior of the stability pact signed by euro area countries:

$$r_t^n = \exp(\frac{1-\chi}{\beta})(r_{t-1}^n)^{\chi}((\frac{\pi_t + \pi_t^*}{2})^{b_\pi})^{1-\chi} m_t \tag{33}$$

b_π is the weight that the monetary authority puts on the deviation of CPI inflation and is set equal to 1.5. m_t is a temporary monetary policy shock. In addition following Clarida, Gali' and Gertler (2000) and Rotemberg and Woodford (1997) we assume that monetary policy applies a certain degree χ of interest rate smoothing. Aside from being consistent with most evidence on monetary

[13] Hall (2003) proves that such a wage rule follows inside the range defined by the bargaining set.

policy rules the interest rate smoothing helps to generate more persistent effect of monetary policy shocks.

3.4 Equilibrium Conditions

Aggregate output is obtained by aggregating production of individual firms and by subtracting the resources wasted into the search activity:

$$Y_t = n_t z_t \int_{\tilde{a}_t}^{\infty} a \frac{f(a)}{1 - F(\tilde{a}_t)} da - \kappa v_t \tag{34}$$

After imposing market clearing, aggregating and recalling that $p_{h,t} = e_t p^*_{h,t}$, we can express the resource constraint as:

$$n_t z_t \int_{\tilde{a}_t}^{\infty} a_t \frac{f(a)}{1 - F(\tilde{a}_t)} da - \kappa v_t = \left(\frac{p_{h,t}}{p_t}\right)^{-\eta} (1-\gamma)\, c_t + \left(\frac{p_{h,t}}{e_t p^*_t}\right)^{-\eta} \gamma^* c^*_t + \frac{\psi}{2}\left(\frac{p^i_{h,t}}{p^i_{h,t-1}} - 1\right)^2 y_t \tag{35}$$

We assume zero total net supply of bonds.

3.5 Calibration

Preferences. Time is taken as quarters. We set the discount factor $\beta = 0.99$, so that the annual interest rate is equal to 4 percent. We set the elasticity of substitution between domestic and foreign goods η equal to 1.5 as in Backus, Kehoe and Kydland (1992). The parameter on consumption in the utility function is set equal to one. This value is compatible with a steady state trade balanced growth path. We set the steady state balanced growth ratio of exports over GDP to $\gamma = 0.25$, value compatible with data for European countries. Finally we assume that the steady state net asset position is symmetric between the two countries. Following Schmitt-Grohe and Uribe (2003) and consistently with Lane and Milesi-Ferretti (2003) we set the elasticity of the spread on foreign bonds to the net asset position equal to 0.000742.

Production. Following Basu and Fernald (1997) we set the value added mark-up of prices over marginal cost to 0.2. This generates a value for the price elasticity of demand, ε, of 6. We set the cost of adjusting prices $\psi = 100$ to generate a slope of the log-linear Phillips curve equal to 0.10. This is compatible with the estimates by Benigno and Lopez-Salido (2002) for France and

Germany. We have also checked our results with different values for ψ and verified that they remain unchanged.

Labor market frictions parameters. The matching technology is a homogenous of degree one function which is characterized by the parameter ξ. Consistently with estimates by Blanchard and Diamond (1991) we set this parameter to 0.4. We set the firm matching rate, $q(\theta)$, to 0.7 which is the value used by denHaan, Ramsey and Watson (1997). The probability for a worker of finding a job, $\theta q(\theta)$, is set equal to 0.6, which implies an average duration of unemployment of 1.67 as reported ion Cole and Rogerson (1996). With those values it is possible to determine the number of vacancies as well as the vacancy/unemployment ratio. We set the exogenous separation probability, ρ^x, to 0.08 and the steady state overall separation rate, $\rho(\tilde{a})$, to 0.1. With those values it is possible to obtain the endogenous separation rate, $\rho^n(\tilde{a}) = \frac{(\rho(\tilde{a})-\rho^x)}{(1-\rho^x)}$, and the threshold value, $\tilde{a} = F^{-1}(\rho^n)$. The idiosyncratic shock is distributed as a lognormal with unitary mean and standard deviation equal to 0.20. Finally we set the degree of wage rigidity, λ, equal to 0.5 as benchmark value.

Labor market institutions. As in Krause and Lubik (2005) the unemployment benefit is obtained as solution to the steady state. In particular we assign we assign values to the unemployment benefit parameter, b, so as to generate values for the $\frac{b}{w}$ ratio which are in the range of the ones used in figure (1) and (2).

Exogenous shocks and monetary policy: We consider domestic and foreign aggregate productivity shocks, z_t and z_t^*. We follow Backus, Kehoe and Kydland (1992) and calibrate their standard deviations to 0.008, their correlation to 0.258 and their persistence to 0.95. We also consider an i.i.d. common monetary policy shock, m_t, whose standard deviation is calibrated using data from Mojon and Peersman (2000). Following several empirical studies for Europe (see Clarida, Gali' and Gertler (2000), Angeloni and Dedola (1998) and Andres, Lopez-Salido and Valles (2003) among others) we set the interest rate smoothing parameter, χ, equal to 0.8.

4 Quantitative Properties of the Model

In this section we analyze the main quantitative properties of the model and the impulse response functions of the main variables. We have two goals in mind. First, we want to validate the model, showing that it mimics well the main business cycle properties of the euro area economy. Second, we calculate impulse responses to provide a first assessment on how different values of the replacement rate generate different responses of wages, marginal costs, and inflation, to better understand the structural links among these variables. Having done this, the next section will be devoted to assess whether the model can replicate the stylized facts shown earlier.

Table (2) shows standard deviations of selected variables (relative to output) for euro area data[14] and for the model economy. Standard deviations for the model have been computed by simulating the model 100 times for 200 periods and calculations are based on Hodrick-Prescott filtered series. As customary in the real business cycle literature, we simulate both technology and common monetary policy shocks, all of which are calibrated on euro area data (see calibration section). In computing the statistics for this table we assumed complete symmetry between the two countries for all parameters, including those of the labor market – in the next section instead we will allow these parameters to vary to show their impact on the relevant volatilities. This implies that the sizes of the standard deviations for the home and the foreign countries are very similar[15]. We observe that the model is able to replicate well the standard deviations of output, consumption, employment and inflation in the euro area[16]. Another way to assess the quantitative properties of our model economy concerns the model ability to replicate the international co-movements. It is well-known that output and employment are positively correlated across countries (see Backus, Kehoe and Kydland (1985) and Faia (2005)). Our simulations (with both productivity and monetary policy shocks) show that our model economy generates a correlation between home and foreign output of 0.53 and a correlation between home and foreign employment of 0.93.

We now use impulse response analysis to provide a first assessment of the differential impact of different replacement rates on the two countries dynamics. We calibrate the model so that the home country has a smaller replacement rate than the foreign country, while in all the other parameters

[14] Standard deviations of euro area data for GDP, consumption, inflation are taken from Agresti and Mojon (2003) who computed them by averaging standard deviations for all euro area countries. The data used in Agresti and Mojon (2003) are for the period 1970-2000 and have been de-trended using the band pass filter by Baxter and King (1999). The standard deviation for employment is taken from Backus, Kehoe and Kydland (1985).

[15] Although not the same since the productivity shocks have a correlation of 0.25.

[16] Unfortunately it is not possible to calculate empirical standard deviations for vacancies and labor market tightness since it is not possible to find long enough series for euro area countries. The model standard deviations are somewhat lower than the ones calculated by Krause and Lubik (2003) for the U.S. (8.27 for vacancies and of 14.96 for labor market tightness).

the two countries are symmetric. In particular we set the replacement ratio for the home and the foreign country equal to 0.22 and 0.77.

We start by considering positive technology shocks. Figure (3) we report the impulse response functions of domestic variables to domestic technology shock (solid line in each panel) and of foreign variables to a foreign technology shocks (dashed line in each panel).

By plotting in the same panels impulse responses to shocks of the same size we can appreciate the impact of different replacement rates across countries. Let's start to analyze the impulse responses of domestic variables to a domestic productivity shock. On impact, as we can see from figure (3), domestic output rises but domestic employment and wages fall. The fall in employment is due mainly to the assumption of price rigidity (see Gali' (2005))[17]. The threshold for the individual productivity increases in the first period since the initial fall in employment induces firms ti fire first the less productive workers. In the subsequent periods prices can fully adjust hence employment increases while individual productivity decreases below its steady state level. This mechanism would be observable also in a closed economy but in an open economy framework it is amplified by the terms of trade effect. Because of the domestic technology improvement domestic goods become cheaper than foreign ones hence domestic exports and demand increase.

Let's now analyze the dynamic of foreign variables in response to a foreign productivity shock. Since the foreign country has a higher replacement rate this comparison can reveal the role played by replacement rates. As already noted, employment and wages decline in both countries after a positive technology shock. Since in the home country domestic workers face a lower replacement rate, they also face worst outside option, hence they are willing to accept a larger reduction in wages in order to keep their jobs. Hence in response to a domestic technology shocks domestic wages fall by more than foreign wages under an equal sized foreign technology shocks. Moreover the fall in domestic marginal costs and inflation in response to domestic technology shocks is higher than the fall in foreign marginal costs and inflation under foreign technology shocks.

Figure (4) shows the dynamic of home and foreign variables after a monetary policy tightening. In our setting (currency union, same transmission mechanisms), this is a perfectly symmetric

[17] Due to price rigidity, firms in the first period will not reduce the prices as they would have done without adjustment costs. Therefore, aggregate demand increases by less than in the flexible price case. Since the productivity increase allows to produce the same amount with less work this leads to lower employment and real wages.

demand shock. Output and employment contract in both countries. However domestic wages, marginal costs and inflation fall below the foreign ones. This is because domestic workers face lower replacement rates, hence worst outside options in case of unemployment. This implies that domestic workers are willing to accept bigger reductions in wages in order to keeps their jobs. The higher volatility in domestic wages induces also higher volatility in marginal costs and inflation.

In general we can conclude that under both demand and supply shocks real wages, marginal cost and inflation are more sensitive for countries with lower replacement rates.

4.1 Matching the Data

We conduct our data matching exercise by showing that the model can reproduce the relationship in the data between ratios of volatilities (of real wages, marginal costs and inflation) and ratios of replacement rates across pairs of countries. The reason why we do this instead of simply showing the relationship between replacement rate levels and volatility levels for an individual country is that, when changing the value of the replacement rate in (say) the foreign country, the equilibrium volatilities change both at home and abroad, even if the replacement rate at home remains unchanged. The volatility spillover is stronger if the two economies are closely interconnected, as is the case in EMU. Hence, in order to correctly match the extent to which differences in labor market structures generate differences in volatility for our three variables, we need to be able to approximate well the interpolating curves shown in figure (2) (panels a, b and c).

Figure (5) (a, b, and c) shows the exponential interpolation curves shown in figure (2) together with its model-based equivalents. Model-based standard deviations are computed using simulated series with length T=200 and calculations are based on the Hodrick-Prescott filtered series. We shock the model with both technology and monetary policy shocks calibrated on euro area data, as described earlier. Considering both shocks allows us to account for the closest possible match between the data and the model. The range of variation for the ratio of the replacement rates corresponds to the one found for the euro area countries from the Nickell and Nunziata (2001) dataset.

As we can see, the model is able to replicate the negative relations found in the data for all the three variables, thereby confirming our mechanism. Interestingly the model-based relations are non-linear and convex with respect to the origin, as our exponential interpolations. The shapes of the theoretical curves broadly (though not perfectly, as one would expect) match the empirical ones[18].

4.2 The Impact of Employment Protection

To further assess the ability of our model to replicate empirical facts regarding the impact of labor market institutions on the business cycle we repeated the entire analysis so far described but using instead of the *replacement rate* an indicator of the *employment protection*. This indicator can be considered as a proxy of the *worker bargaining power,* ς, and data are taken again from the dataset of Nickell and Nunziata (2001).

In the theoretical model a positive relation exists between business cycle responses of real wages, marginal costs and inflations on the one side and the sizes of the bargaining power, ς,on the other[19]. Intuitively an increase in the workers' bargaining power increases the value of an existing job relative to the outside option. This implies that in response to shocks workers are more willing to accept large swings in real wages while keeping the existing jobs.

Data for the EMU countries show an inverse relation between employment protection and replacement rates exactly as in the model[20]. This implies a positive relation between business cycle responses of real wages, marginal costs and inflations on the one side and the employment protection on the other.

We therefore conclude that the model implications remain valid even when labor market institutions are proxied by a different and equally important indicator.

5 Conclusions

In this paper we study the role of labor market differences in generating differential inflation volatility among euro area countries. To do this we use a stylized DSGE model where labor market frictions are an important determinant of the dynamics of marginal costs of firms, which in turn are a main driver of inflation. We find that differences in labor market institutions (proxied by the

[18] The model generates a negative relation also between absolute levels of real wages, marginal cost and inflation on the one side and the levels of replacement rates on the other. However, the shape of the curve is not convex, but concave relative to the origin. Results are not reported for brevity but are available on request.

[19] Note that in the steady state of our model there is a negative relation between the replacement rate and the bargaining power.

[20] Figures regarding the aforementioned relations are available upon request.

unemployment insurance replacement rates, or alternatively by a measure of workers' bargaining power) can generate significant volatility differentials in real wages, marginal costs for firms and inflation when the model is subject to a variety of realistic shocks. The volatilities of the three aforementioned variables tend to be higher when the unemployed is less protected (low replacement rate) or the employed is more protected (high bargaining power). The link between labor market institutions and volatilities embodied in our model approximates well the one observed in the data.

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Table 1: **Masures of benefit replacement rates (benefit as a ratio to average earnings before taxes taken from Nickell and Nunziata). Average over 1985 to 1995.**

Countries	Benefit Duration
Austria	0.75
Belgium	0.77
Finland	0.53
France	0.49
Germany	0.61
Ireland	0.54
Italy	0.09
Netherlands	0.47
Portugal	0.60
Spain	0.26

Table 2: **Business cycle properties of the euro area economy and of the model economy.**

	Euro area	Model economy	
Standard deviation		Home country	Foreign country
Output	1.14	1.59	1.61
Consumption	0.78	0.93	0.94
Inflation (GDP deflator)	0.5	0.5	0.49
Employment	0.85	0.87	0.85
Vacancies	...	5.17	5.04
Tightness	...	11.38	11.13

Statistics for the euro area are taken from Agresti and Mojon (2003) except for the standard deviation of employment which is taken from Backus, Kehoe and Kydland (1985).

All standard deviations are relative to output. Statistics from the model are Hodrick-Prescott filtered. and are computed under two correlated productivity shocks and one common monetary policy shock.

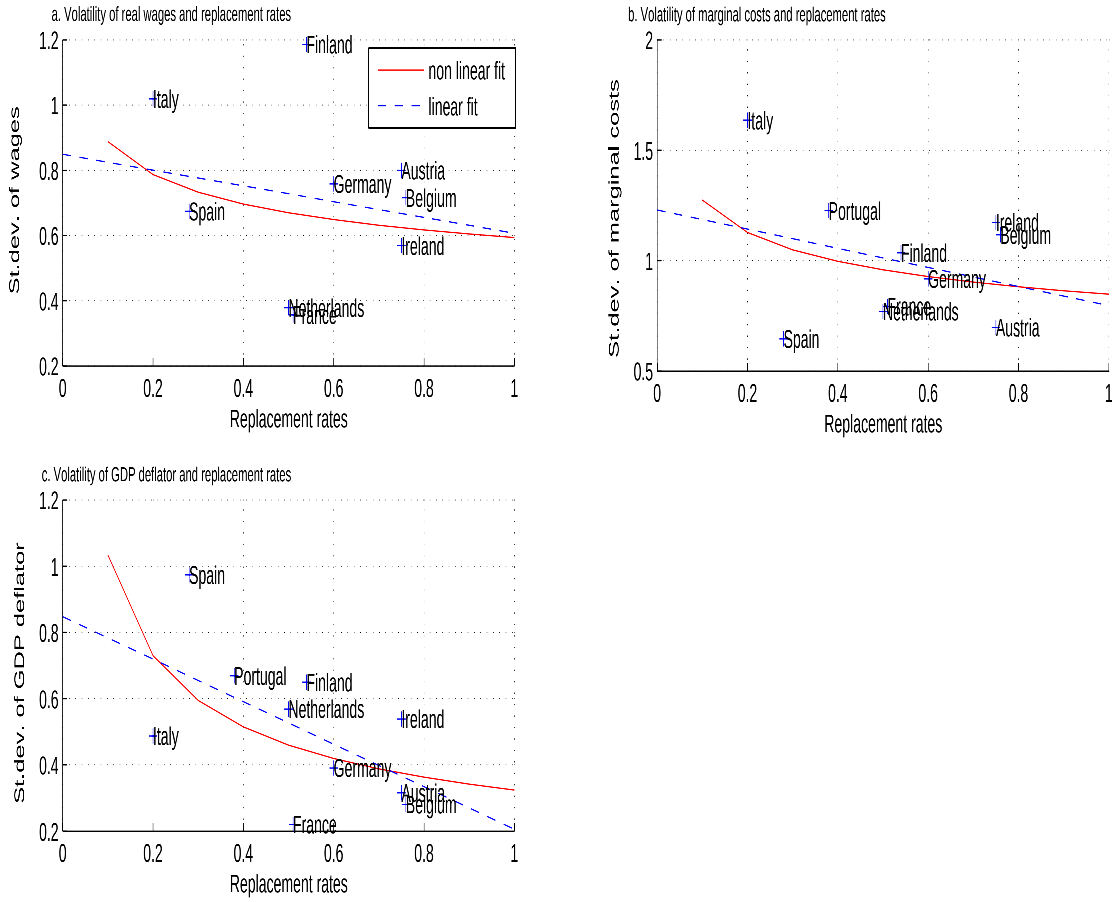

Figure 1: **Relation between standard deviation of wages, marginal costs and inflation (relative to that of output) and replacement rates for the EMU countries.**

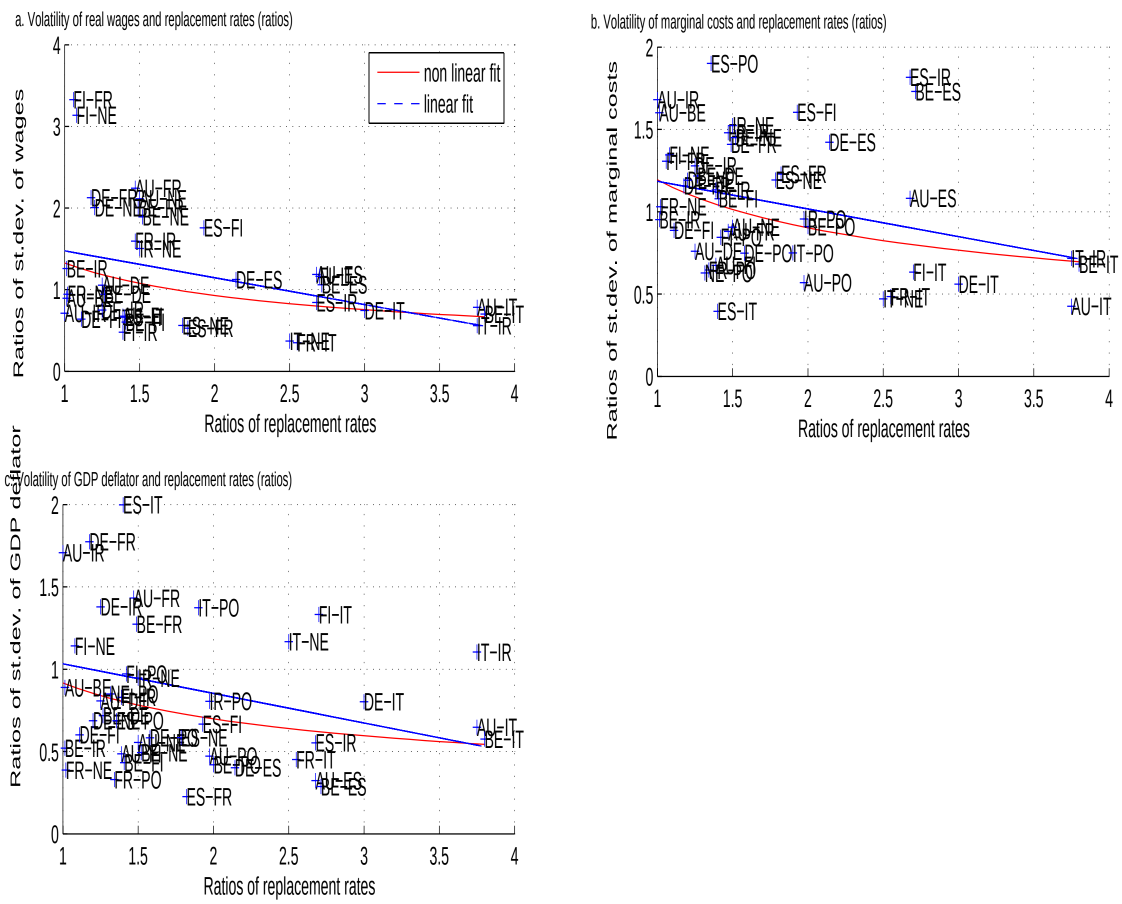

Figure 2: **Relation between ratios of standard deviation of wages, marginal costs and inflation (relative to that of output) and ratios of replacement rates for the EMU countries.**

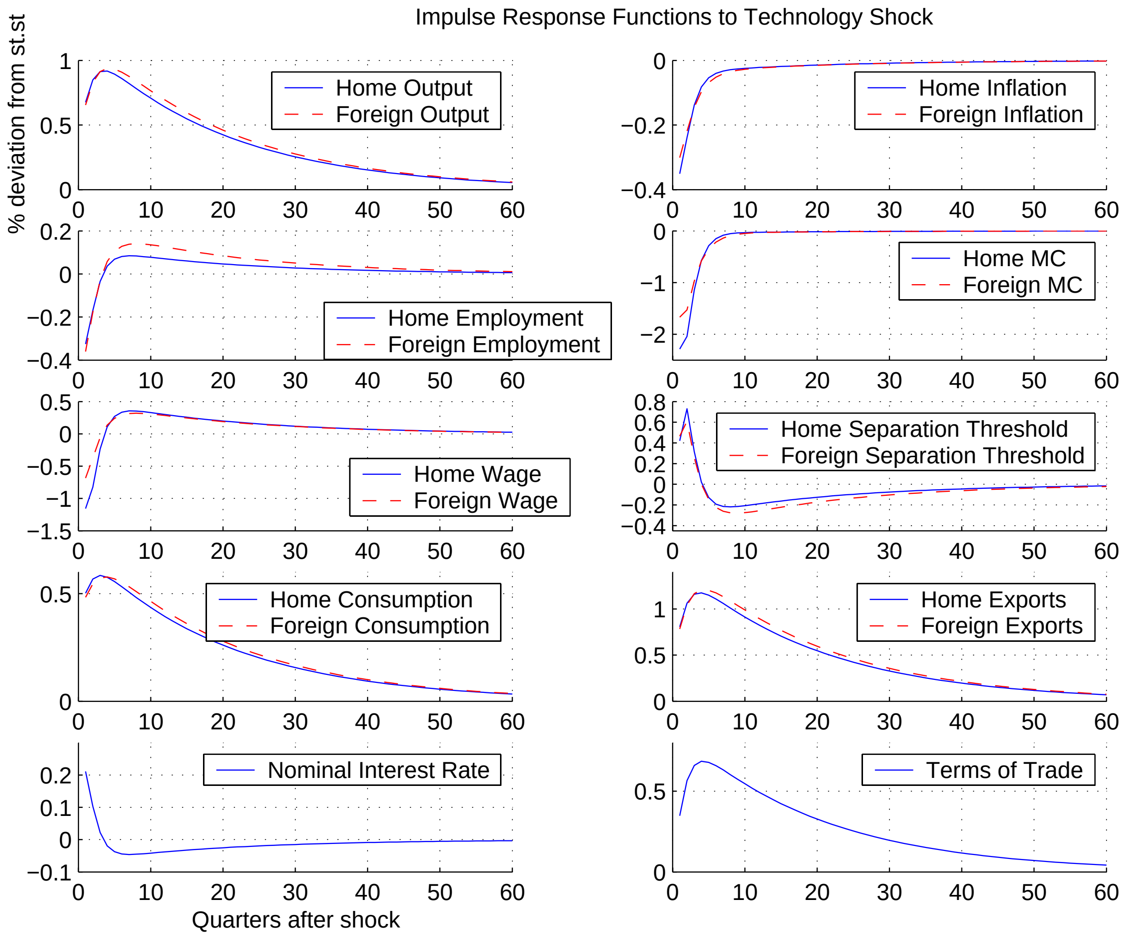

Figure 3: **Impulse responses of selected domestic and foreign variables to domestic (solid line) and foreign technology (dashed line) shocks.**

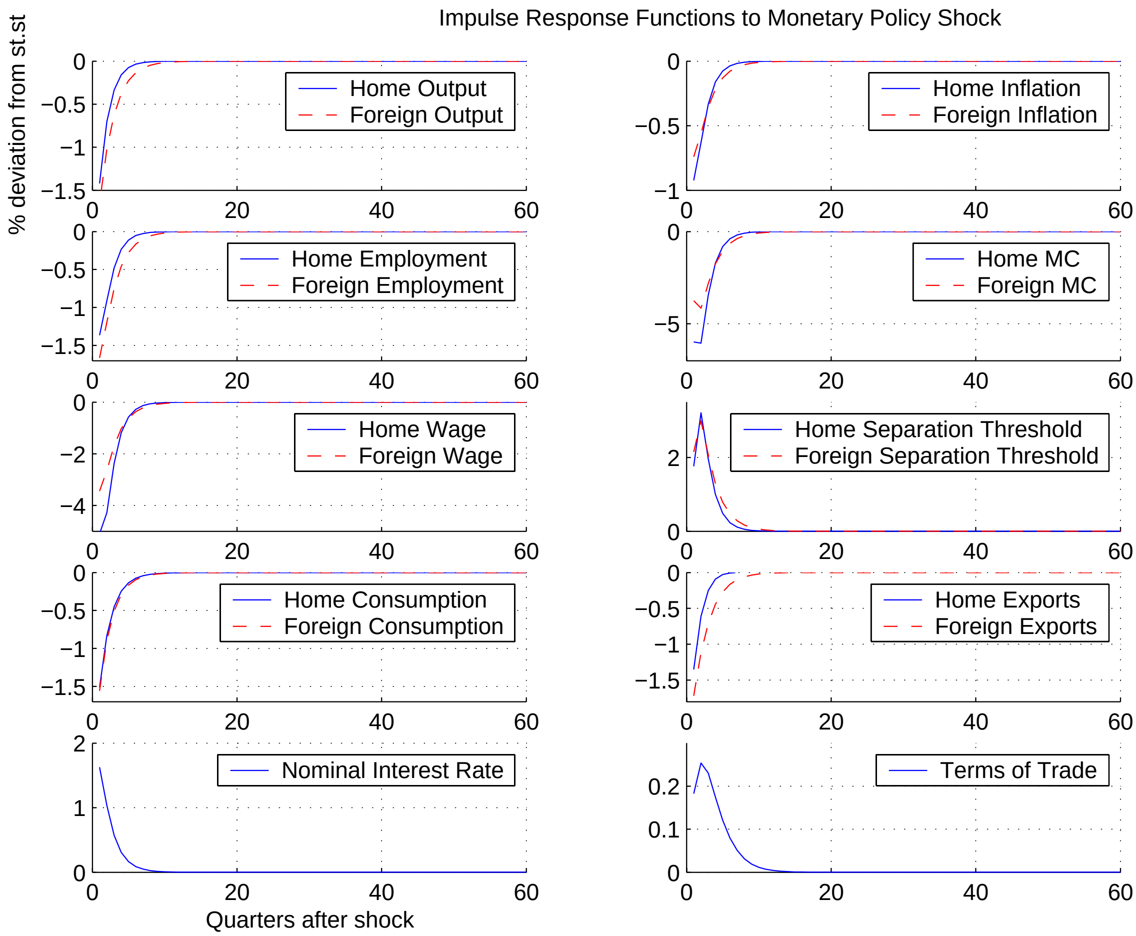

Figure 4: **Impulse responses of selected domestic and foreign variables to common monetary policy shocks.**

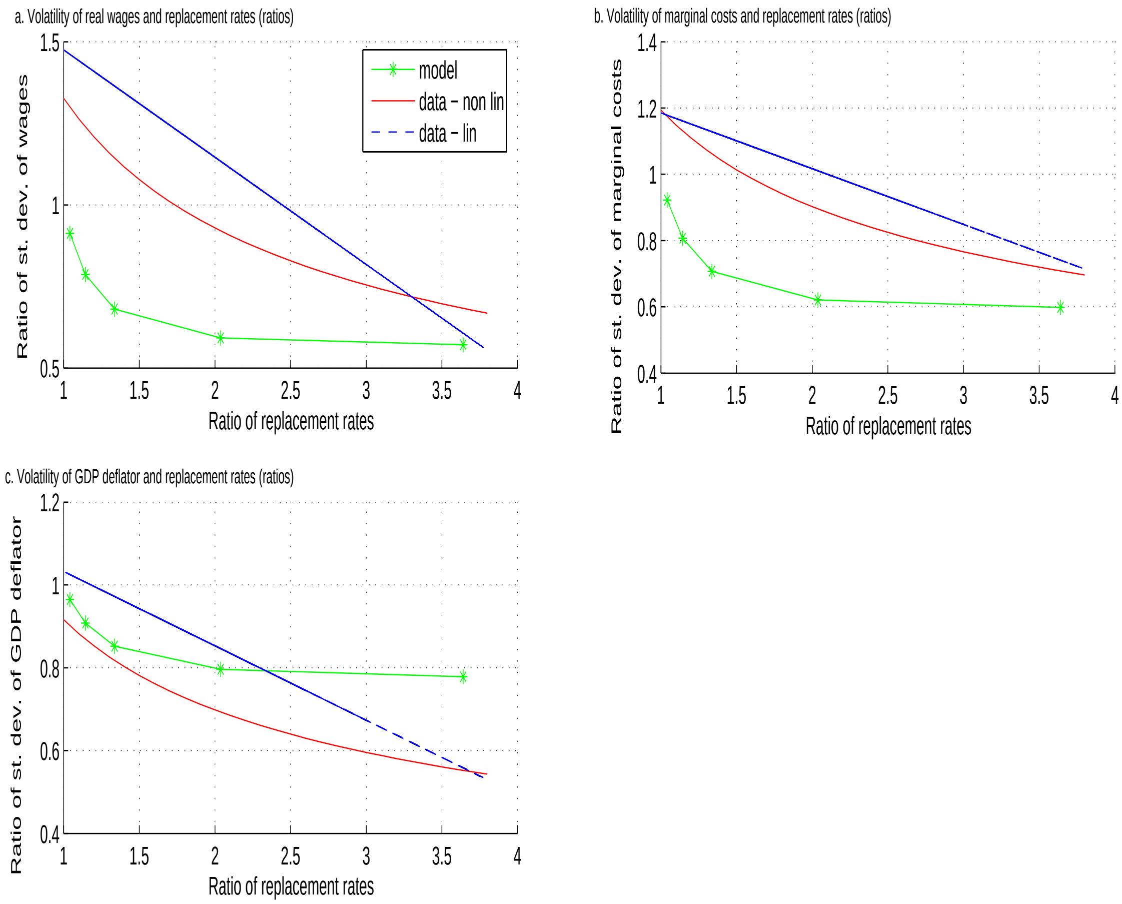

Figure 5: **Relation between ratios of standard deviation of wages, marginal costs and inflation (relative to that of output) and ratios of replacement rates both in the data and in the model.**