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Taking Real Wage Rigidities Seriously: Implications for Optimal Policy Design in a Currency Union

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Taking Real Wage Rigidities Seriously: Implications for Optimal Policy Design in a Currency Union

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ABSTRACT This paper analyzes optimal monetary and fiscal policy in a monetary union from a union-wide perspective, using a multi-country New Keynesian business-cycle model with rigid real wages. Fiscal policy is implemented at the country level through decisions regarding government spending, while the monetary authority sets a common nominal interest rate. It is found that in the presence of country-specific shocks as well as symmetric shocks, there is a country-level trade-off between stabilizing inflation and the output gap. After a union-wide shock, the common monetary authority also faces a trade-off. If shocks are symmetric, the optimal union-wide policy requires that the common central bank conduct a countercyclical policy, allowing for more relative inflation volatility than the amount actually allowed by the ECB. The role of policies is reversed at the domestic level, where the government stabilizes the economy via a countercyclical policy, regardless of whether shocks are symmetric.

KEY WORDS: Monetary union, inflation inertia, real wage rigidities, countercyclical policy

1. Introduction

Due to the latest economic downturn, the public (and academic) debate about monetary policy in the Euro area has flared up again. Although under some political pressure, the European Central Bank (ECB) adheres to its principle of stabilizing the price level. Compared to its US counterpart, the Federal Reserve

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System (Fed), the ECB uses monetary policy in order to stabilize the economy, but it does so very tentatively. This policy is in line with some of the cutting-edge models used for advice regarding monetary policy. Strict price-level targeting corresponds to the recent emphasis in modeling economies within the New Keynesian (NK) framework on stabilizing the output gap. In this setting, there is no trade-off between price stability and the stability of output around potential. In the last few years, this modeling framework has become very popular as a theoretical basis for policy decisions for Western central banks. This dynamic modeling approach assumes imperfect competition in the goods market and sluggish nominal price adjustment. Inspired by a seminal paper of Clarida *et al.* (1999), much research effort has been put into the advancement of these NK theories.

The formation of a monetary union in Europe and the debate about the 'Stability and Growth Pact' (SGP) make the analysis of fiscal and monetary interactions an especially important topic. It is often argued that the loss of monetary policy flexibility due to the merger of currencies increases the potential role of fiscal policy as a stabilization tool and the need for cooperation within Europe with regard to fiscal policy. Therefore, to optimally characterize policy in the European Monetary Union (EMU), the fiscal stance has to be taken into account. The interaction of monetary and fiscal policy in a NK modeling framework has been examined, for instance, by Corsetti and Pesenti (2001) and Schmitt-Grohé and Uribe (2004) (for a closed economy) or by Lombardo and Sutherland (2004) and Leith and Wren-Lewis (2008) (for an open economy).

Despite its potential relevance for political decision makers, only a few papers considering monetary and fiscal aspects in a currency union have been written in recent years. Most of the existing literature that does analyzes monetary and fiscal policy within a micro-founded, two-country sticky-price model of a monetary union (e.g. Beetsma and Jensen, 2005; Ferrero, 2009). As a two-country approach may be useful for discussing issues concerning the interaction between two large economies (e.g. the EU and the US), it can hardly be viewed as a realistic description of a monetary union such as the EMU, which currently has 16 member states. Just recently, Galí and Monacelli (2008) proposed a framework that incorporates the features mentioned above but comprises many open economies linked by trade and financial flows. As most of the member states of the EMU are small relative to the union as a whole, domestic policy decisions have little impact on other member states. Next to a more realistic modeling approach, this framework provides the possibility of studying policy problems for a single member country considered in isolation. The implications for monetary and fiscal policy, however, are (qualitatively) similar: (a) the common central bank never faces a trade-off between stabilizing output and inflation (i.e., stabilizing the price level is always optimal), and (b) an active domestic fiscal policy is only justified by the inefficient response of the terms of trade.

After having been largely ignored by monetary economists for a long time, the importance of real rigidities for monetary policy has received fresh impetus with a recent paper by Blanchard and Galí (2007). They show that including rigid real wages in a NK business-cycle model leads to a notable trade-off between stabilizing the price level and the welfare-relevant output gap. Moreover, as already highlighted in Galí *et al.* (2001), by constituting a channel from wage

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to inflation dynamics through firms' marginal costs, a slow adjustment in wages will translate into more persistent movements in inflation, which is particularly found in European data.

Real wage rigidity indeed seems to be an important feature of European labor markets. As found by Apaia and Pichelmann (2007), who use micro data from all EMU countries, the half-lives of deviations of the real wages from their equilibrium level vary between three quarters and three years.

As a result, in the analysis of European-wide monetary and fiscal policy design, real wage rigidity can hardly be neglected. Despite its importance, research in this direction its still in its infancy. Campolmi and Faia (2006) and Abbritti (2007) are the first (and as far as I know remain the only) authors to include real wage rigidity in a dynamic model of a currency union.

Thus, in my opinion, an analytical framework of the EMU should have the following four properties: it has to rely on the assumptions of standard NK theory (i.e. imperfect competition and nominal rigidities), should include a monetary and fiscal authority, has to comprise many open economies (not only two), and has to incorporate real rigidities.

The model I propose in this paper meets all desiderata listed above. More precisely, I use a version of the Galí and Monacelli (2008) model extended by a partial adjustment process of the real wage and households as monopolistic labor suppliers. I focus on policy rules that are optimal (in welfare terms) from the union's and not from the national perspective. This implies that union-wide monetary policy and domestic fiscal policy are perfectly coordinated to maximize overall welfare. Moreover, I assume that both fiscal and monetary authorities implement Ramsey solutions (i.e., optimal commitment strategies).

The main findings of the analysis are as follows. Because I assume that a single member country has no impact on union-wide economic conditions, an idiosyncratic shock does not affect union-wide economic dynamics. Therefore, the common central bank has no need to intervene. However, if each member country is affected by a shock (or it is not idiosyncratic), the common central bank faces a trade-off between stabilizing the price level and the welfare-relevant output. The quantitative simulations show that the optimal volatility of inflation (relative to output gap volatility) increases with the importance of real rigidities. This stands in contrast with the findings of Galí and Monacelli (2008). Furthermore, I find that optimal domestic fiscal policy also plays a national stabilization role if shocks are symmetric, as rigid real wages are an additional source of a trade-off, along with inefficient adjustments in terms of trade. The basic rationale for this is simple. Rigid real wages prevent marginal costs from adjusting efficiently. This causes pressure on the national price level. To dampen (dis)inflation, the optimal policy absorbs the (dis)inflationary pressure by a change in output (relative to its efficient outcome), which has to be stimulated to some degree by national fiscal policy. Because optimal domestic fiscal policy has an important stabilizing role, from a union-wide perspective, external constraints such as the SGP should be seen in a different light.

The remainder of this paper is set out as follows: section 2 describes the related literature. The underlying model is outlined in section 3. Then, a short overview of the implementation method is given, and the baseline calibration of the model

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is presented. The results of the analysis are reported in section 6. Section 7 concludes.

2. Related Literature

An extensive amount of work has been done on monetary policy in micro-founded models with sticky prices. Additionally, the interaction between monetary and fiscal policy in such a framework has been analyzed in recent years (e.g., Schmidt-Grohe & Uribe, 2004, or Leith & Wren-Lewis, 2008). Although it has become acutely important with the creation of the EMU, multi-country versions of these models have attained less attention. Benigno (2004) analyzes the optimal monetary policy in a two-country framework. Neglecting the role of fiscal policy, he shows that in the presence of idiosyncratic shocks to technology, stabilizing the price level is desirable from a welfare perspective. In a similar setting but including national fiscal authorities, Beetsma and Jensen (2005) furthermore find evidence that countercyclical spending on national level is welfare enhancing from a union-wide perspective. As aforementioned, Galí and Monacelli (2008) also study optimal monetary policy and the role of fiscal stabilization. However, in a multi-country framework, they derive quite similar implications for how monetary and fiscal policy should be implemented. Based on the Galí and Monacelli (2007) model, Forlati (2007) analyzes fiscal policy under no-coordination. She finds that the normative prescriptions emphasized by the authors mentioned above are no longer valid once policymakers are not coordinated. In this case, optimal monetary policy does not imply that the central bank stabilizes the average union inflation, as it has to take into account the distortions caused by the lack of coordination among fiscal policymakers. Ferrero (2009) additionally examines the role of distortionary taxation in a two-country framework, again from a union-wide perspective. In his setting, monetary policy should achieve aggregate price level stability, while fiscal policy should stabilize country-specific shocks via permanent variations of government spending and tax gaps but abstain from creating inflationary expectations at the union level.

A first step in introducing real rigidities in a two-country model of a currency union is taken by Campolmi and Faia (2006). They focus on the investigation of the impact of labor-market imperfections on inflation differentials between members rather than on optimal policies. Closer to the framework used in this paper is the modeling approach used in Abbritti (2007). However, Abbritti considers a world consisting of only two countries and additionally assumes market rigidities, which generate involuntary unemployment. He introduces a real wage rigidity that follows a stochastic process. Furthermore, the studies of Campolmi and Faia (2006) and Abbritti (2007) do not include a fiscal sector in their analysis; neither is a welfare analysis or a derivation of optimal policies part of their analysis.

In addition to the literature on sticky price models of a currency union, papers using real wage rigidities in NK models should be briefly reviewed. Just recently Blanchard and Galí (2007) reconsider the impact of rigid real wages on monetary policy design in a closed economy. Within a basic NK model, they show that the presence of the inertial adjustment of real wages leads to a notable trade-off in monetary policy design. They find that under this additional assumption,

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there is a trade-off between stabilizing inflation and the welfare-relevant output. Moreover, they find that taking into account rigid real wages is a crucial element in understanding persistent inflation.

Next to sticky inflation dynamics, real wage rigidity can also help to explain observed labor-market fluctuations. As shown by Hall (2005) and Shimer (2005) real wage rigidity is necessary to explain the large cyclical variation in job vacancies.[1]

Inspired by these papers, some richer sticky price models with rigid real wages – additionally considering labor-market frictions – have been developed (e.g. Christoffel & Linzert, 2005; Faia, 2008).

Especially in European countries, inertial adjustment in real wages seems to be an important feature for properly understanding labor market dynamics. It is often argued that European labor markets are rigid in many perspectives. High firing costs and unemployment benefits and collective wage bargaining in particular prevent wages from adjusting instantaneously. There is a lot of micro-founded theory for possible reasons intensifying this rigidity. Among others, one could mention efficient wage contracts, loss aversion, strong union power, or fairness considerations.[2] Empirical evidence for rigid real wages has been given by a number of studies in recent years.[3] They all attest relatively high real wage rigidity in the EU (compared with the US).

3. The Model

The model I use to derive the optimal monetary and fiscal policy in a currency union is, in the spirit of Galí and Monacelli (2008), a variant of a dynamic New Keynesian (NK) model applied to a mass of small open economies sharing the same currency. The world consists of a continuum of small open economies indexed by $i \in (0, 1)$. Each economy is of measure zero; from this, it follows that a domestic policy decision has no impact on the rest of the union. The absence of feedback effects allows, in contrast to a more conventional two-country model, us to assess the optimal policy problem for a single member country considered in isolation, which is one of the central exercises in this paper. It is assumed here that all countries share identical preferences, technologies, and market structures but have different real wage rigidities.

3.1 *People*

Consider a typical country belonging to the union, say, country i. This country is populated by a mass of households indexed by $h \in (0, 1)$. Otherwise, preferences are the same across households; each household h in country i thus seeks to

[1]However, the effects of real wage rigidity are still matter of some controversy. See, for instance, Mortensen and Nagypál (2007) for a critical review.

[2]For instance, Bewley (1999) provides an overview of recent research in this direction.

[3]See, for example, Bauer *et al.* (2007), Barwell and Schweitzer (2007), Deviciente *et al.* (2007), Dickens *et al.* (2007), Du Caju *et al.* (2007), Heckel *et al.* (2008), Holden and Wulfsberg (2007).

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maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \quad U(C_t^i, N_t^i(h), G_t^i), \tag{1}$$

where

$$U(C_t^i, N_t^i(h), G_t^i) \equiv (1-\chi) \log C_t^i + \chi \log G_t^i - \frac{(N_t^i(h))^{1+\phi}}{1+\phi}, \tag{2}$$

with $\chi \in (0,1)$ as a weight attached to public consumption. That is, preferences are defined over the consumption of private and public goods, C_t^i and G_t^i, and labor $N_t^i(h)$, which is assumed to be immobile across countries.[4] The composite of private consumption is defined by

$$C_t^i \equiv \frac{(C_{i,t}^i)^{1-\alpha}(C_{F,t}^i)^{\alpha}}{(1-\alpha)^{(1-\alpha)}\alpha^{\alpha}}, \tag{3}$$

where $C_{i,t}^i$ represents the household's consumption of domestic goods. Formally, $C_{i,t}^i$ is a CES aggregation of all goods produced in country i itself, given by

$$C_{i,t}^i \equiv \left(\int_0^1 C_{i,t}^i(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{4}$$

where $j \in (0,1)$ denotes the type of good. As described below, it is assumed here that each country produces a continuum of differentiated goods indexed by j, where each good is produced by a separate firm. Moreover, there is no good produced in more than one country.

Nevertheless, people in country i consume goods produced in foreign countries. This is, again, a CES aggregation of the goods produced in all other member states indexed by $f \in (0,1)$, namely:

$$C_{F,t}^i \equiv \int_0^1 \left(\int_0^1 C_{f,t}^i(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} df. \tag{5}$$

The home bias in private consumption is denoted as $1-\alpha$. Alternatively, α can be understood as an 'index of openness' in country i. Finally, the elasticity of substitution between varieties produced within any country is represented by $\epsilon > 1$.

The representative household in country i seeks to optimally allocate a given level of expenditure across the various goods available. That is, it adjusts the share of a particular good in its consumption bundle to exploit any relative price

[4] One also could have introduced real money balances as an argument. However, if it enters additively (as empirical evidence suggests, see Ireland, 2004, for the case of the US, and Andrés *et al.*, 2006, for the case of the EMU), a money-market equilibrium plays no role for the dynamics when the nominal interest rate is the monetary policy instrument. Therefore, money is ignored in the remainder.

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differences, i.e. the cost of consumption is minimized. Optimizing the expenditure for any individual good implies the demand functions of domestic and foreign goods, respectively:

$$C^i_{i,t}(j) = \left(\frac{P^i_t(j)}{P^i_t}\right)^{-\epsilon} \tag{6}$$

$$C^i_{f,t}(j) = \left(\frac{P^f_t(j)}{P^f_t}\right)^{-\epsilon}, \tag{7}$$

for all $i, f, j \in (0,1)$. Here, $P^i_t \equiv (\int_0^1 P^i_t(j)^{1-\epsilon} dj)^{1/1-\epsilon}$ represents an index of prices of all domestically produced goods, for all $i \in (0,1)$. As there are no trading frictions, the law of one price is assumed to hold in all single-good markets. This assumption implies that one can equally define $P^f_t \equiv (\int_0^1 P^f_t(j)^{1-\epsilon} dj)^{1/1-\epsilon}$ as a (producer) price index for the bundle of goods imported from country f. It follows from equations (6) and (7) that $\int_0^1 P^i_t(j) C^i_{i,t}(j) dj = P^i_t C^i_{i,t}$ and $\int_0^1 P^f_t(j) C^i_{f,t}(j) dj = P^f_t C^i_{f,t}$. Moreover, the optimal allocation of expenditures implies

$$P^f_t C^i_{f,t} = P^\star_t C^i_{F,t}, \tag{8}$$

for all $f \in (0,1)$. $P^\star_t \equiv \exp \int_0^1 p^f_t df$ denotes the union-wide price index. Note that from the perspective of any individual country, $P^\star_t$ is also the price index of imported goods.

Next, one can define the consumer price index (CPI) as $P^i_{c,t} \equiv (P^i_t)^{1-\alpha}(P^\star_t)^\alpha$. It follows that one can write the optimal allocation of expenditures between domestic and imported goods, respectively, in country i as

$$P^i_t C^i_{i,t} = (1-\alpha) P^i_{c,t} C^i_t \tag{9}$$

$$P^\star_t C^i_{F,t} = \alpha P^i_{c,t} C^i_t. \tag{10}$$

At this point, one can combine the previous results to write the total (optimal) consumption expenditures of the representative household in country i as

$$P^i_t C^i_{i,t} + P^\star_t C^i_{F,t} = P^i_{c,t} C^i_t. \tag{11}$$

As usual, maximization of equation (1) is subject to a sequence of flow budget constraints given by

$$\int_0^1 P^i_t(j) C^i_{i,t}(j) dj + \int_0^1 \int_0^1 P^f_T(j) C^i_{f,t} dj df + E_t\{Q_{t,t+1} D^i_{t+1}\}$$
$$\leq D^i_t + W^i_t(h) N^i_t(h) - T^i_t, \tag{12}$$

where $W_t(h)^i$ denotes the nominal wage, and D^i_{t+1} represents the quantity of one-period, nominal risk less discount bonds purchased in period $t = 0, 1, 2, \ldots$ and

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maturing in period $t+1$. Each bond pays one unit of the common currency, and its price is Q_t, which is common across countries. T_t^i is a lump-sum component of income, which may include, among other items, lump-sum taxes, dividends from the ownership of (domestic) firms, etc.

Given optimal allocation of expenditures, the household's period budget constraint can be written as

$$P_{c,t}^i C_{i,t}^i + E_t\{Q_{t,t+1} D_{t+1}^i\} \leq D_t^i + W_t^i(h) N_t^i(h) - T_t^i, \tag{13}$$

Additionally, the household is assumed to be a monopolistic competitive supplier of labor facing the following constant-elasticity labor demand function

$$N_t^i(h) = \left(\frac{W_t^i(h)}{W_t^i}\right)^{-\eta_t^i} N_t^i, \tag{14}$$

N_t^i is country i's per capita employment, and W_t^i its aggregate nominal wage index defined as

$$W_t^i \equiv \left(\int_0^1 W_t^i(h)^{1-\eta_t^i} dh\right)^{1/(1-\eta_t)}. \tag{15}$$

Maximizing equation (1) with respect to $\{C_t^i\}_{t=0}^{\infty}$, $\{G_t^i\}_{t=0}^{\infty}$, and $\{N_t^i(h)\}_{t=0}^{\infty}$ and subject to equations (13), (14) and a solvency constraint, leads to the optimality conditions:

$$\frac{C_t^i (N_t^i(h))^{\phi}}{1-\chi}(1+\mu_t^i) = \frac{W_t^i(h)}{P_{c,t}^i} \tag{16}$$

$$\beta R_t^{\star} E_t \left\{\left(\frac{C_t^i}{C_{t+1}^i}\right)\left(\frac{P_{c,t}^i}{P_{c,t+1}^i}\right)\right\} = 1, \tag{17}$$

where $\mu_t^i \equiv 1/(1-\eta_t^i)$ is the optimal wage markup in country i and $R_t^{\star} = 1/(E_t\{Q_{t,t+1}\})$ denotes the usual gross nominal one-period return. Alternatively, one can write the marginal rate of substitution (MRS) between consumption and leisure in equation (16) and the Euler equation in equation (17) in log-linearized form (henceforth, lower-case letters denote the logs of the respective variables):

$$w_t^i(h) - p_{c,t}^i = c_t^i + \phi n_t^i(h) + \log(1+\mu_t^i) - \log(1-\chi) \tag{18}$$

$$c_t^i = E_t\{c_{t+1}^i\} - (r_t^{\star} - E_t\{\pi_{c,t+1}^i\} - \rho), \tag{19}$$

where the CPI inflation is defined as $\pi_{c,t}^i \equiv p_{c,t}^i - p_{c,t-1}^i$ and $\rho \equiv -\log\beta$ denotes the time discount rate.

Note that because no worker is unable to set a nominal wage at any time (e.g. through a staggered wage-setting scheme as in Erceg *et al.*, 2000), all workers in country i will charge the same nominal wage and the same level of hours. We can thus write $W_t^i(h) = W_t^i$ and $N_t^i(h) = N_t^i$ in the remainder. Otherwise, I allow for

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exogenous variations in the markup due to shifts in μ_t^i, which can be interpreted as the exogenous variation in workers' market power or, more generally (as it is modeled here), as a cost-push shock on the firm side.[5] It is assumed that μ_t^i is equal to a normally distributed, serially uncorrelated innovation with zero mean and finite variance $\sigma^2_{\mu^i}$.

3.1.1 Some definitions and identities

Before proceeding with the analysis, I introduce some definitions and identities that I will need in what follows. First, I define the effective terms of trade between two countries, say, country i and f, that is, the price of country f's domestically produced goods in terms of country i's, as

$$\mathcal{S}^i_{f,t} \equiv \frac{P^f_t}{P^i_t}. \tag{20}$$

Consequently, I define the effective terms of trade for country i as

$$\begin{aligned} \mathcal{S}^i_t &\equiv \frac{\int_0^1 P^f_t df}{P^i_t} = \frac{P^\star_t}{P^i_t} \\ &= exp \int_0^1 (p^f_t - p^i_t) df \\ &= exp \int_0^1 s^i_{f,t}. \end{aligned} \tag{21}$$

Alternatively, writing equation (21) in logs yields $s^i_t = \int_0^1 s_{f,t} df$. Using the definition of CPI and equation (21), one can relate $P^i_{c,t}$ and the domestic price level P^i_t according to

$$P^i_{c,t} = P^i_t (\mathcal{S}^i_t)^\alpha, \tag{22}$$

or in logs:

$$p^i_{c,t} = p^i_t + \alpha s^i_t. \tag{23}$$

Subtracting a lagged version of equation (23) from the same equation, one can also relate domestic inflation, i.e., $\pi^i_t \equiv p^i_t - p^i_{t-1}$, and CPI inflation according to

$$\pi^i_{c,t} = \pi^i_t + \alpha \Delta s^i_t. \tag{24}$$

This makes it clear that the gap between CPI inflation and domestic inflation is equal to the percentage (as it is expressed in logs) change in terms of trade relative

[5]The assumption of exogenous variation in the markup is twofold. First, it keeps an already rich model clear and tractable. Second, it can be interpreted more generally as a cost-push shock. Of course, variations in wage rigidity could be an endogenous source for variation in the markup, but I abstract from this to draw more general conclusions.

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to the index of openness. Obviously, considering the aggregate price level, one has $p^\star_{c,t} = p^\star_t$ and hence $\pi^\star_{c,t} = \pi^\star_t$, as the terms of trade clearly vanish for the union as a whole. Formally, this can be seen by integrating equation (23) over i and using the fact that $\int_0^1 s^i_t di = 0$.

Furthermore, it is assumed that financial markets are complete at both the domestic and the international level. This assumption implies perfect consumption risk sharing within each country and the equalization of the marginal utilities of consumption between countries. Using the definition for the bilateral terms of trade, the risk-sharing condition can be expressed as

$$C^i_t = C^f_t (\mathcal{S}^i_{f,t})^{1-\alpha}, \tag{25}$$

for all $i, f \in (0, 1)$.[6] In logs and integrated over all $f \in (0, 1)$, this yields $c^i_t = c^\star_t + (1 - \alpha)s^i_t$, where $c^\star_t \equiv \int_0^1 c^f_t df$.

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3.1.2 *Introducing real wage rigidities*

In Europe (and to some degree in the US), there are no sudden and significant shifts in the aggregate wage level observed. Moreover, due to collective wage-bargaining agreements, wages change only infrequently. As a result, a wage that can be freely adjusted in each period is hardly consistent with (European) reality. For this reason, many authors have recently focused on the examination of sluggish wage adjustment.

Erceg *et al*. (2000) and Christiano *et al*. (2005) introduce nominal wage rigidity into the NK business cycle model by a Calvo-type wage-setting scheme. As in the setting of final good prices, firms are randomly chosen to change their wages, while the remaining firms maintain their wage level. However, in Europe, most wages are bargained at a sector-wide level and are not allowed to fluctuate freely; once settled, most wages remain unchanged for a given period. Moreover, as argued in Christoffel and Linzert (2005) the Calvo wage rigidity modeling strategy neglects the crucial interdependence of the wage-bargaining process with other labor-market issues, such as the flows in and out of employment or the level of unemployment. Furthermore, Hall (2005) and Shimer (2005) have argued that real (and not nominal) wage rigidity is central to explaining the cyclical behavior of unemployment and vacancies.

Hall (2005) proposes a modeling strategy of sluggish wage adjustment that improves the cyclical properties of labor-market models. He introduces wage rigidity as a constant wage rule, which may be interpreted as a wage norm or social consensus. In this paper, we use a version of Hall's notion of a wage norm in order to introduce real wage rigidity. In particular, it is assumed that the real wage $W^i_{r,t}$ paid to a worker in country i in period $t = 0, 1, 2, \ldots$ is a weighted average of a notional real wage $W^i_{n,t}$ and a wage norm $\overline{W}^i_t$, that is,

$$W^i_{r,t} = (W^i_{n,t})^{\kappa^i} (\overline{W}^i_t)^{1-\kappa^i}, \tag{26}$$

[6]Equation (25) only holds under the assumption of symmetric initial conditions and initial zero net foreign asset holdings. For a detailed derivation of this result, see Galí and Monacelli (2008).

with $0 \leq \kappa^i \leq 1$. Of course, this form of real wage adjustment is unmodeled and ad hoc,[7] but it can be thought of as a reduced-form representation of a more intricate search unemployment setup. A micro-foundation of such a setup has been discussed in Bodart *et al.* (2006). Concretely, I set $W^i_{n,t} = W^i_{r,t-1}$ and $\overline{W}^i_t = MRS_t$. I thus assume a partial adjustment model of the form

$$\frac{W^i_t}{P^i_{c,t}} = \left(\frac{W^i_{t-1}}{P^i_{c,t-1}}\right)^{\kappa^i} (MRS^i_t)^{1-\kappa^i}, \tag{27}$$

or written in logs

$$w^i_t - p^i_{c,t} = \kappa^i(w^i_{t-1} - p^i_{c,t-1}) + (1-\kappa^i)mrs^i_t, \tag{28}$$

where $\kappa \in [0,1]$ for all $i \in (0,1)$ indicates the degree of real persistence in country i.[8] This approach is used in several recent papers, for example, Blanchard and Galí (2007), Christoffel and Linzert (2005), Faia (2008), Campolmi and Faia (2006), Krause and Lubik (2007) and Uhlig (2007). Although I do not provide a micro foundation of this approach within my model, it constitutes a plausible starting point for analyzing the impact of real wage rigidities on the dynamics of the economy and thus on monetary and fiscal policy.

3.2 *Policy Authorities*

The monetary-policy instrument of the common monetary authority is the union-wide nominal interest rate $R^\star_t$. Following Woodford (2003), the model abstracts from monetary frictions and considers the limit of a 'cashless economy'. Seigniorage thus does not represent a source of revenues for national governments.

In contrast to the nominal interest rate, the government purchases are not common across all member countries. As with the private consumption of domestic and imported goods, I define country i's household's public consumption G^i_t as a CES aggregation of all public consumption goods available:

$$G^i_t \equiv \left(\int_0^1 G^i_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{29}$$

where $G^i_t(j)$ denotes the consumption of good $j \in (0,1)$ or, equivalently, the quantity of good j purchased by the government. It is thus assumed that national governments only purchase goods produced in their own country.[9] While this

[7] As shown in Blanchard and Galí (2007) a more complex model with staggered real wage setting would lead to similar conclusions.

[8] Generally, one would want to guarantee that the real wage exceeds the MRS at all times in order to prevent workers from working more than desired, given the wage. For this reason, we consider the real wage in country i from the household's perspective, i.e. $\frac{W_t}{P^i_{c,t}}$, and not the real wage in terms of the producer price index given by $\frac{W^i_t}{P^i_t}$.

[9] For instance, Brulhart and Trionfetti (2004) find evidence for (strong) home bias.

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is an extreme situation, fiscal policy remains effective at stabilizing the national economies in the presence of asymmetric disturbances, as long as the public spending indexes remain biased towards nationally produced goods. As in the case of private consumption, one can derive the government demand schedules for each public good available. Here, I assume that the government allocates expenditures across individual goods to minimize total cost. That is, the optimal public purchase for any good $j \in (0,1)$ is given by

$$G_t^i(j) = \left(\frac{P_t^i(j)}{P_t^i}\right)^{-\epsilon} G_t^i. \tag{30}$$

To simplify matters, I assume that public spending is financed by lump-sum taxation, so that Ricardian equivalence holds.

3.3 *Firms*

In any individual country, a continuum of firms produces a single good each, indexed by $j \in (0,1)$. They sell their products in monopolistic competitive goods markets. To guarantee a Pareto-efficient steady state of the economy, I assume a constant subsidy to labor τ^i, financed by lump-sum taxes, to undo the distortions in the steady state caused by imperfect competition.[10] Goods are produced with the use of labor. The production function for each good $j \in (0,1)$ produced in each country $i \in (0,1)$ thus has the linear form

$$Y_t^i(j) = A_t^i N_t^i(j), \tag{31}$$

where $a_t^i = log(A_t^i)$ is a country-specific exogenous stochastic technological factor common to all firms in the respective country. This productivity shifter is assumed to follow an AR(1) process, given by:

$$a_t^i = \rho_a a_{t-1}^i + \epsilon_t^i, \quad \epsilon_t^i \sim WN(0, \sigma_\epsilon), \tag{32}$$

with $\rho_a \in (0,1)$.

The labor used by each firm j is a CES composite of individual households' labor supply in country i, given by

$$N_t^i(j) = \left(\int_0^1 N_t^i(h)^{\frac{\eta_t^i - 1}{\eta_t^i}} dh\right)^{\frac{\eta_t^i}{\eta_t^i - 1}}. \tag{33}$$

Aggregating over all profit-maximizing firms in the domestic economy finally yields the labor demand in equation (14). Because in equilibrium each household in country i charges the same wage and supplies the same amount of labor,

[10]Note that the efficient allocation is similar to the one in Galí and Monacelli (2008). Of course, real rigidities do not affect the social planner's problem at all, nor does a markup shock affect the steady state of the model. Moreover, given that $W_t^i(h) = W_t^i$ and $N_t^i(h) = N_t^i$, the labor demand function represents no additional constraints for the social planner's problem.

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the firms' decision problem with regard to total labor demand simply involves the aggregates $N^i_t(j)$ and W^i_t. Due to the labor subsidy, the firms' profits per unit of productivity are $P^i_t(j)Y^i_t(j) - (1-\tau^i)\frac{W^i_t}{P^i_t}{}^i N^i_t(j)/A^i_t$ for all $j \in (0,1)$. The linear technology implies that the real marginal costs (henceforth referred to as marginal costs for simplicity) are independent of the level of production and thus are common across firms. Marginal costs in logs are given by[11]

$$mc^i_t = \log(1-\tau^i) + (w^i_t - p^i_t) - a^i_t. \tag{34}$$

Additionally, firms are subject to some constraints on the frequency with which they can adjust their prices of the goods they sell. A current modeling strategy is to use the formalism proposed in Calvo (1983). That is, each firm may reset its price only with probability $1-\theta$ in any given period, independent of the time elapsed since the last adjustment. As a result, in each period, only a fraction of $1-\theta$ of all producers reset their prices, while the rest, θ, keep their prices unchanged. As a consequence, the average duration of a price is given by $(1-\theta)^{-1}$, and θ can be naturally interpreted as an index of price stickiness. It can be shown that if prices are set in the style of Calvo, maximizing profits yields the optimal price-setting strategy:

$$\bar{p}^i_t = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\{mc^i_{t+k} + p^i_{t+k}\}, \tag{35}$$

where $\bar{p}^i_t$ denotes the log of newly set prices in country i, and μ is the log of the desired gross mark-up prevailing in a zero-inflation steady state. Here, firms resetting their prices will choose a price that corresponds to the desired mark-up over a weighted average of their current and expected (nominal) marginal costs, with the weight being proportional to the probability of the price remaining effective at each horizon θ^k.

3.4 *The Dynamic Equilibrium*

In this section, I summarize conditions determining the dynamic equilibrium of the system. The following definition characterizes an equilibrium for every member country of the currency union:

Definition 1 *Given fiscal and monetary policies, exogenous processes as well as the definitions of terms of trade and the CPI, and under the assumption of perfect risk sharing, an imperfect competitive equilibrium is a sequence of quantities and prices such that:*

1. *Households in each country maximize utility subject to their flow budget constraint, a natural borrowing limit, and the demand for labor, taking domestic*

[11] Note that $w^i_t - p^i_t$ denotes the real wage in terms of the (log) producer price index p^i_t. As mentioned above, I differentiate between producer and consumer price indexes; i.e. the (log) real wage from the consumer's perspective is given by $w^i_t - p^i_{c,t}$.

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and foreign prices as given. This results in the optimality conditions, equations (16) and (17) for all countries $i \in (0,1)$.

2. *Firms in each country maximize profits subject to their technology constraint, taking real wages and the national and union-wide demand for their goods as given. The profit maximizing strategy leads to the optimality condition in equation (35) for all countries $i \in (0,1)$.*
3. *All markets clear. That is, for the goods market we require that $y_t^i(j) = c_{i,t}^i(j) + \int_0^1 c_{i,t}^f(j)df + g_t^i(j)$ and for the labor market $n_t^i = \int_0^1 n_t^i(j)dj$, for all countries $i \in (0,1)$.*

I show in the following that an equilibrium according to this definition can be summarized – for the national level and for the union as a whole, respectively – by just two equations: the domestic (resp. union-wide) dynamic IS equation, and the domestic (resp. union-wide) 'New-Keynesian Phillips Curve'.

3.4.1 Demand and output determination – the dynamic IS equation

Using the optimal allocation of expenditures between domestic and imported goods determined by equations (6), (7), (9), and (10), the definitions of the terms of trade, as well as the assumption about perfect financial markets in equation (25), the aggregate market-clearing condition for country i can be written as

$$Y_t^i = \int_0^1 \left(\frac{P_t^i(j)}{P_t^i} \right)^{-\epsilon} dj \left[C_t^i (\mathcal{S}_t^i)^\alpha + G_t^i \right] \tag{36}$$

$$\approx C_t^i (\mathcal{S}_t^i)^\alpha + G_t^i, \tag{37}$$

where we made use of the fact that $\int_0^1 \left(\frac{P_t^i(j)}{P_t^i} \right)^{-\epsilon} dj \approx 1$ is a valid second-order Taylor approximation around a zero-inflation steady state.[12] The term $C_t^i(\mathcal{S}_t^i)^\alpha$ describes the total private consumption in country i.

For further reference, it will be useful to express key equations of the economy's equilibrium in terms of (log) deviations from a steady state. (In the following, a hat denotes the deviation from a steady state of the respective variable.) The aggregated goods market-clearing condition in equation (36) approximated around a static, symmetric zero-inflation steady state yields

$$\hat{y}_t^i = (1-\gamma)(\hat{c}_t^i + \alpha s_t^i) + \gamma \hat{g}_t^i, \tag{38}$$

where $\gamma \equiv \frac{G}{Y}$ is the efficient steady-state government spending share,[13] $(1-\gamma)$ thus denotes the steady-state share of private consumption. Note that $\hat{s}_t^i = s_t^i$, as $\bar{s}^i = 0$. (In the following, a bar denotes the steady state value of the respective variable.)

[12] This result has, for instance, been shown in Galí (2008).

[13] This result follows directly from Galí and Monacelli (2008). As no expansion of the present model affects the steady state, it is similar to the one in this reference paper.

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Obviously, aggregate output in country i is positively connected to the effective terms of trade, depending proportionally on the 'index of openness'. This fact can be explained by foreign demand. To see this more clearly, one can derive an expression for equation (38) in terms of foreign, i.e., union-wide, demand. By combining the latter equation with equations (21) and (25), one can describe the dynamics in the domestic goods market as

$$\hat{y}_t^i = \gamma \hat{g}_t^i + (1-\gamma)\hat{c}_t^\star - (1-\gamma)(p_t^i - p_t^\star). \tag{39}$$

Equation (39) establishes that country i's output is, next to domestic government spending, positively related to union-wide consumption (which is an index for the strength of foreign demand) and inversely related to domestic prices (relative to average prices in the union). By integrating equation (39) over i, one obtains the union-wide market-clearing condition:

$$\hat{y}_t^\star = \gamma \hat{g}_t^\star + (1-\gamma)\hat{c}_t^\star. \tag{40}$$

By using results from the utility-maximizing behavior of households, one can now easily derive one of the key equations in NK models, the dynamic IS equation (or DIS, for short). First, we consider the home economy in country i. Notice that the Euler equation in equation (17) can be written in terms of log deviations from the steady state as

$$\hat{c}_t^i = E_t\{\hat{c}_{t+1}^i\} - (r_t^\star - E_t\{\pi_{c,t+1}^i\} - \rho). \tag{41}$$

Combining this expression with equation (38) yields the domestic DIS equation (approximated around a symmetric steady state):

$$\begin{aligned}\hat{y}_t^i = {} & E_t\{\hat{y}_{t+1}^i\} - (1-\gamma)(r_t^\star - E_t\{\pi_{c,t+1}^i\} - \rho) \\ & - (1-\gamma)\alpha E_t\{\Delta s_{t+1}^i\} - \gamma E_t\{\Delta \hat{g}_{t+1}^i\}.\end{aligned} \tag{42}$$

This equation fully characterizes the demand side of country i's economy. Obviously, this equilibrium condition has to hold for all member countries indexed by $i \in (0,1)$. Consequently, one can derive the union-wide DIS equation by integrating equation (42) over i:

$$\hat{y}_t^\star = E_t\{\hat{y}_{t+1}^\star\} - (1-\gamma)(r_t^\star - E_t\{\pi_{t+1}^\star\} - \rho) - \gamma E_t\{\Delta \hat{g}_{t+1}^\star\} \tag{43}$$

3.4.2 Aggregate supply – the New Keynesian Phillips Curve

The next task is to derive the second key equation that summarizes the dynamics on the supply side of the economy.

Note first that clearing the market for aggregate labor in country i implies

$$\begin{aligned}N_t^i = \int_0^1 N_t^i(j)dj = \frac{Y_t^i}{A_t^i}\int_0^1 \left(\frac{P_t^i(j)}{P_t^i}\right)^{-\epsilon} dj \\ \approx \frac{Y_t^i}{A_t^i},\end{aligned} \tag{44}$$

where the latter equations follow from the production technology in equation (31) and the goods market-clearing condition in equation (36). The relation between

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output and employment in terms of deviations from the steady-state is thus simply given by:

$$\hat{y}_t^i = a_t^i + \hat{n}_t^i. \tag{45}$$

It can be shown that the profit-maximizing price-setting strategy, equation (35), can be manipulated such that one finally obtains an expression that determines the inflation dynamics in the economy. This equation is often referred to as the New Keynesian Phillips Curve (or NKPC, for short) and is given by

$$\pi_t^i = \beta E_t\{\pi_{t+t}^i\} + \lambda \widehat{mc}_t^i, \tag{46}$$

where $\lambda \equiv (1-\beta\theta)(1-\theta)\theta^{-1}$ is strictly decreasing in the index of price stickiness. $\widehat{mc}_t^i$ denotes the log deviation of marginal cost from its steady-state value. Inflation thus results from aggregate firms' price-setting decisions, which in turn are determined by current and expected marginal costs. Accordingly, it makes sense to analyze the cyclical behavior of marginal costs. For this purpose, I derive a relationship between economy's marginal costs and key variables measuring aggregate economic activity.

Note first that one can write marginal costs in equation (34) as

$$mc_t^i = (w_t^i - p_{c,t}^i) + (p_{c,t}^i - p_t^i) - a_t^i + \log(1-\tau^i). \tag{47}$$

This can be combined with equation (23) to produce

$$mc_t^i = (w_t^i - p_{c,t}^i) + \alpha s_t^i - a_t^i + \log(1-\tau^i). \tag{48}$$

From equation (48), it can be seen that an increase in productivity must lead either to an increase in real wages or terms of trade or to a decrease in marginal costs. As will be evident later, depending on how policy is conducted, the outcome is either reflected in output or inflation.

Combining this expression of marginal costs with the partial-adjustment real wage equation in equation (28) and the mrs_t^i in equation (18), one gets:

$$\begin{aligned} mc_t^i &= \kappa^i mc_{t-1}^i + (1-\kappa^i L)(\alpha s_t^i - a_t^i + \log(1-\tau^i)) \\ &\quad + (1-\kappa^i)(c_t^i + \phi n_t^i - \log(1-\chi) + \log(1+\mu_t^i)) \\ &\approx \alpha s_t^i - a_t^i + \log(1-\tau^i) + \frac{1-\kappa^i}{1-\kappa^i L}(c_t^i + \phi n_t^i - \log(1-\chi) + \mu_t^i), \end{aligned} \tag{49}$$

where L denotes the Lag-operator, and in equation (49) we used a first-order Taylor approximation of $\log(1+\mu_t^i)$. Expression (49) suggests that a higher real wage rigidity indicates a higher inertial adjustment of marginal costs. This is in line with empirical evidence. In a seminal paper, Galí *et al.* (2001) empirically finds that real wage rigidity is indeed a significant factor in accounting for sluggish cyclical movement in marginal costs.

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In order to express the latter equations in terms of deviations from the steady state, we make use here of equations (38), (45) and the fact that $\bar{s}^i = \bar{a}^i = \bar{\mu}^i = 0$.

$$\begin{aligned}\widehat{mc}_t^i &= \kappa^i \widehat{mc}_{t-1}^i + (1-\kappa^i L)(\alpha s_t^i - a_t^i) \\ &\quad + (1-\kappa^i)\left(\left(\phi + \frac{1}{1-\gamma}\right)\hat{y}_t^i - \frac{\gamma}{1-\gamma}\hat{g}_t^i - \alpha s_t^i - \phi a_t^i + \mu_t^i\right) \\ &= \alpha s_t^i - a_t^i + \frac{1-\kappa^i}{1-\kappa^i L}\left(\left(\phi + \frac{1}{1-\gamma}\right)\hat{y}_t^i - \frac{\gamma}{1-\gamma}\hat{g}_t^i - \alpha s_t^i - \phi a_t^i + \mu_t^i\right).\end{aligned} \tag{50}$$

Clearly, a cost-push shock increases marginal costs; however, the positive effect dies out if $\kappa^i \to 1$, as households cannot take advantage of their market power. A sudden shift in technology reaches its maximum impact on marginal costs if $\kappa^i \to 0$. In contrast, if real wages are rigid, households will not adjust their labor supply efficiently, and as a result, marginal costs decline less. In addition, it is seen that marginal costs depend positively on the terms of trade and are proportionally dependent on α, although, again, to a lesser extent if κ^i is high. This can be explained by rigid real wages from the households' perspective, i.e. assessed in terms of current and lagged CPI (which in turn depends on the terms of trade, as shown above).

Interestingly, there is a negative relationship between public spending and marginal costs. To give an intuition for this result, consider the implications from the aggregate market-clearing condition in equation (38): given the output, an increase in government spending crowds out domestic consumption and/or decreases the terms of trade; that is, it generates real appreciation. Both tend to have a negative effect on the mrs_t^i and thus, depending on κ^i, on the real wage. A stronger effect on the real wage increases the degree to which marginal costs are reduced. Moreover, the negative effect of government spending on marginal costs increases in the government share γ. Again, the goods market-clearing condition can be used as an illustration. For a given output, an increase in government spending is associated with a larger decrease in domestic consumption and/or terms of trade, if the government share is high. As a result, the effect on the real wage and thus on marginal costs increases with γ.

Because marginal costs feed into the determination of prices through the NKPC, we establish a direct channel of real wage rigidities to translate into the aggregate inflation of country i. This is done by combining equations (46) and (50), and after some straightforward algebra, the NKPC can be written as

$$\begin{aligned}\pi_t^i &= \kappa^i \pi_{t-1}^i + \beta E_t\{\pi_{t+1}^i\} - \kappa^i \beta E_{t-1}\{\pi_t\} + \lambda\kappa^i \alpha \Delta s_t^i \\ &\quad - \lambda(1 + (1-\kappa^i)\phi)a_t^i + \lambda\kappa^i a_{t-1}^i + \lambda(1-\kappa^i)\mu_t^i + \lambda(1-\kappa^i) \\ &\quad \times \left(\phi + \frac{1}{1-\gamma}\right)\hat{y}_t^i - \frac{\lambda(1-\kappa^i)\gamma}{1-\gamma}\hat{g}_t^i.\end{aligned} \tag{51}$$

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Integrating this expression over all member states yields the NKPC for the union as a whole, namely

$$\pi_t^\star = \kappa^\star \pi_{t-1}^\star + \beta E_t\{\pi_{t+1}^\star\} - \kappa^\star \beta E_{t-1}\{\pi_t\} - \lambda(1 + (1-\kappa^\star)\phi)a_t^\star + \lambda\kappa^\star a_{t-1}^\star + \lambda(1-\kappa^\star)\mu_t^\star + \lambda(1-\kappa^\star) \times \left(\phi + \frac{1}{1-\gamma}\right)\hat{y}_t^\star - \frac{\lambda(1-\kappa^\star)\gamma}{1-\gamma}\hat{g}_t^\star, \tag{52}$$

where $\kappa^\star \equiv \int_0^1 \kappa^i di$, $a_t^\star \equiv \int_0^1 a_t^i di$, and $\mu_t^\star \equiv \int_0^1 \mu_t^i di$ for all $i \in (0,1)$.

So far, I have derived log-linear equilibrium conditions for inflation and output according to the definition above. I have shown that the equations describing the equilibrium behavior of our economy can be summarized by just two equations. Given a function for government spending and a nominal interest rate characterizing the monetary policy, the equilibrium is determined for each individual economy by equations (42) and (51) or for the union as a whole by equations (43) and (52).

4. Calibration and Implementation

In the following numerical analysis of the model, we assume that time is taken as quarters. We set the discount factor $\beta = 0.99$, so that the riskless annual return is about 4%. Following Galí and Monacelli (2008), we set the value-added steady-state mark-up of prices over marginal costs to 1.2. This generates a value for the price elasticity of demand, ϵ, of 6. Moreover, we assume a labor-supply elasticity of 1/3, which implies that $\phi = 3$. That roughly goes in line with empirical findings for the euro area (e.g., Smets & Wouters, 2003). The degree of domestic and union-wide real wage rigidity is set to a benchmark value of 0.8. This value implies a half-life of deviations of the real wage from its equilibrium level of about 3 quarters, which corresponds to recent empirical evidence for the euro area in Arpaia and Pichelmann (2007). The Calvo parameter is set to 0.8, which corresponds to an average nominal price duration of 5 quarters, which is in line with the empirical findings for the euro area (see Altissimo *et al.*, 2006). For the degree of home bias in private consumption, we follow Forlati (2007) and set $\alpha = 0.4$. The weight of the public bundle in the preferences is set to $\chi = \gamma = 0.25$, which roughly corresponds to the average share of government consumption in GDP for the EMU. Finally, by following standard RBC literature (e.g. Backus *et al.*, 1992), we calibrate the domestic productivity shock as a first-order autoregressive process with a standard deviation of 0.008 and a persistence of 0.95. We assume the union-wide (symmetric) shock to technology to have the same stochastic properties. The domestic and the aggregate markup shocks are assumed to be i.i.d. normal with zero mean and standard deviation to 0.01, which corresponds to the estimation results in Lippi and Neri (2007). Where there is no other indication, I further assume this baseline calibration in the following quantitative analysis. Finally, for the calibration of the Taylor-type rule, used as a benchmark monetary policy rule, I refer to the estimation results in Smets and Wouters (2003); that is, we set $\phi_r^{TR} = 0.9$, $\phi_\pi^{TR} = 1.658$ and $\phi_y^{TR} = 0.148$.

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In order to solve the system of linear rational-expectations equations with lagged expectations, we follow the numerical procedure proposed by Meyer-Gohde (2010) but add some computational extensions. Basically, this approach is based on the method of undetermined coefficients for the infinite MA representation.

5. Results

5.1 *Policy Trade-offs*

5.1.1 *Member country's trade-off*

In a previous section, we derived a dynamic equilibrium in terms of real (aggregate) variables. In order to better interpret the business-cycle behavior of the economy from a welfare point of view, we further use the conventional notation of gap variables. That is, from now on we consider the deviations of the actual economy's variables from the welfare-optimal level (i.e. the outcome in a Pareto-efficient allocation). That is, smaller gaps indicate smaller welfare losses.

To rewrite the equilibrium equations derived above, in terms of gap variables, note first that the deviations of marginal costs in a flexible price/wage setting from its efficient steady-state are given by

$$\widehat{\overline{mc}}_t^i = \left(\frac{1}{1-\gamma} + \phi\right)\hat{\bar{y}}_t^i - \frac{\gamma}{1-\gamma}\hat{\bar{g}}_t^i - (1+\phi)a_t^i = 0, \tag{53}$$

for all $i \in (0, 1)$ and $t = 0, 1, 2, \ldots$

Next, we define $\tilde{y}_t^i \equiv y_t^i - \bar{y}_t^i$ and $\tilde{g}_t^i \equiv g_t^i - \bar{g}_t^i$ as the output gap and the government spending gap, respectively. Moreover, I define a measure for the fiscal stance: $\tilde{f}_t^i \equiv \tilde{g}_t^i - \tilde{y}_t^i = (g_t^i - y_t^i) - \log\chi$, which I will refer to as the fiscal gap. Using these definitions and imposing an optimal steady-state government-spending share ($\gamma = \chi$), one can subtract equation (53) from equation (51) to rewrite the NKPC for country i in terms of gap variables:

$$\begin{aligned}\pi_t^i &= \kappa^i\pi_{t-1}^i + \beta E_t\{\pi_{t+1}^i\} - \kappa^i\beta E_{t-1}\{\pi_t^i\} + \lambda\kappa^i\alpha\Delta s_t^i \\ &\quad - \lambda\kappa^i\Delta a_t^i + \lambda(1-\kappa^i)\mu_t^i + \lambda(1-\kappa^i)(1+\phi)\tilde{y}_t^i - \frac{\lambda(1-\kappa^i)\chi}{1-\chi}\tilde{f}_t^i.\end{aligned} \tag{54}$$

Because domestic policy depends on union-wide decision making, one can combine equations (39), (40) and the fact that inflation differentials that support an efficient allocation are inversely proportional to productivity growth differentials[14] to obtain an equation that determines the output gap differentials in terms

[14] That is, $\pi_t^i - \pi_t^\star = -(\Delta a_t^i - \Delta a_t^\star)$. The derivation of this result can be found in Galí and Monacelli (2008).

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of fiscal gap differentials and changes in inflation differentials:

$$\Delta\tilde{y}_t^i - \Delta\tilde{y}_t^\star = \frac{\chi}{1-\chi}\left(\Delta\tilde{f}_t^i - \Delta\tilde{f}_t^\star\right) - \left[\left(\pi_t^i - \pi_t^\star\right) + \left(\Delta a_t^i - \Delta a_t^\star\right)\right]. \tag{55}$$

The previous two expressions describe the dynamics of the domestic price level, the output gap, and the fiscal gap, given the aggregate variables determined by union-wide policy.

It is directly seen from equation (54) that a positive markup shock inevitably puts some pressure on the domestic price level, which could only be absorbed by fluctuations in output (if no fiscal gap is created). The domestic authority will thus necessarily face a trade-off. The upward pressure on domestic prices decreases with κ^i. The reason for this change is well understood. An increase in households' market power rises the mrs_t^i. Depending on the inertia of the adjustment process, this affects the real wage paid by firms and thus affects marginal costs and thereby firms' price-setting behavior.

While the trade-off due to a markup shock is simple and easy to grasp, the one resulting from a shock in technology is a little more complex. The latter two equations make clear that the trade-off is twofold. Consider first the situation in which real wages are fully flexible, that is, $\kappa^i = 0$. Then, equation (54) describing the behavior of the price level implies that by closing the output and fiscal gap at all times, the price level is fully stabilized. However, equation (55) states that, given a union-wide policy and in the presence of asymmetric productivity shocks, closing gap variables requires adjustment in the terms of trade and thus in the domestic price level (or vice versa). Because symmetric shifts to technology, however, imply inflation differentials to be inversely proportional to the productivity growth differentials, no further adjustment in the terms of trade (or in the domestic price level) is required while output and fiscal gaps are closed. Of course, in a flexible wage/sticky price setting the results are similar to those presented in Galí and Monacelli (2008).

Things differ substantially if real wage rigidities are present. It is easily seen from equation (54) that closing the output and fiscal gaps at all times no longer implies full price-level stability, even if shocks are purely symmetric. To understand the basic source of this trade-off, consider again the economy's factor-price frontier in equation (48). Note that under flexible wages, a sudden shift in domestic productivity leads to an increase in real wages. If real wages are sticky, a shock in domestic productivity also leads to a decline in marginal costs.[15] Obviously, greater sluggishness in the real wage indicates greater decreases in marginal costs.

It is seen in a previous section that the NKPC provides a direct channel for marginal costs to translate into the aggregate domestic inflation. The dynamic relationship implied by equation (46) makes clear that as marginal costs decrease, the price level experiences greater (downward) pressure. From equation (54) it follows that increasing pressure on the price level (and thus on the terms of trade) can only be absorbed by a decline in output relative to its efficient outcome (and/or by creating a positive fiscal gap). To conclude, in the presence of real wage

[15]This is because domestic authorities cannot avoid that the terms of trade adjust inefficiently.

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rigidities in country i, even given symmetric shocks to technology, stabilizing the price level and gap variables simultaneously is not possible.

Furthermore, equation (54) implies that, given $\kappa^i > 0$, a change in the output gap, even if it is purely transitory, has a persistent impact on the domestic inflation (if no fiscal gap is created). As mentioned earlier, the rationale for this phenomenon is very simple: any change in the workers' reservation wage resulting either from a change in output (and thus a change in employment) or a change in households' market power will affect the real wage (and hence marginal costs) only gradually, with that effect outliving the eventual return of output to its natural level.

5.1.2 *Union-wide trade-offs*

In order to derive the implications for union-wide policies, we integrate equation (54) over i, which yields the aggregate NKPC for the union as a whole

$$\pi_t^\star = \kappa^\star \pi_{t-1}^\star + \beta E_t\{\pi_{t+1}^\star\} - \kappa^\star \beta E_{t-1}\{\pi_t^\star\} - \lambda\kappa^\star \Delta a_t^\star + \lambda((1-\kappa^\star)\mu_t^\star + \lambda(1-\kappa^\star)(1+\phi)\tilde{y}_t^\star - \frac{\lambda(1-\kappa^\star)\chi}{1-\chi}\tilde{f}_t^\star. \quad (56)$$

Secondly, one can use equation (43) to derive an expression that determines the union-wide output gap:

$$\begin{aligned}\tilde{y}_t^\star &= E_t\{\tilde{y}_{t+1}^\star\} - (1-\chi)(r_t^\star - E_t\{\pi_{t+1}^\star\} - \overline{rr}_t^\star) - \chi E_t \Delta \tilde{g}_{t+1}^\star \\ &= \frac{\chi}{1-\chi}\tilde{f}_t^\star - (r_t^\star - E_t\{\pi_{t+1}^\star\} - \overline{rr}_t^\star) + E_t\{\tilde{y}_{t+1}^\star\} - \frac{\chi}{1-\chi}E_t\{\tilde{f}_{t+1}^\star\}, \quad (57)\end{aligned}$$

where $\overline{rr}_t^\star$ is the natural rate of interest, given by:

$$\begin{aligned}\overline{rr}_t^\star &= \rho + \frac{1}{1-\chi}(E_t\{\Delta\bar{y}_{t+1}^\star - \chi E_t\{\bar{g}_{t+1}^\star\}) \\ &= \rho + E_t\{\Delta\bar{y}_{t+1}^\star\} \\ &= \rho + \{E_t \Delta a_{t+1}^\star\}. \quad (58)\end{aligned}$$

The NKPC in equation (56) and the DIS equation in equation (57) now fully describe the dynamics of aggregate inflation and the output gap, given a monetary policy rule in the form of a nominal interest rate and a fiscal policy determining the fiscal gap for all member states.

Because each member country is assumed to be of measure zero, a domestic shock has no effect on union-wide dynamics. Consequently, closing union-wide gap variables is always feasible (and optimal) and goes along with a constant aggregate inflation.

Of course, if shocks are not idiosyncratic, the conclusion differs substantially. Again, the trade-off resulting from a union-wide markup shock can be easily explained by considering the union as a closed economy: an increase in aggregate households' market power leads to an increase in the union-wide real wage,

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depending on the rigidity, and thus to an increase in marginal costs on the firms' side and thus in the union's price level.

While a cost-push shock is a well-known source of a trade-off between stabilizing inflation and welfare-relevant output in NK models, a shock to technology is usually not. From equation (56), it is directly seen that, given the standard assumption of flexible real wages (i.e., $\kappa^\star = 0$), the inflation and output gap can be stabilized simultaneously in the face of a union-wide shift to productivity. This result is standard in basic NK business-cycle theory and is by Blanchard and Galí (2007) referred to as 'divine coincidence'. Given sluggish adjustments of real wages and an union-wide shock to technology, the NKPC in equation (56) implies that there is no longer an exact relation, however complex, between aggregate inflation and the welfare-relevant union-wide output gap. However, note that if either real wages or producer prices are fully flexible, the 'divine coincidence' is valid again. This is a result already shown by Erceg *et al*. (2000) and Christiano *et al*. (2005) for a single closed country's economy with staggered nominal wage setting.[16] This can be easily explained by considering the union as a single closed economy, as zero variance of inflation implies that firms are on their optimal labor demand schedules at all times. Moreover, because more flexibility in the real wages implies that the people's labor supply schedule is closer to the firms' optimal demand for labor, one has less variation in inflation and gap variables. To see this formally, consider the union-wide NKPC in equation (52). Smaller values of $\kappa^\star$ lead to a smaller trade-off. Alternatively, if prices adjust more freely, firms can be kept closer to their optimal labor demand schedules. Technically speaking, a decrease in θ causes a decrease in λ. Again, a smaller value of λ indicates a smaller trade-off considered above.

5.2 *Optimal Monetary and Fiscal Policy Design*

The aim of this paper is to derive optimal monetary and fiscal policy rules for a currency union. Optimality is measured in terms of aggregate welfare. That is, a union-wide monetary policy and domestic fiscal policies seek to maximize aggregate welfare (or minimize aggregate welfare losses). In other words, I assume that all political authorities in the currency union act in perfect coordination with the best interests of the union; that is, national governments do not use their fiscal instruments to pursue policies in favor of domestic interests.[17] As welfare is defined as the aggregate household utility, the policymakers' (perfect coordinated fiscal and monetary authorities) joint objective is similar to the one in a union-wide social planner problem[18] and they will choose the same efficient steady state. The only difference is that political authorities are subject to the equilibrium conditions for any individual member country, as discussed above. In

[16]Basically, the implications for the union as a whole are closely related to those of a closed economy studied in Blanchard and Galí (2007).

[17]Forlati (2007) analyzes the case of non-coordination in a basic multi-country model of a currency union.

[18]This is because there are no (static) distortions in the steady state, given that the subsidy is set correctly.

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the following, I derive optimal policies for domestic and union-wide authorities under full commitment and full coordination.

As the analysis is based on gap variables instead of real variables, a welfare objective based on π_t^i, $\tilde{y}_t^i$, and $\tilde{f}_t^i$ for all $i \in (0,1)$ and $t = 0, 1, 2, \ldots$ has to be formulated. Because the specification of utility as well as the steady state of my model do not differ from those in Galí and Monacelli (2008), a second-order approximation of the average utility losses of union households, due to non-zero variances in the gap variables, can be derived similarly as in this reference paper. The quadratic loss-function takes the form

$$\mathbb{WL} = \frac{1}{2}\sum_{t=0}^{\infty}\beta^t \int_0^1 \left(\frac{\epsilon}{\lambda}(\pi_t^i)^2 + (1+\phi)(\tilde{y}_t^i)^2 + \frac{\chi}{1-\chi}(\tilde{f}_t^i)^2\right) di$$
$$+ \, t.i.p + \|\mathcal{O}(\zeta_t)\|^3, \tag{59}$$

where $t.i.p$ denotes 'terms independent from policy' and $\|\mathcal{O}(\zeta_t)\|^3$ are terms of higher order.

There are several important qualitative features, which are evidently seen from equation (59). The welfare cost of variation in the price level is increasing with the substitutability across varieties produced within any country and the average duration of prices. Note that a rise in the price level in, say, country i follows a decline in the effective terms of trade. Therefore, higher values of ϵ lead to a higher cost of inflation. Again, welfare is independent of inflation, but only in the special case of completely flexible prices. This result can intuitively be comprehended by regarding the dynamics of inflation determined by the NKPC in equation (46).

Moreover, it can be perceived that the cost of output deviation from its welfare-optimal level is decreasing with the labor-supply elasticity, that is, $1/\phi$. Notice that an increase in the output gap implies an increase in employment relative to its welfare-optimal level. Consequently, a higher labor supply elasticity indicates less-costly variation in employment and thus in output. Finally, it should be intuitively clear that the cost of variation in the fiscal stance depends positively on the weight attached to public consumption.

As mentioned above, the policy makers' task is to minimize the welfare losses for all member states $i \in (0,1)$ and all periods of time $t = 0, 1, 2, \ldots$, subject to the single-country equilibrium conditions (54) and (55), as well as the 'aggregation' constraints:

$$\pi_t^\star = \int_0^1 \pi_t^i di, \quad \tilde{y}_t^\star = \int_0^1 \tilde{y}_t^i di, \quad \tilde{f}_t^\star = \int_0^1 \tilde{f}_t^i di. \tag{60}$$

Minimizing the appropriate Lagrangian with respect to $\{\pi_t^i, \tilde{y}_t^i, \tilde{f}_t^i\}$ for all $i \in (0,1)$ and all $t = 0, 1, 2, \ldots$ leads to the following optimality conditions:

$$\frac{\partial}{\partial \pi_t^i}: \quad \frac{\epsilon}{\lambda}\pi_t^i + \left((1+\kappa^i\beta) - \kappa^i\beta L^{-1} - L\right)\psi_{\pi,t}^i + \psi_{y,t}^i - \psi_{\pi,t}^\star = 0 \tag{61}$$

$$\frac{\partial}{\partial \tilde{y}_t^i}: \quad (1+\phi)\tilde{y}_t^i - \lambda(1-\kappa^i)(1+\phi)\psi_{\pi,t}^i + (1-\beta L^{-1})\psi_{y,t}^i - \psi_{y,t}^\star = 0 \tag{62}$$

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$$\frac{\partial}{\partial \tilde{f}_t^i}: \quad \frac{\chi}{1-\chi}\tilde{f}_t^i + \frac{\lambda(1-\kappa^i)\chi}{1-\chi}\psi_{\pi,t}^i - \frac{\chi(1-\beta L^{-1})}{1-\chi}\psi_{y,t}^i - \psi_{f,t}^\star = 0 \tag{63}$$

$$\frac{\partial}{\partial \pi_t^\star}: \quad -\int_0^1 \psi_{y,t}^i di + \psi_{\pi,t}^\star = 0 \tag{64}$$

$$\frac{\partial \mathcal{L}}{\partial \tilde{y}_t^\star}: \quad -(1-\beta L^{-1})\int_0^1 \psi_{y,t}^i di + \psi_{y,t}^\star = 0 \tag{65}$$

$$\frac{\partial}{\partial \tilde{f}_t^\star}: \quad \frac{\chi(1-\beta L^{-1})}{1-\chi}\int_0^1 \psi_{y,t}^i di + \psi_{f,t}^\star = 0, \tag{66}$$

where $\psi_{\pi,t}^i$, $\psi_{y,t}^i$, $\psi_{\pi,t}^\star$, $\psi_{y,t}^\star$, and $\psi_{f,t}^\star$ denote the discounted Lagrange multipliers associated with the constraints in equations (54), (55), and (60).

5.2.1 *Union-wide equilibrium dynamics under the optimal policy*

In order to derive the implied path for $\pi_t^\star$, $\tilde{y}_t^\star$, and $\tilde{f}_t^\star$, one can integrate equation (61) over i, and by combining the resulting expression with equation (64), one gets

$$\frac{\epsilon}{\lambda}\pi_t^\star + \left((1+\kappa^\star\beta) - \kappa^\star\beta L^{-1} - L\right)\int_0^1 \psi_{\pi,t}^i di = 0. \tag{67}$$

Similarly, integrating equation (62) over i and combining with equation (65) yields

$$(1+\phi)\tilde{y}_t^\star - \lambda(1-\kappa^\star)(1+\phi)\int_0^1 \psi_{\pi,t}^i di = 0. \tag{68}$$

Now, by combining the latter two equations, one can derive a monetary policy rule that specifies a condition to be fulfilled by the central bank's target variables:

$$\pi_t^\star = -\frac{1+\kappa^\star\beta}{\epsilon(1-\kappa^\star)}\tilde{y}_t^\star + \frac{\kappa^\star\beta}{\epsilon(1-\kappa^\star)}E_t\{\tilde{y}_{t+1}^\star\} + \frac{1}{\epsilon(1-\kappa^\star)}\tilde{y}_{t-1}^\star, \tag{69}$$

for all $t = 0, 1, 2, \ldots$ The previous equation has a simple interpretation: in the face of disinflationary pressure due to a shift in aggregate technology, the central bank must respond by driving the union-wide output above its efficient level and thus creating a positive output gap in order to dampen the downward pressure on the union's price level. Vice versa, the central bank seeks to create a negative output gap in view of inflationary pressure due to an aggregate markup shock. Of course, the pressure on the price level increases with $\kappa^\star$ and so does the output gap created by the central bank. By combining equation (66) with equation (68), one gets the following equation, describing the dynamic behavior of aggregate gap variables:

$$\tilde{f}_t^\star = -\tilde{y}_t^\star, \tag{70}$$

for $t = 0, 1, 2, \ldots$ It is evident that aggregate government spending remains at its efficient level at all times, that is, $\tilde{g}_t^\star = 0$ for $t = 0, 1, 2, \ldots$. As fiscal policy is not

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a valid instrument for stabilizing the union-wide economy, the common central bank takes over this role. Technically, one could combine equations (56),(69), and (70) to describe the target variables' dynamics under the optimal policy.

The optimal targeting rule for the monetary policy derived above implicitly assumes that the central bank can choose its desired level of inflation, output gap, and fiscal gap. Of course, in practice, the policy maker cannot set all three target variables simultaneously. One possibility to achieve the desired outcome is to set its policy instrument, namely the nominal interest rate, such that the optimal allocation is achieved.

By combining equations (57), (69) and (70), it can be seen that in the welfare-optimal equilibrium the nominal interest rate then equals

$$r_t^\star = \phi_y^1 \tilde{y}_{t-1}^\star + \phi_y^2 \tilde{y}_t^\star + \phi_y^3 E_t\{\tilde{y}_{t+1}^\star\} + \phi_\pi^1 \pi_t^\star + \phi_\pi^2 E_t\{\pi_{t+1}\} + \overline{rr}_t^\star, \qquad (71)$$

for all $t = 0, 1, 2, \ldots$, and where $\phi_y^1 \equiv -\frac{1}{1+\kappa^\star\beta}$, $\phi_y^2 \equiv -\frac{\chi}{1-\chi}$, $\phi_y^3 \equiv \left(\frac{\chi}{1-\chi} - \frac{\kappa^\star\beta}{1+\kappa^\star\beta}\right)$, $\phi_\pi^1 \equiv \frac{\epsilon(1-\kappa^\star)}{1+\kappa^\star\beta}$, and $\phi_\pi^2 \equiv 1$.

A helpful exercise to draw explicit conclusions for monetary policy is to compare the optimal rule with actual policy conducted by the ECB. As a benchmark for actual policy, we use a standard Taylor-type rule estimated for the EMU. The Taylor-type rule takes the form

$$r_t^\star = \phi_r^{TR} r_{t-1}^\star + \left(1 - \phi_r^{TR}\right) \phi_\pi^{TR} \pi_{t-1} + \left(1 - \phi_r^{TR}\right) \phi_y^{TR} \tilde{y}_{t-1}, \qquad (72)$$

which is similar to the one used in Mattesini and Rossi (2009). Of course, in the Taylor-rule scenario, fiscal policy remains an invalid instrument for stabilizing the aggregate economy; that is, we assume equation (70) holds.

The IRFs of the optimal rule and the Taylor rule, in the face of symmetric shocks, are considered in Figure 1. It is seen that under both policies, fluctuations in the union-wide price level and aggregate output are increasing with real wage rigidity. The reasons are discussed in section 5.1.2. Moreover, both policy rules lead to qualitatively similar dynamics. However, since the Taylor-type rule is strictly backward looking, policy reacts with some delay compared with the optimal policy. Additionally, the optimal policy seems to put relatively more weight on reducing the output gap, while the Taylor rule focuses relatively more strongly on price-level stability.

5.2.2 *Domestic equilibrium dynamics under the optimal policy*

In this section, the paths of inflation will be derived, along with the output gap and fiscal gap in a member state as implied by the optimal policy derived above. For this purpose, note first that equation (65), together with equation (66), can be written as

$$\psi_{f,t}^\star = -\frac{\chi}{1-\chi}\psi_{y,t}^\star.$$

Combining equation (62) with equation (63) and using the latter expression yields:

$$\lambda\phi(1-\kappa^i)\psi_{\pi,t}^i = (1+\phi)\tilde{y}_t^i + \tilde{f}_t^i. \qquad (73)$$

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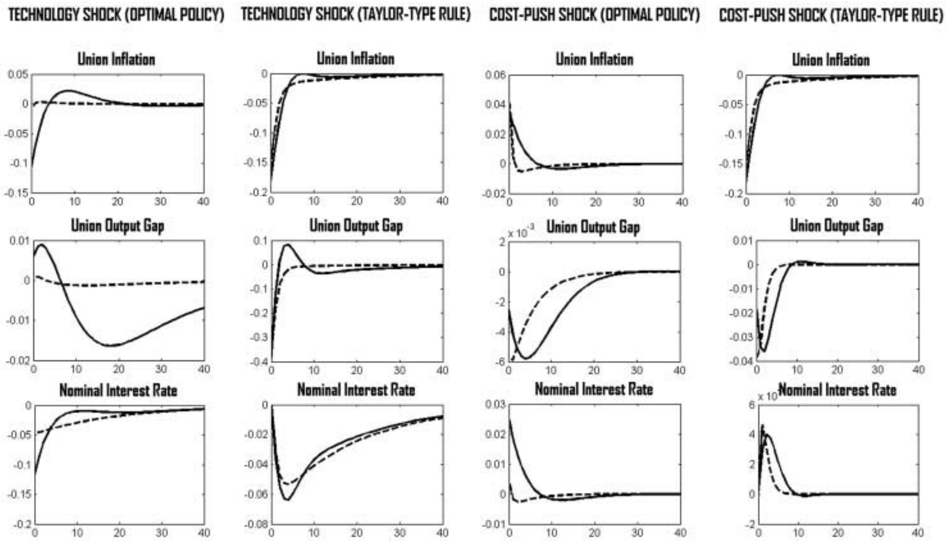

Figure 1. Small Impulse responses of union-wide variables under the optimal policy mix and the Taylor-type rule to 1% symmetric technology shock and 1% symmetric markup shock, respectively. Aggregate real wage rigidity $\kappa^\star = 0.8$ (solid line), $\kappa^\star = 0.2$ (dashed line).

Reconsider that the NKPC for each member state is derived from its basic version in equation (46). This makes clear that equation (54) is a binding constraint for the optimization task as long as $\lambda > 0$ and thus as long as $\theta > 0$ holds. Thus, as long as prices are less than fully flexible, $\psi^i_{\pi,t}$ is a positive number strictly greater than zero. From this, it follows that under the union-wide optimal policy, neither $\tilde{y}^i_t$ nor $\tilde{f}^i_t$ remains at its efficient level (this is also the case if real wages are fully flexible).

Next, I derive a dynamic equilibrium of the domestic economy in country i. First, one can combine equation (61) with equation (64) to get

$$\pi^i_t = -\frac{\lambda}{\epsilon}\psi^i_{\pi,t} + \frac{\lambda\kappa^i\beta}{\epsilon(1+\kappa^i\beta)}E_t\{\psi^i_{\pi,t+1}\} + \frac{\lambda}{\epsilon(1+\kappa^i\beta)}\psi^i_{\pi,t-1} - \frac{\lambda}{\epsilon(1+\kappa^i\beta)}\Psi^i_{\tilde{y},t}, \tag{74}$$

where $\Psi^i_{\tilde{y},t} \equiv \psi^i_{\tilde{y},t} - \int_0^1 \psi^i_{\tilde{y},t}di$. Note that the aggregate multiplier must evolve exogenously from country i's perspective; the equilibrium relationship thus holds for any value of $\int_0^1 \psi^i_{\tilde{y},t}di$. Similarly, combining equation (62) with equation (65) yields

$$\tilde{y}^i_t = \lambda(1-\kappa^i)\psi^i_{\pi,t} - \frac{1}{1+\phi}\Psi^i_{\tilde{y},t} + \frac{\beta}{1+\phi}E_t\{\Psi^i_{\tilde{y},t+1}\}. \tag{75}$$

Finally, equation (63) together with equation (66) can be written as

$$\tilde{f}^i_t = -\lambda(1-\kappa^i)\psi^i_{\pi,t} + \Psi^i_{\tilde{y},t} - \beta E_t\{\Psi^i_{\tilde{y},t+1}\}. \tag{76}$$

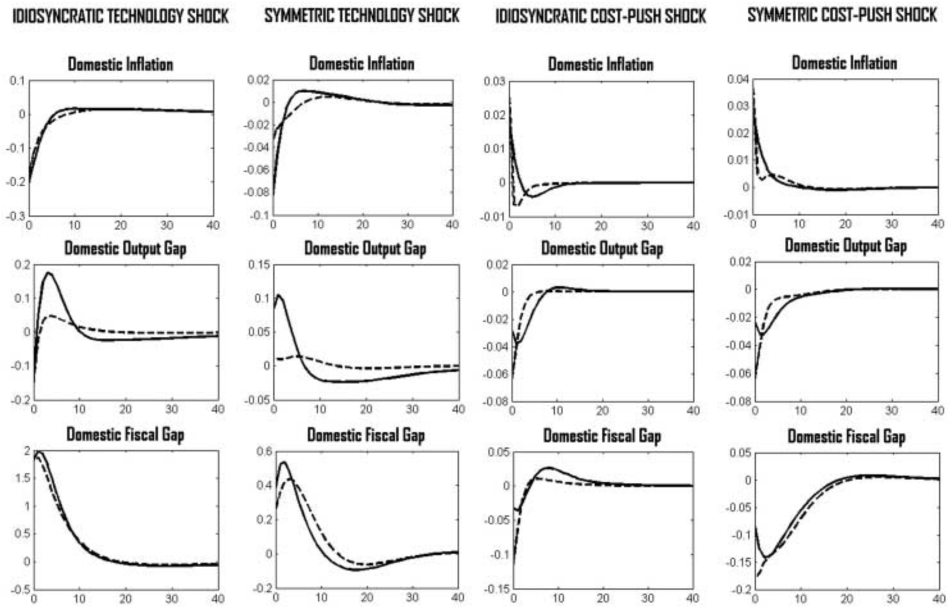

Figure 2. Impulse responses of domestic variables under the optimal policy mix to 1% technology shock and 1% markup shock. Shocks are symmetric and idiosyncratic, respectively. Domestic real wage rigidity $\kappa^i = 0.8$ (solid line), $\kappa^i = 0.2$ (dashed line).

Now, we can define a rational expectations equilibrium under union-wide optimal policies for country i as an allocation of $\{\pi_t^i, \tilde{y}_t^i, \tilde{f}_t^i, \psi_{\pi,t}^i, \Psi_{\tilde{y},t}^i\}$ for all $t = 0, 1, 2, \ldots$ that satisfies equations (54), (55), (74), (75), and (76).

Note that this description of a rational expectations equilibrium is only valid if, and only if, $\theta > 0$. If prices in country i are fully flexible, equation (73) can be written as

$$\frac{1}{1+\phi}\tilde{f}_t^i = -\tilde{y}_t^i$$

and, when combined with equations (54) and (55), describes the equilibrium dynamics of the domestic economy, given flexible prices.

The equilibrium dynamics for country i facing idiosyncratic and symmetric shocks are illustrated in Figure 2. Comparing the results with the optimal policies for the union-wide level, one can asses that the roles of monetary and fiscal policy are reversed. While fiscal policy is not used to stabilize the aggregate economy, monetary policy will not be employed to stabilize the local economies, as it cannot affect cross-country inflation differentials. Instead, domestic fiscal policy takes this role.

Consider first the case where only the domestic economy is hidden by a shock. Of course, any exogenous variation puts the domestic price level under pressure, as neither prices nor wages can adjust directly. Therefore, to the extent that the price level reacts gradually, a shift in productivity will be absorbed by a combination of a fall in the output gap and a rise in the fiscal gap. As discussed in a previous section,

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a higher real wage rigidity leads to a greater downward pressure on the price level in the face of a technology shock. Consequently, the expansion in output also has to increase to dampen the additional disinflationary pressure. Expanding the fiscal gap is necessary to bring about some demand to accommodate the desired expansion in output.

In contrast, to work against the inflationary pressure resulting from an increase in households' market power, the optimal policy requires a decline in output. Because the initial pressure on the price level decreases with κ^i, the reduction in output, which is necessary to dampen inflation, does as well. In this scenario, the optimal policy requires that output decline by more than the amount by which firms would reduce production because of increasing costs. The national government thus also has to cut public demand.

However, if shocks are symmetric, domestic fiscal policies are not needed to adjust cross-country inflation differentials; they must only absorb the pressure on the price level due to real wage rigidities. This is a crucial insight of this model and an important implication for optimal policy design in the EMU.

5.2.3 *Optimal volatility*

The analysis so far provides some advice for conducting policy optimally in the presence of real wage rigidity. Studying union-wide dynamics, it is seen that a higher real wage rigidity leads to a greater impact on inflation and output in all scenarios considered. In particular, the variability of inflation, contradicts (to some degree) the actual policy of the ECB, which emphasizes price-level stability as a central goal. In order to draw more explicit conclusions on the quantitative importance of real wage rigidity in determining the deviation of the optimal policy from a policy aimed at attaching greater importance on price-level stability, a closer look at the optimal variability of the target variables is helpful. Figure 3 shows

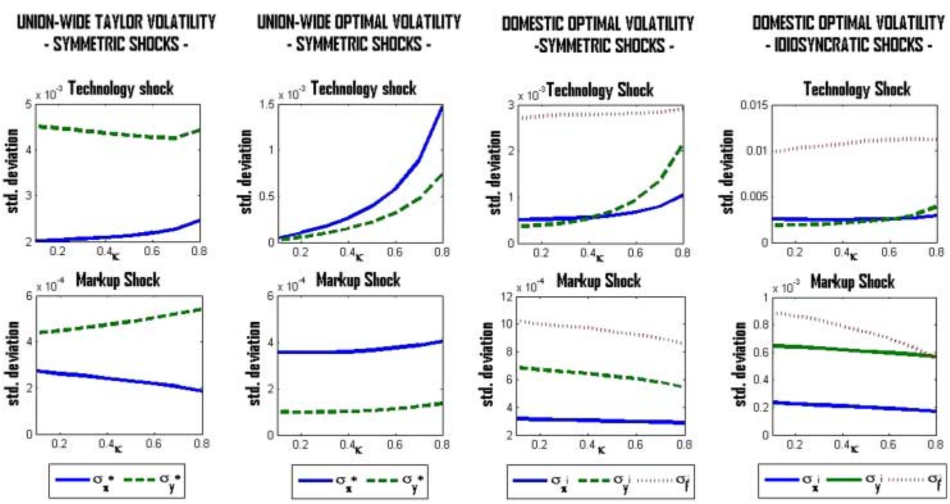

Figure 3. Optimal (Ramsey) and Taylor volatility of inflation, output gap, and fiscal gap for different values of real rigidity.

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simulation-based computations of the optimal volatility of inflation, output, and the fiscal gap for different values of real wage rigidity.

Not surprisingly, the volatility of aggregate inflation and the aggregate output gap increases with real wage rigidity; therefore, the incentive for the common central bank to deviate from a strict inflation target should be higher. Moreover, optimal inflation volatility on the aggregate level is always higher (and increases more steeply with $\kappa^{\star}$) than optimal output gap volatility. Compared with the policy implied by the Taylor rule, the common central bank should indeed allow for greater variability in the price level relative to the variability in output.

Optimal volatility analysis on the domestic level also confirms the results found in the previous section. As expected, the optimal fluctuations in output at the national level are higher than those in price (at least for a reasonable degree of real rigidity). Furthermore, total volatility is higher (lower) in the event of an idiosyncratic technology (markup) shock.

6. Conclusion

In this paper, we investigate the consequences of real wage rigidities for optimal fiscal and monetary policy in a framework of a multi-country NK model of a currency union, where monetary policy is implemented throughout a union by a single central bank, and the fiscal policy is left to domestic authorities. We use shocks to productivity growth and wage-markup shocks in order to analyze the equilibrium dynamics of the domestic and union-wide economy. We assume that a domestic policy decision has no impact on other member countries and thus on the (aggregate) union-wide economy. As a consequence, one has to sharply distinguish between idiosyncratic and symmetric shocks. Considering the first scenario, we find that only the domestic country's authorities are facing a trade-off between stabilizing output around potential and inflation. In the second scenario, the common monetary authority also faces a trade-off between stabilizing the aggregate price level and the welfare-relevant output.

As marginal costs feed into the determination of prices through the NKPC, we establish a direct channel of real wage rigidities to translate into (aggregate) inflation dynamics. It is shown that any considered exogenous variation puts pressure on the (aggregate and domestic) price level, as firms' marginal costs cannot adjust efficiently. It is found that rigid real wages indeed provide evidence for inflation inertia.

We derive optimal monetary and fiscal policy from a union-wide perspective in the form of targeting rules. This is done by maximizing the aggregate welfare of the union. We thereby assume the full commitment and perfect coordination of the monetary and fiscal authorities, as the common objective is to maximize union-wide welfare. To approximate a welfare objective, a pure quadratic loss function is used, which approximates the welfare losses associated with variations in the target variables. While fiscal policy cannot be used to stabilize the aggregate economy, common monetary policy does. Optimal monetary policy suggests that if nominal and real rigidities are present, and a shock is common to all member countries, the central bank stabilizes union-wide economy via a slightly countercyclical policy to dampen the pressure on the (aggregate) price level. The

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countercyclical activity increases with the importance of real rigidities. Compared with an estimated Taylor rule for the EMU, I find that optimal monetary policy should allow for higher inflation volatility relative to output volatility.

The role of fiscal and monetary policy is reversed at the national level. The reason is twofold. In the presence of idiosyncratic shocks, domestic authorities cannot avoid that the terms of trade respond inefficiently (because of the impossibility of resorting to nominal exchange rate adjustment), nor can they evade the (dis)inflationary pressure due to real rigidities. Reducing the pressure on the price-level variations in output is needed, and this must be induced by fiscal measures. Consequently, national fiscal policy is also justified as a stabilization tool from a union-wide perspective. However, if shocks are symmetric, inflation differentials do not provide a rationale for a countercyclical policy; only the sluggish adjustment of real wages does so. Again, the pressure on the price level has to be absorbed by a change in output. To create this output gap, the national government has to bring about or cut the necessary demand. In addition, at the domestic level, the importance of governmental intervention depends crucially on the degree of real rigidity.

Of course, the present model used for policy analysis is an abstraction of the real world. Many essential features are not yet included, as there is always a trade-off between tractability and realism. Some aspects seem likely to be relevant for the design of policy. We abstract from the need to rely on distortionary taxes, the effects of government debt policies, and the likely existence of incomplete Ricardian behavior on the part of households. Moreover, by relaxing the assumption of perfect risk sharing, one could possibly generate a complementary role for fiscal policy as a cross-country insurance tool. Further research is necessary to include more features related to reality.

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