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ABSTRACT

Monetary and Fiscal Policy Interactions in a Micro-Funded Model of a Monetary Union*

So far, the 'New Open Economy Macroeconomics' literature has primarily focused on monetary policy and monetary policy rules, rather than paying attention also to fiscal policy. This is an omission because, especially with the advent of EMU, the burden on fiscal policy as an instrument for macroeconomic stabilization has potentially increased. In this Paper, we focus on the interactions between monetary and fiscal policy in a micro-founded model of monetary union. By extending a two-country, New-Keynesian model with public spending, we find that the forward-looking Phillips curves depend on consumption, terms of trade and public spending deviations from their respective stochastic natural rates. We study the optimal coordinated monetary and fiscal policies for various settings. Generally, we find that the gains from policy commitment and from the use of fiscal policy as an instrument for stabilization are economically non-trivial. We also consider simple monetary and fiscal policy rules and investigate to what extent these rules can approximate the optimal solution under commitment.

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Keywords: fiscal policy rules, monetary policy rules, monetary union and policy mix

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1 Introduction

An extensive amount of work has now been done on monetary policy in micro-founded models with sticky prices.[1] However, this literature has so far paid little attention to the role of fiscal policy in multi-country versions of these models and how monetary and fiscal policy interact in the stabilization of shocks. Early work on standard micro-founded models for fiscal policy in multi-country models includes, for example, Turnovsky (1988) and Devereux (1991). Among recent papers on monetary policy with micro-foundations and sticky prices that also include fiscal policy are Schmitt-Grohé and Uribe (2001) for a closed economy and Corsetti and Pesenti (2001a) in the context of a two-country model. In the context of European Monetary Union (EMU) the issue of the interaction between monetary and fiscal policy is of particular importance for a variety of reasons. Key questions are whether fiscal policy should be more active in stabilizing country-specific shocks now that monetary policy can no longer address these shocks and whether fiscal constraints (such as the Stability and Growth Pact) might hamper stabilization.

In this paper, we try to address the abovementioned gap in the literature by combining monetary and fiscal policy in a micro-founded, two-country model of a monetary union.[2] Our framework extends a recent model developed by Benigno (2001). We derive the dynamics of the two economies assuming that prices adjust only slowly and that, in addition to a common monetary policy, there are national fiscal authorities pursuing active stabilization policies using public spending. The supply-side features forward-looking Phillips curves, with inflation not only driven by the terms of trade and consumption, as in Benigno (2001), but also by public spending. Given that in Europe there is an increasing discussion about the need to coordinate fiscal policies, we assume that the latter are set in a coordinated fashion, with the aim of maximizing welfare at the union level.

As a benchmark, we explore the optimal monetary and fiscal policies when the authorities can commit and countries are characterized by equal degrees of price rigidity. The optimal monetary policy ensures that both union-wide inflation and consumption are at their natural (efficient) levels. While monetary policy in this special, symmetric case does not face a stabilization trade-off and is *not* subject to a time-consistency problem, fiscal policy *is* subject to such a problem. In particular, by committing to an active stabilization policy using public spending, policymakers influence expectations in such a way that *national* inflation rates and the terms of trade (relative to their natural level) become more stable. Indeed, a failure to commit fiscal policy leads to non-trivial welfare losses.

We investigate several variations on our benchmark. One is to have fiscal policy ex-

[1] For example, see the volume edited by Taylor (1999) or the Special Issue of the *Journal of Monetary Economics* 43(3) (1999), for a number of recent contributions.

[2] Hence, we implicitly assume that monetary policy is coordinated because there is a common central bank that sets monetary policy for the entire union. Examples of papers that consider the desirability of monetary policy coordination in the context of recent open-economy models are Obstfeld and Rogoff (2001), Corsetti and Pesenti (2001a,b), Benigno and Benigno (2001), Clarida et al. (2002), Canzoneri et al. (2002) and Sutherland (2002).

clusively directed at the efficient provision of public goods, so that it takes no part in macroeconomic stabilization. Restricting fiscal policy in this way leads to welfare losses that are equal to a permanent reduction in consumption of the order of 0.5 - 1 percentage point when compared with the benchmark. Second, we consider cross-country differences in price rigidity. Here, we find that the optimal common monetary policy puts a more-than-proportionate emphasis on stabilizing the inflation rate of the country with the highest degree of price rigidity. As a result, the other country is characterized by more variable inflation and, therefore, its fiscal policy is more actively used. Finally, we vary the cross-country correlation of the supply shocks. Because it is the variance of the *difference* between the supply shocks of the two countries that determines the macroeconomic fluctuations, with perfectly correlated shocks, appropriate policy choices ensure that the equilibrium coincides with the efficient flexible-price equilibrium. When the shock correlation drops, welfare losses rise proportionately, whether or not fiscal policy can be used as an instrument for stabilization at the national level.

As the final step in our analysis we explore simple policy rules. Their advantage is that they are relatively simple to understand and transparent. As a result, it may be easier to commit to them than to the optimal policy.[3] First, we explore rules that mimic the optimal monetary policy as closely as possible and have public spending respond to the terms of trade, thereby stabilizing national inflation. In particular, a terms-of-trade deterioration should lead to a contractionary fiscal policy. This combination of policy rules improves on the optimal policy under discretion. Nevertheless, it is beaten by the optimal commitment policy with a loss equivalent to a permanent consumption reduction in the order of 0.3 to 0.6 percentage points.

A standard monetary policy Taylor-rule, combined with rules in which public spending reacts to the output gap, also performs well in general and produces losses very close to those under the combination of rules described above. The optimal fiscal rules are countercyclical and for our baseline parameter combination a 1 percentage point increase in the output gap causes a fall in spending of somewhat more than 1 percentage point.

Obviously, our analysis will be subject to a number of limitations, of which we mention only a few here: because of Ricardian equivalence, public debt plays no explicit role here; governments have recourse to lump-sum taxes/subsidies that are used to offset monopolistic distortions; and public spending contributes directly to individuals' utility. We view the present paper as an early step in combining monetary and fiscal policy in a New-Keynesian model of a monetary union and explore only the relaxation of the last-mentioned assumption. However, we realize that relaxing other assumptions may well affect the results in ways that would be worthwhile to investigate in further research.

The remainder of this paper is structured as follows. Section 2 presents the model. Section 3 derives the steady state, the flexible-price equilibrium, and the sticky-price

[3] Note our qualifier "may." Svensson (2001), for example, argues strongly against such instrument rules, and concludes that optimizing behavior implying targeting rules (essentially the first-order conditions resulting from the optimization) is more transparent.

equilibrium conditional on the policy instruments. Section 4 discusses the setup of the policy analysis, while Section 5 presents and discusses the (numerical) results under the optimal policies and our rules. Finally, Section 6 concludes the main body of the paper.

2 The model

We extend the basic model developed by Benigno (2001) by introducing public spending as an instrument for stabilization and by introducing demand-side preference shocks. The presentation of the model and the notation closely parallels that of Benigno (2001).

2.1 Utilities and private consumption

There are two countries labeled H(ome) and F(oreign). These countries form a monetary union. The population of the union is a continuum of agents on the interval $[0,1]$. The population on the segment $[0,n)$ belongs to country H, while the population on $[n,1]$ belongs to country F. In period t, the utility of the representative household j living in country i is given by

$$U_t^j = \mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left[U\left(C_s^j, \epsilon_s^i\right) + V\left(G_s^j\right) - v\left(y_s^j, z_s^i\right)\right], \quad 0<\beta<1, \tag{1}$$

where C_s^j is consumption, G_s^j is per-capita public spending, and y_s^j is the amount of goods that household j produces. The functions U and V are strictly increasing and strictly concave, and v is increasing and strictly convex in y_s^j. Thus, households receive utility from consumption and public spending, but experience disutility from their work effort. Further, ϵ_s^i is a shock which affects the demand for consumption goods, and z_s^i is a shock affecting the disutility of work, which will throughout be interpreted as a supply (e.g., technology) shock.[4] We assume that these shocks are perfectly observable by all the agents (households and policymakers — introduced below). For convenience, we also assume that the variances of z_s^H and z_s^F are equal.

The consumption index C^j is defined as

$$C^j \equiv \frac{\left(C_H^j\right)^n \left(C_F^j\right)^{1-n}}{n^n\left(1-n\right)^{1-n}}, \tag{2}$$

where C_H^j and C_F^j are the Dixit and Stiglitz (1977) indices of the sets of imperfectly substitutable goods produced in countries H and F, respectively:

$$C_H^j \equiv \left[\left(\frac{1}{n}\right)^{1/\sigma} \int_0^n c^j\left(h\right)^{\frac{\sigma-1}{\sigma}} dh\right]^{\frac{\sigma}{\sigma-1}}, \quad C_F^j \equiv \left[\left(\frac{1}{1-n}\right)^{1/\sigma} \int_n^1 c^j\left(f\right)^{\frac{\sigma-1}{\sigma}} df\right]^{\frac{\sigma}{\sigma-1}}, \tag{3}$$

[4] We could have introduced real money balances as an argument in (1). However, if it enters additively (as empirical evidence suggests — see Ireland, 2000, for the case of the U.S. and Andrés et al., 2001, for the case of EMU), money market equilibrium plays no role for the dynamics when the nominal interest rate is the monetary policy instrument. Therefore, we ignore money in the remainder.

where $c^j(h)$ and $c^j(f)$ are j's consumption of Home- and Foreign-produced goods h and f, respectively, and $\sigma > 1$ is the elasticity of substitution across goods produced within a country.

The price index of country i is given by $P^i = (P_H^i)^n (P_F^i)^{1-n}$ where

$$P_H^i = \left[\left(\frac{1}{n}\right)\int_0^n p^i(h)^{1-\sigma}\,dh\right]^{\frac{1}{1-\sigma}}, \quad P_F^i = \left[\left(\frac{1}{1-n}\right)\int_n^1 p^i(f)^{1-\sigma}\,df\right]^{\frac{1}{1-\sigma}},$$

and where $p^i(h)$ and $p^i(f)$ are the prices in country i of the individual goods h and f produced in Home and Foreign, respectively. Because there are no trade barriers and the two countries share a common currency, the price of each good is the same in both countries. Combined with the fact that preferences are identical in the entire union, purchasing power parity holds. In the sequel, we will therefore drop the country superscript for prices. The terms of trade, T, is defined as the ratio of the price of a bundle of goods produced in country F and a bundle of goods produced in country H. That is, $T \equiv P_F/P_H$.

The allocation of resources over the various consumption goods takes place in three steps. The intertemporal trade-off, analyzed below, determines C^j. Given C^j, the household selects C_H^j and C_F^j so as to minimize total expenditure PC^j under restriction (2). Then, given C_H^j and C_F^j, the household optimally allocates spending over the individual goods by minimizing $P_H C_H^j$ and $P_F C_F^j$ under restriction (3). The implied demands for individual good h, produced in country H, and individual good f, produced in country F, are, respectively,

$$c^j(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma} T^{1-n} C^j, \quad c^j(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma} T^{-n} C^j. \tag{4}$$

We assume that public spending is financed either by debt issuance or lump-sum taxation, so that Ricardian equivalence holds. Public spending in countries H and F is given by the following indices, respectively:

$$G^H = \left[\frac{1}{n}\int_0^n g(h)^{\frac{\sigma-1}{\sigma}}\,dh\right]^{\frac{\sigma}{\sigma-1}}, \quad G^F = \left[\frac{1}{1-n}\int_n^1 g(f)^{\frac{\sigma-1}{\sigma}}\,df\right]^{\frac{\sigma}{\sigma-1}}, \tag{5}$$

where $g(h)$ and $g(f)$ are public spending on individual goods h and f produced in Home and Foreign, respectively. Hence, we assume that the national governments only purchase goods produced in their own country. While this is an extreme situation, fiscal policy remains effective at stabilizing the individual economies in the face of asymmetric disturbances as long as the public spending indices remain biased towards nationally-produced goods. As will become evident below, government spending will be expansionary when prices are sticky.[5] In this respect, we should emphasize that government spending in this

[5] If we were to relax the assumption that the government can levy lump-sum taxes, changes in the amount of public spending would lead to fluctuations in distortionary taxes, thereby affecting the supply-side of the economy and potentially diminishing the stimulating effect of an increase in government spending. However, this is beyond the scope of the present paper.

model is associated with government purchases and not with government outlays on public wages. The latter are often thought to be contractionary.[6]

Minimization of $P_H G^H$ and $P_F G^F$ under restriction (5) yields the governments' demands for the individual goods h and f:

$$g(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma} G^H, \quad g(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma} G^F. \tag{6}$$

Hence, combining (4) and (6), the total demands for the goods h and f are

$$y(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma} \left[T^{1-n} C^W + G^H\right], \quad y(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma} \left[T^{-n} C^W + G^F\right], \tag{7}$$

where $C^W \equiv \int_0^1 C^j dj$, is aggregate consumption in the union.

Following Benigno and Benigno (2001), we assume that financial markets are complete both at the domestic and at the international level. Furthermore, each individual's initial holding of any type of asset is zero. These assumptions imply perfect consumption risk-sharing within each country and equalization of the marginal utilities of consumption between countries:

$$U_C\left(C_t^H, \epsilon_t^H\right) = U_C\left(C_t^F, \epsilon_t^F\right). \tag{8}$$

Further, the Euler equations are

$$U_C\left(C_t^i, \epsilon_t^i\right) = (1 + R_t)\beta \mathrm{E}_t\left[U_C\left(C_{t+1}^i, \epsilon_{t+1}^i\right)(P_t/P_{t+1})\right], \quad i = H, F, \tag{9}$$

where R_t is the nominal interest rate on an internationally-traded nominal bond. This is taken to be the union central bank's policy instrument. Finally, using the appropriate aggregators, aggregate demand in both countries is found as

$$Y^H = T^{1-n} C^W + G^H, \quad Y^F = T^{-n} C^W + G^F. \tag{10}$$

2.2 Firms

Individual j is the monopolist provider of good j. We use Calvo's (1983) approach to modelling price stickiness. In each period, there is a fixed probability $(1 - \alpha^i)$ that producer j who resides in i can adjust his prices. This producer takes account of the fact that a change in the price of his product affects the demand for it. However, because he is infinitesimally small, he neglects any effects of his actions on aggregate variables. Hence, if individual j has the "chance" to reset his price in period t, he chooses his price, denoted $p_t(j)$, to maximize

$$\mathrm{E}_t \sum_{k=0}^{\infty} \left(\alpha^i \beta\right)^k \left[\lambda_{t+k}^i \left(1 - \tau^i\right) p_t(j)\, y_{t,t+k}(j) - v\left(y_{t,t+k}(j), z_{t+k}^i\right)\right],$$

[6] See Wynne (1996) and Finn (1998) for theoretical examples, and Alesina et al. (1999) for empirical evidence for the OECD countries. However, Fatás and Mihov (2001) cannot unambiguously confirm this finding for the U.S.

where $y_{t,t+k}(j)$ is given by (7), assuming that $p_t(j)$ still applies at $t+k$, $\lambda^i_{t+k} \equiv U_C\left(C^i_{t+k}, \epsilon^i_{t+k}\right)/P_{t+k}$ is the marginal utility of nominal income and τ^i is a proportional tax rate on nominal income. This yields:

$$p_t(j) = \frac{\sigma}{(\sigma-1)(1-\tau^i)} \frac{\mathrm{E}_t\left[\sum_{k=0}^{\infty} (\alpha^i\beta)^k v_y\left(y_{t,t+k}(j), z^i_{t+k}\right) y_{t,t+k}(j)\right]}{\mathrm{E}_t\left[\sum_{k=0}^{\infty} (\alpha^i\beta)^k \lambda^i_{t+k} y_{t,t+k}(j)\right]}. \tag{11}$$

Realizing that, in equilibrium, each producer in a given country and a given period will set the same price when offered the chance to reset its price, it is easy to show that

$$P^{1-\sigma}_{H,t} = \alpha^H P^{1-\sigma}_{H,t-1} + \left(1-\alpha^H\right) p_t(h)^{1-\sigma}, \tag{12}$$

$$P^{1-\sigma}_{F,t} = \alpha^F P^{1-\sigma}_{F,t-1} + \left(1-\alpha^F\right) p_t(f)^{1-\sigma}. \tag{13}$$

3 Equilibrium

3.1 Steady state and efficient flex-price equilibrium

Under flexible prices, (11) is replaced by

$$p_t(j) = \frac{\sigma}{(\sigma-1)(1-\tau^i)} \frac{v_y\left(y_{t,t}(j), z^i_t\right)}{\lambda^i_t}. \tag{14}$$

Because each agent in a given country chooses the same price, we have that $p_t(j) = P_{H,t}$ for all j living in Home, so that

$$U_C\left(C^H_t, \epsilon^H_t\right) = \frac{\sigma}{(\sigma-1)(1-\tau^H)} T^{1-n}_t v_y\left(T^{1-n}_t C^W_t + G^H_t, z^H_t\right), \tag{15}$$

and that $p_t(j) = P_{F,t}$ for all j living in Foreign, so that

$$U_C\left(C^F_t, \epsilon^F_t\right) = \frac{\sigma}{(\sigma-1)(1-\tau^F)} T^{-n}_t v_y\left(T^{-n}_t C^W_t + G^F_t, z^F_t\right). \tag{16}$$

In the sequel, we confine ourselves to equilibria in which the tax rates τ^H and τ^F are set so as to offset the distortion arising from monopolistic competition:

$$\frac{\sigma}{(\sigma-1)(1-\tau^H)} = \frac{\sigma}{(\sigma-1)(1-\tau^F)} = 1. \tag{17}$$

We assume that the steady state is characterized by zero inflation in both countries, and denote by an upper-bar the steady-state value of a variable. The steady-state values $\overline{C} \equiv \overline{C}^H = \overline{C}^F = \overline{C}^W$ and $\overline{T}$, conditional on $\overline{G}^H$ and $\overline{G}^F$, follow upon setting the shocks to zero in (15) and (16), with (17) imposed. Hence, they are implicitly defined by

$$U_C\left(\overline{C}, 0\right) = \overline{T}^{1-n} v_y\left(\overline{T}^{1-n}\overline{C} + \overline{G}^H, 0\right) = \overline{T}^{-n} v_y\left(\overline{T}^{-n}\overline{C} + \overline{G}^F, 0\right). \tag{18}$$

Assuming a symmetric steady state, it follows that $\overline{T} = 1$. We obtain the steady state values $\overline{G}^H$ and $\overline{G}^F$ by setting the shocks to zero in (21) below:

$$V_G\left(\overline{G}^H\right) = v_y\left(\overline{Y}^H, 0\right), \quad V_G\left(\overline{G}^F\right) = v_y\left(\overline{Y}^F, 0\right). \tag{19}$$

Finally, we obtain the steady-state nominal (=real) interest rate from (9) as $1+\overline{R}=1/\beta$.

Before we continue, we introduce some notation. Following Benigno (2001), we denote with a superscript "W" a world aggregate and with a superscript "R" a relative variable. Hence, for a generic variable X, we define $X^W \equiv nX^H + (1-n)\,X^F$ and $X^R \equiv X^F - X^H$. Further, we denote by a tilde the flex-price log-deviation from the steady state, i.e., $\widetilde{X} \equiv \ln\left(X/\overline{X}\right)$.

For the flexible-price equilibrium that we consider, we assume that the fiscal authorities coordinate. Hence, they choose G_t^H and G_t^F to maximize

$$\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left\{ \begin{array}{c} n\left[U\left(C_s^H,\epsilon_s^H\right)+V\left(G_s^H\right)-v\left(Y_s^H,z_s^H\right)\right] \\ +(1-n)\left[U\left(C_s^F,\epsilon_s^F\right)+V\left(G_s^F\right)-v\left(Y_s^F,z_s^F\right)\right] \end{array} \right\}, \tag{20}$$

again subject to (15) and (16), with (17) imposed. Because there are no distortions, this programme gives the highest possible weighted welfare level. Therefore, we term the resulting equilibrium the *efficient flex-price equilibrium*. The fiscal choice problem implies the following optimality conditions:

$$V_G\left(G_t^H\right) = v_y\left(Y_t^H,z_t^H\right), \quad V_G\left(G_t^F\right) = v_y\left(Y_t^F,z_t^F\right). \tag{21}$$

These conditions are derived in Appendix A, where we also derive the complete solution for the efficient flex-price equilibrium:

$$\widetilde{C}_t^W = \frac{\eta\rho_g}{\rho\left[\rho_g+\eta\left(1-\xi_c\right)\right]+\eta\xi_c\rho_g} S_t^W - \frac{\rho\left[\rho_g+\eta\left(1-\xi_c\right)\right]}{\rho\left[\rho_g+\eta\left(1-\xi_c\right)\right]+\eta\xi_c\rho_g} D_t^W, \tag{22}$$

$$\widetilde{G}_t^W = \frac{\eta\rho}{\rho\left[\rho_g+\eta\left(1-\xi_c\right)\right]+\eta\xi_c\rho_g}\left(S_t^W+\xi_c D_t^W\right), \tag{23}$$

$$\widetilde{G}_t^R = \frac{\eta}{\rho_g\left(1+\eta\xi_c\right)+\eta\left(1-\xi_c\right)} S_t^R, \tag{24}$$

$$\widetilde{T}_t = -\frac{\eta\rho_g}{\rho_g\left(1+\eta\xi_c\right)+\eta\left(1-\xi_c\right)} S_t^R, \tag{25}$$

where, $\rho \equiv -U_{CC}\left(\overline{C},0\right)\overline{C}/U_C\left(\overline{C},0\right)$, $\rho_g \equiv -V_{GG}\left(\overline{G}\right)\overline{G}/V_G\left(\overline{G}\right)$, ξ_c is the steady-state consumption share of output, and $\eta \equiv v_{yy}\left(\overline{Y}^H,0\right)\overline{Y}^H/v_y\left(\overline{Y}^H,0\right) = v_{yy}\left(\overline{Y}^F,0\right)\overline{Y}^F/v_y\left(\overline{Y}^F,0\right)$, because $\overline{Y}^H=\overline{Y}^F$. Furthermore, we have defined S_t^i $(i=H,F)$ such that $v_{yz}\left(\overline{Y}^i,0\right)z_t^i = -\overline{Y}^i v_{yy}\left(\overline{Y}^i,0\right)S_t^i$ and D_t^i such that $U_{C\epsilon}\left(\overline{C},0\right)\epsilon_t^i = \overline{C}U_{CC}\left(\overline{C},0\right)D_t^i$. Hence, S_t^i and D_t^i are proportional to the supply and demand shocks, respectively. We will refer to the outcomes of the above variables in the efficient flex-price equilibrium as the *(stochastic) natural rates.*

As we will see below, fluctuations in the natural terms of trade will be the source of the policy trade-offs in the model under sticky prices. As (25) shows, the natural terms of trade fluctuate when non-identical supply shocks hit the two economies.

We can explain this as follows. A positive supply shock in Home relative to Foreign induces an increase in Home production relative to Foreign production. As trade is balanced due to the complete markets assumption, equilibrium is restored when the price of Home goods relative to Foreign goods decreases, i.e., when $\widetilde{T}_t$ increases. Any demand disturbances, however, have *no* effect on the natural terms of trade. They merely alter the marginal utilities of consumption, but by the same amount in both countries due to perfect risk sharing. Therefore, production effort changes by the same amount in both countries, leaving any relative price change superfluous.

Finally, assuming that the inflation rate in the flex-price equilibrium is zero, we derive the natural rate of the nominal interest rate as

$$\widetilde{R}_t = \rho \mathrm{E}_t \left[\left(\widetilde{C}^W_{t+1} - \widetilde{C}^W_t \right) + \left(D^W_{t+1} - D^W_t \right) \right]. \tag{26}$$

3.2 Equilibrium dynamics under sticky prices

Under sticky prices, the aggregate demand block is given by (8), (9) and (10), while the aggregate supply block is (11), (12), (13). Applying the appropriate linearizations (see Appendix B), together with the initial conditions, we end up with the following dynamic system, where a hat indicates the log-deviation from the steady state when prices are sticky, i.e., $\widehat{X} \equiv \ln \left(X / \overline{X} \right)$:

$$\mathrm{E}_t \left(\widehat{C}^W_{t+1} - \widetilde{C}^W_{t+1} \right) = \left(\widehat{C}^W_t - \widetilde{C}^W_t \right) + \rho^{-1} \left[\left(\widehat{R}_t - \widetilde{R}_t \right) - \mathrm{E}_t \left(\pi^W_{t+1} \right) \right], \tag{27}$$

$$\widehat{Y}_{H,t} = \xi_c \left[(1-n) \widehat{T}_t + \widehat{C}^W_t \right] + (1-\xi_c) \widehat{G}^H_t, \tag{28}$$

$$\widehat{Y}_{F,t} = \xi_c \left[-n \widehat{T}_t + \widehat{C}^W_t \right] + (1-\xi_c) \widehat{G}^F_t, \tag{29}$$

$$\begin{aligned} \pi^H_t = {} & \beta \mathrm{E}_t \pi^H_{t+1} + k^H (1+\eta\xi_c)(1-n) \left(\widehat{T}_t - \widetilde{T}_t \right) + k^H (\rho + \eta \xi_c) \left(\widehat{C}^W_t - \widetilde{C}^W_t \right) \\ & + k^H \eta (1-\xi_c) \left(\widehat{G}^H_t - \widetilde{G}^H_t \right), \end{aligned} \tag{30}$$

$$\begin{aligned} \pi^F_t = {} & \beta \mathrm{E}_t \pi^F_{t+1} - k^F (1+\eta\xi_c) n \left(\widehat{T}_t - \widetilde{T}_t \right) + k^F (\rho + \eta \xi_c) \left(\widehat{C}^W_t - \widetilde{C}^W_t \right) \\ & + k^F \eta (1-\xi_c) \left(\widehat{G}^F_t - \widetilde{G}^F_t \right), \end{aligned} \tag{31}$$

$$\widehat{T}_t = \widehat{T}_{t-1} + \pi^F_t - \pi^H_t, \tag{32}$$

where we have made use of the fact that, upon log-linearizing (8) under both flexible and sticky prices, we obtain $\widehat{C}^W_t - \widetilde{C}^W_t = \widehat{C}^H_t - \widetilde{C}^H_t = \widehat{C}^F_t - \widetilde{C}^F_t$, and where,

$$k^H \equiv \frac{\left(1-\alpha^H \beta\right)\left(1-\alpha^H\right)}{\alpha^H (1+\eta\sigma)}, \quad k^F \equiv \frac{\left(1-\alpha^F \beta\right)\left(1-\alpha^F\right)}{\alpha^F (1+\eta\sigma)}.$$

In the following, the *gap* of a variable (including inflation) is defined as the difference between its sticky-price and its flex-price solution or natural rate. Equation (27) is the consumption Euler equation expressed in terms of the world consumption gap and the world real interest rate gap. Equations (28) and (29) are the log-linearized counterparts of (10). Equation (30) is the Home inflation adjustment equation, i.e., the "Phillips curve." Inflation depends positively on expected future inflation as agents setting prices in period t know there is a risk that they cannot change their prices in period $t+1$. Hence, to protect discounted real income, expected future aggregate prices are crucial for price setting. A positive terms-of-trade gap has inflationary implications because demand is switched towards Home goods, and because Home agents' marginal utility of nominal income drops. Both effects will be met by price increases. Moreover, a positive consumption gap and government spending gap are inflationary due to their implied demand pressure. Equation (31) is the analogous foreign inflation adjustment equation. Note that by using (28) and (29), and their efficient flex-price counterparts, we can express these inflation adjustment equations in terms of output and terms-of-trade (and public spending) gaps. As such they resemble the open-economy counterparts of what Roberts (1995) labels the "New Keynesian" Phillips curves.[7] Finally, equation (32) is the definition of the terms of trade expressed through the inflation differential. In sum, equations (27)-(32) will for given paths of $\widehat{R}_t$, $\widehat{G}_t^H$ and $\widehat{G}_t^F$, and for an initial $\widehat{T}_{t-1}$, provide the solutions for the endogenous variables $\widehat{C}_t^W$, $\widehat{Y}_{H,t}$, $\widehat{Y}_{F,t}$, π_t^H, π_t^F and $\widehat{T}_t$.

Before considering our monetary-fiscal policy experiments, it is appropriate to establish under what circumstances a replication of the efficient flex-price equilibrium is feasible in the model.

For illustrative purposes, we first discuss the special case in which public spending does not affect individuals' utility in at least one of the countries. In that case (22)-(25) no longer hold, as these have been derived under the assumption that the fiscal authorities maximize (20) over both G_t^H and G_t^F. The system (27)-(32) remains valid because we derived it solely from the private sector's first-order conditions. One has:

Proposition 1 *Let $\widehat{T}_{t-1} = 0$ and suppose that public spending does not affect individuals' utility in at least one of the countries. Then, the appropriate combination of monetary and fiscal policies closes all the gaps.*

To explain this result, observe that the monetary authority closes the consumption gap by (committing to) setting (for all $s \geq t$) $\widehat{R}_s = \widetilde{R}_s$. Next, if under flexible prices the fiscal authorities set $\widetilde{G}_t^R = S_t^R / (1 - \xi_c)$, then by (46) in Appendix A, $\widetilde{T}_t = 0$. To be specific, suppose that only the Home consumers derive utility from public spending. Then, $\widetilde{G}_t^H$ follows from maximizing (20), with the term $V\left(G_t^F\right)$ dropped, over G_t^H, subject to (15), (16) and (17). The solutions for $\widetilde{G}_t^H$ and $\widetilde{G}_t^R$ then determine $\widetilde{G}_t^F$.[8] As a final step, from (30) and (31), with $\widehat{G}_t^H - \widetilde{G}_t^H = -\frac{(1+\eta\xi_c)(1-n)}{\eta(1-\xi_c)}\left(\widehat{T}_t - \widetilde{T}_t\right)$ and $\widehat{G}_t^F - \widetilde{G}_t^F = \frac{(1+\eta\xi_c)n}{\eta(1-\xi_c)}\left(\widehat{T}_t - \widetilde{T}_t\right)$,

[7] Empirical support for the depicted forward-looking behavior in price setting can be found in Galí and Gertler (1999) and Sbordone (2002) for the U.S. and in Galí et al. (2001) for the Euroland. Note that these studies use real marginal costs instead of the output gap as the driving variable. Recently, however, Neiss and Nelson (2002) have provided a theoretical and empirical reconciliation of marginal-cost based and output-gap based inflation equations. It should be observed that the empirical results of Coenen and Wieland (2000) for Euroland are more supportive of Taylor-style contracts than of Calvo-style contracts.

[8] The Additional Appendix (available upon request) derives $\widetilde{C}_t^W$ and $\widetilde{G}_t^H$ for this case.

national producer inflation rates are zero. Hence, $\widehat{T}_t = \widetilde{T}_t$, so that in equilibrium all gaps are closed. The intuition is that when foreign public spending is "pure waste," it can be adjusted freely to eliminate any fluctuations in the natural rate of the terms of trade. Home public spending can then be set at its efficient level, while monetary policy can stabilize inflation rates perfectly by closing the consumption gap.[9]

For the remainder of the paper, we return to the case in which public spending enters the utility of all individuals. First, we consider two other special cases that produce the efficient flex-price equilibrium. One arises when at least one of the economies is characterized by full price flexibility. It is analogous to what Aoki (2002) obtains for a closed-economy, two-sector model. Formally, we have:

Proposition 2 *Let $\widehat{T}_{t-1} = 0$ and suppose that at least one of the economies is characterized by fully flexible prices ($\alpha^H = 0$ or $\alpha^F = 0$). Then, the appropriate combination of monetary and fiscal policies closes all the gaps.*

To see this, suppose that $\alpha^F = 0$. Hence, by (31),

$$\widehat{T}_t - \widetilde{T}_t = \frac{\rho + \eta\xi_c}{n(1+\eta\xi_c)}\left(\widehat{C}_t^W - \widetilde{C}_t^W\right) + \frac{\eta(1-\xi_c)}{n(1+\eta\xi_c)}\left(\widehat{G}_t^F - \widetilde{G}_t^F\right).$$

We can substitute this expression into (30), to get rid of the terms-of-trade gap. The Home Phillips curve now depends on the consumption gap and the two government spending gaps. If the authorities (commit to) setting (for all $s \geq t$) $\widehat{R}_s = \widetilde{R}_s$, $\widehat{G}_s^H = \widetilde{G}_s^H$ and $\widehat{G}_s^F = \widetilde{G}_s^F$, all gaps are closed. In other words, even though the natural terms of trade fluctuate, the price flexibility in one country serves as a stabilizing device, which assures that the available three policy instruments become sufficient for attaining efficiency.

We can also establish efficiency when the supply shocks fulfill a specific restriction. From the Phillips curves (30) and (31), the following proposition is immediate:

Proposition 3 *Let $\widehat{T}_{t-1} = 0$ and suppose that the supply shocks are perfectly correlated. Then, the appropriate combination of monetary and fiscal policies closes all the gaps.*

By (committing to) setting (for all $s \geq t$) $\widehat{R}_s = \widetilde{R}_s$, $\widehat{G}_s^H = \widetilde{G}_s^H$ and $\widehat{G}_s^F = \widetilde{G}_s^F$, and observing that $\widetilde{T}_s = 0$ with perfectly correlated supply shocks, we obtain an equilibrium in which the consumption gap is closed and the national producer inflation rates are zero. This equilibrium is validated by observing that $\widehat{T}_t = 0$ and, hence, that $\widehat{T}_t = \widetilde{T}_t$. This result holds irrespective of potential differences in the degree of price stickiness between the countries. Hence, in this special case policy can be designed so as to replicate the efficient flex-price equilibrium. The reason is that with three policy instruments and no fluctuations in the natural terms of trade, no policy trade-offs arise.

[9] When for both countries public spending does not enter the individuals' utility, fixing $\widetilde{G}_t^H$ at some value determines $\widetilde{G}_t^F$ via $\widetilde{G}_t^R = S_t^R/(1-\xi_c)$.

Now, suppose that both economies feature some price rigidity, and that the supply shocks are *imperfectly* correlated. Is it still always possible to attain the efficient flex-price equilibrium through appropriate instrument settings? The answer is no. We formally state this result in the following proposition:

Proposition 4 *Assume that $\widehat{T}_{t-1} = 0$ and that $\widetilde{T}_t \neq 0$ (because of an asymmetric supply shock). Then, setting fiscal policy such that $\widehat{G}_s^H = \widetilde{G}_s^H$ and $\widehat{G}_s^F = \widetilde{G}_s^F$ and monetary policy such that $\widehat{C}_s^W = \widetilde{C}_s^W$, for all $s \geq t$, and imposing that $\widehat{T}_s = \widetilde{T}_s$ for all $s \geq t+1$, implies that $\widehat{T}_t \neq \widetilde{T}_t$.*

Proof: let $\widehat{T}_{t-1} = 0$ and $\widetilde{T}_t \neq 0$. Suppose that, with $\widehat{G}_s^H = \widetilde{G}_s^H$, $\widehat{G}_s^F = \widetilde{G}_s^F$ and $\widehat{C}_s^W = \widetilde{C}_s^W$, for all $s \geq t$, and $\widehat{T}_s = \widetilde{T}_s$ for all $s \geq t+1$, we had that $\widehat{T}_t = \widetilde{T}_t$. Then, $\pi_t^H = \pi_t^F = 0$. Hence, $\widehat{T}_t = 0 \neq \widetilde{T}_t$. Contradiction.■

In other words, it is generally not possible to close all gaps at all times when supply shocks are imperfectly correlated. The reason is that the associated fluctuations in $\widetilde{T}_t$ create a policy dilemma. On the one hand, when fiscal policies are aimed at securing efficient public spending levels, the common monetary policy cannot induce the required relative price change without destabilizing national inflation rates. In fact, as we discuss in more detail in Section 5, with equal nominal rigidities (i.e., $\alpha^H = \alpha^F$), the terms of trade are completely insulated from monetary policy (cf. Benigno, 2001). On the other hand, when fiscal policies are aimed at inducing the needed relative price change, public spending is no longer efficient. Hence, only in the special cases described by Propositions 1-3, policy trade-offs will vanish. Note that Proposition 4 confirms Benigno's (2001) finding for the case in which fiscal policy is absent. It thus follows that introducing fiscal policy cannot provide sufficient flexibility for attaining efficiency as can independent currencies in his model. Nevertheless, as we shall see below, fiscal policy may still be helpful in providing macroeconomic stabilization.

4 Setup of the policy analysis

4.1 The objective function

There is an increasing pressure on the countries in the European Union to intensify the coordination of macroeconomic policies. Of course, by now there is a common monetary policy. However, the quest for common policymaking in other areas, such as labor market policies and social policies is becoming louder too. As regards to fiscal policy, some steps have already been taken with the adoption of the Stability and Growth Pact. Sometimes the suggestion is made that it is necessary to set up a political counterweight to the ECB. France, in particular, has repeatedly expressed the need for intensified fiscal coordination and a potential vehicle for such coordination would be to endow the Eurogroup (the Finance Ministers of the Euro area) with (more) formal powers. As we are interested in the coordination of fiscal policies, the relevant objective function for our purpose is the union-level supranational loss function given by:

$$L = \sum_{t=1}^{\infty} \beta^{t-1} \mathrm{E}_1 \left[L_t \right], \tag{34}$$

where

$$\begin{aligned} L_t \;=\; & \lambda_C \left(\widehat{C}_t^W - \widetilde{C}_t^W \right)^2 + \lambda_T \left(\widehat{T}_t - \widetilde{T}_t \right)^2 + \lambda_{GH} \left(\widehat{G}_t^H - \widetilde{G}_t^H \right)^2 \\ & + \lambda_{GF} \left(\widehat{G}_t^F - \widetilde{G}_t^F \right)^2 + \lambda_{\pi^H} \left(\pi_t^H \right)^2 + \lambda_{\pi^F} \left(\pi_t^F \right)^2, \end{aligned} \tag{35}$$

with all weights non-negative. That is, any deviation of endogenous variables from their efficient flex-price level constitutes a welfare loss. While we postulate this loss function, we motivate it by the fact that it generalizes the loss function that Benigno (2001) derives formally for the case in which fiscal policy as an instrument for macroeconomic stabilization is absent. In particular, if $\lambda_{GH} = \lambda_{GF} = 0$, this loss function would have the same format as Benigno's (2001) loss function, which is (minus) a second-order Taylor approximation to a utilitarian welfare function which weighs equally the utility of each individual in the union and where the parameters in (35) are functions of the "deep" parameters of the model (see below).

4.2 The policies

We consider several types of policies. One type concerns the *optimal policies*. Here, we distinguish between commitment and discretion, as there will generally be gains from commitment as mentioned in the Introduction. The technical details for the computation of the optimal policies are available upon request from the authors.[10] As one of our main questions concerns the contribution of fiscal policy to the stabilization of shocks, within the set of optimal policies, we consider "full" optimization over the complete vector of policy instruments $\left(\widehat{R}_t \quad \widehat{G}_t^H \quad \widehat{G}_t^F \right)'$ and restricted optimization over monetary policy only, with fiscal policy restricted to be passive in the sense that $\widehat{G}_t^H = \widetilde{G}_t^H$ and $\widehat{G}_t^F = \widetilde{G}_t^F$. That is, fiscal policymaking is exclusively concerned with securing the efficient provision of public goods, and takes no part in stabilizing other macroeconomic variables.

We will also explore various *policy rules*. Although such rules are generally suboptimal relative to the optimal commitment policy, the latter is often merely regarded as a benchmark. In reality it would be hard to achieve, because the policymakers would have an incentive to deviate from the optimal plan. Although policy rules generally also require commitment, the incentive to deviate from the rule would be weaker if it is transparent and simple, so that deviations from the rule can easily be detected and punished, either through a loss of confidence from the public/financial markets or by other policymakers.

[10] The policies and associated losses are computed numerically using the solution algorithms described by, e.g., Backus and Driffill (1986), Svensson (1994) and Söderlind (1999).

For example, the latter might exclude the "misbehaving" policymaker from their joint decision-making process (see, however, the caveat on policy rules versus fully optimal policymaking in Footnote 3).

The monetary and fiscal policy rules that we will consider all fall within the rather general class of rules given by

$$\begin{aligned}\widehat{R}_t - \widetilde{R}_t &= \left(b_H \pi_t^H + b_F \pi_t^F\right) + b_C \left(\widehat{C}_t^W - \widetilde{C}_t^W\right) \\ &\quad + b_T \left(\widehat{T}_t - \widetilde{T}_t\right) + \left[d_H \mathrm{E}_t \left(\pi_{t+1}^H\right) + d_F \mathrm{E}_t \left(\pi_{t+1}^F\right)\right],\end{aligned} \tag{36}$$

$$\begin{aligned}\widehat{G}_t^H - \widetilde{G}_t^H &= -g_{CH} \left(\widehat{C}_t^W - \widetilde{C}_t^W\right) - g_{TH} \left(\widehat{T}_t - \widetilde{T}_t\right), \\ \widehat{G}_t^F - \widetilde{G}_t^F &= -g_{CF} \left(\widehat{C}_t^W - \widetilde{C}_t^W\right) + g_{TF} \left(\widehat{T}_t - \widetilde{T}_t\right),\end{aligned} \tag{37}$$

which, for example, allow for the possibility to contract monetary policy when inflation or the consumption gap increases and to contract fiscal policy when the consumption gap increases or the terms-of-trade gap deteriorates. We will not optimize the combination (36) and (37) over all parameters. This would require an immense amount of computing time. More importantly, this would in some instances lead to coefficients of infinity (as we will explain below), which essentially makes no sense. Therefore, we consider specializations of the combination of rules (36) and (37), where in some cases we impose constraints on the coefficients of these rules.

4.3 The benchmark parameter combination

We largely follow Benigno (2001) in our choice of the benchmark parameter combination. The calibration is based on the assumption that each period corresponds to a quarter of a year. Benigno calibrates his model to the EMU situation and divides the area into two groups, one corresponding to relatively low nominal wage rigidity and the other corresponding to relatively high wage rigidity. Both groups have a weight of approximately 50% in Euro-area GDP, so that $n = 0.5$. We set $\beta = 0.99$, which implies a steady-state real rate of return of 1% on a quarterly basis. Parameter σ, capturing the degree of monopolistic competition, is set such that it is consistent with a steady-state mark up of prices over marginal costs of 15%. Hence, we set $\sigma = 7.66$. The benchmark values for α^H and α^F are selected so as to produce an average duration of a price contract of 1 year, so that $\alpha^H = \alpha^F = 0.75$. We deviate from Benigno (2001) in our assumptions about the coefficient of relative risk aversion (RRA) for private consumption and the elasticity of the labor supply. Regarding the former, we assume that $\rho = 2.5$.[11] We set the RRA coefficient for government spending, ρ_g, also at 2.5. Further, we set the elasticity of the labor supply at 0.1, implying $\eta = 10$. Finally, based on 0.6 and 0.2 being reasonable approximations for the private and government consumption shares of output in reality, we assume that $\xi_c = 0.75$, so that private consumption is three times as large as government consumption.

[11] For example, see Beetsma and Schotman (2001) and the references therein.

The next step in the choice of the benchmark parameter values concerns the choice of the loss function parameters. Here, we make use of the expressions that Benigno (2001) — in the absence of endogenous government spending — derives for these parameters as functions of the "deep" model parameters. This yields the following expressions (up to an irrelevant proportionality factor):

$$\begin{aligned} \lambda_C &= \frac{(\rho+\eta)/\sigma}{n/k^H + (1-n)/k^F}, \quad \lambda_T = \frac{n(1-n)(1+\eta)/\sigma}{n/k^H + (1-n)/k^F}, \\ \lambda_{\pi^H} &= \frac{n/k^H}{n/k^H + (1-n)/k^F}, \quad \lambda_{\pi^F} = 1 - \lambda_{\pi^H}. \end{aligned}$$

We link the weight on public spending to its relative weight in output. Therefore, in the benchmark, we set $\lambda_G = \lambda_C [(1-\xi_c)/\xi_c]$.

The final step involves the choices about the shocks. We already note that the particular process chosen for the demand shock plays no role (see below). For the supply shocks we assume the following $AR(1)$ process:

$$S_t^i = 0.97 S_{t-1}^i + \mu_{S,t}^i, \; i = H, F,$$

where the $\mu_{S,t}^i$ are white-noise innovations. The chosen degree of autocorrelation is high. However, this seems reasonable when we assume that the supply shocks represent technology shocks. We set the standard deviation of the innovations in the process for these shocks at 0.7%. This provides a reasonable unconditional standard deviation of the supply shocks. These assumptions are in line with the standard assumptions of the real-business-literature (e.g., see Cooley and Prescott, 1995).

In the sequel, we consider a number of variations on the baseline parameter combination. We allow for asymmetries in the degree of price rigidity. In particular, we consider the case in which $\alpha^H = 0.5$ and $\alpha^F = 0.75$. The estimates in Galí et al. (2001) of α for Euroland range from 0.67 to 0.81, while for the U.S. they range from 0.56 to 0.60. Hence, the degree of asymmetry that we consider seems to be at the higher end. The benefit is that the range of variation in our parameter settings is more likely to cover the actual variation in rigidity in reality. We also vary the degree of (contemporaneous) correlation of the supply shocks and the elasticity of the labor supply. Finally, given our ignorance about the precise weight to be attached to public spending gaps in the loss function, we explore the robustness of the results for variations in this weight.

5 Discussion of the (numerical) results

Before we turn to the results of the numerical analysis, we narrow down the set of possible parameters combinations that we need to investigate. In particular, we can exclude demand shocks from the analysis, as the following proposition shows:

Proposition 5 *The demand shocks are irrelevant for the equilibrium gaps under the optimal policies and the policy rules we consider. Therefore, they are also irrelevant for the equilibrium welfare losses associated with these policies.*

Even though the demand shocks affect the efficient flex-price equilibrium and thereby also the deviations of variables under sticky prices from their steady state values, the *gaps* of all the variables are unaffected by the demand shocks. For the optimal policies one can immediately see this result, if one realizes that the system (35), (27), (30), (31) and (32), with the latter rewritten as

$$\widehat{T}_t - \widetilde{T}_t = \widehat{T}_{t-1} - \widetilde{T}_{t-1} + \pi_t^F - \pi_t^H - \left(\widetilde{T}_t - \widetilde{T}_{t-1}\right), \tag{38}$$

is exhaustively expressed as a set of relations among gaps of variables and $\widetilde{T}_t - \widetilde{T}_{t-1}$. We can relabel all the gaps as, say, Z_{1t}, Z_{2t},... Then, observing by (25) that $\widetilde{T}_t - \widetilde{T}_{t-1}$ only depends on the (current and one-period lagged) relative supply shock, we are left with a system without demand shocks. This reasoning also once again explains why supply shocks in general *do* matter here. As regards to the irrelevance of the demand shocks in the case of our rules, we observe that the combination of rules (36) and (37) is exhaustively expressed in terms of gaps and national inflation rates, so that complementing the system (35), (27), (30), (31) and (32) by these rules yields again a system in gaps and the relative supply shocks. Reiterating the "relabelling trick," we thus have a system without demand shocks.

We have assumed that all the shocks and, thus, also the natural levels of variables are observable. Hence, when conducting optimal policies or implementing a rule, policymakers respond to the true natural rates. However, in practice, shocks are usually only imperfectly observable. As a result, natural levels can at most be imprecisely computed and their computation will generally affect the outcomes under optimal policies or under rules. Hence, given the imprecise knowledge about the natural levels of variables, practical policymaking is often based on deviations of variables, such as output, from a trend. Apart from problems with the observation of shocks, in practice there is also uncertainty about the correct macroeconomic model. This translates as an additional source of uncertainty into the computation of the natural levels of variables. Therefore, when assessing the performance of the policies to be investigated below we have to bear in mind these qualifications. Although beyond the scope of the present paper, it would be useful in further research to explore policy rules that are robust against the abovementioned concerns.

5.1 The optimal policies

In this section we explore optimal policies. Appendix C characterizes formally the solution, but we stick to intuitive explanations here. We start with the *benchmark case* of full optimization over all three policy instruments under commitment and under the assumption that both countries are characterized by equal rigidities (i.e., $\alpha^H = \alpha^F$ and, thus, $k^H = k^F \equiv k$), that they are equally large (i.e., $n = \frac{1}{2}$) and that the supply shocks are uncorrelated. Because rigidities are equal, we can separate the model into two parts. Taking a weighted average of (30) and (31), we obtain the "world" Phillips curve

$$\pi_t^W = \beta \mathrm{E}_t \pi_{t+1}^W + k \left[(\rho + \eta \xi_c) \left(\widehat{C}_t^W - \widetilde{C}_t^W \right) + \eta (1 - \xi_c) \left(\widehat{G}_t^W - \widetilde{G}_t^W \right) \right], \qquad (39)$$

while subtracting (30) from (31), and using (32), yields:

$$\widehat{T}_t - \widehat{T}_{t-1} = \beta \mathrm{E}_t \left(\widehat{T}_{t+1} - \widehat{T}_t \right) - k (1 + \eta \xi_c) \left(\widehat{T}_t - \widetilde{T}_t \right) + k\eta (1 - \xi_c) \left(\widehat{G}_t^R - \widetilde{G}_t^R \right), \qquad (40)$$

which shows that the terms of trade are completely insulated from monetary policy in this case, but not from fiscal policy. The combination of optimal policies is as follows. The monetary authority commits to setting the interest rate at the natural rate, which closes consumption gap and produces zero world inflation at all dates (because $\widehat{G}_t^W = \widetilde{G}_t^W$, as we explain below). However, in the present situation not all gaps can be closed, as Proposition 4 already showed, because zero world inflation hides opposite movements in local inflation rates, which prevent the terms of trade from always attaining its natural level. Public spending under the optimal plan is used to reduce the terms-of-trade gap, thereby dampening its effects on local inflation. When the terms-of-trade gap is positive (say), causing upward pressure on Home inflation, Home fiscal policy should be contractionary, and vice versa for the other country. In this symmetric case, the public spending gaps are equally large in absolute value, so that they offset each other in (39). (Appendix C shows this formally.)

We shall now explore a number of variations on the benchmark case. First, we investigate the benefits from commitment by computing the solution when policies are conducted under discretion. When the economies feature an equal degree of price rigidity, the commitment problem arises exclusively in fiscal policy, as there are no trade-offs in monetary policy, as we explained above. However, the fiscal authorities can gain if they commit to more aggressive and persistent policy responses towards shocks [the inertial nature of spending under commitment is seen formally in Appendix C, equations (54) and (55)]. This will affect inflation expectations, and thus help to stabilize current inflation.[12] As a result, the terms-of-trade gap will become more stable. Although these gains come at the cost of more variable public spending, they dominate this cost. Hence, the discretionary scenario where fiscal policy is less active and persistent towards stabilizing shocks is welfare inferior, as the inflation/spending trade-off is worse since inflation expectations are not affected as strongly as under commitment. We present the losses for the two cases in Table 1, in the columns L^c and L^d, respectively. However, to assess the welfare gains from commitment in "real world terms," we compute the permanent (and constant) percentage change in the consumption gap that would produce a given difference in losses. Call this

[12] This is analogous to the optimality of committing to an inertial monetary policy in a closed economy when shocks induce monetary policy trade-offs; cf. Woodford (1999a).

percentage change c. We thus solve:

$$\frac{\lambda_C}{1-\beta}\left(\frac{c}{100}\right)^2 = L^i - L^c,$$

where L^c is the loss under commitment with full optimization, and L^i is the loss under the regime (in this case, full optimization under discretion) that we want to compare with L^c in terms of "consumption equivalents". We report the figures in column D of Table 2 and observe that the benefit from commitment is non-trivial, as it is equivalent to a permanent consumption gain of more than 0.5% for the benchmark case.

The purpose of the next variation is to explore the gains from using public spending for macroeconomic stabilization. To this end, we restrict fiscal policy to be passive (i.e., $\widehat{G}_t^H = \widetilde{G}_t^H$ and $\widehat{G}_t^F = \widetilde{G}_t^F$), so that it is only occupied with the efficient provision of public spending. The column L^{cp} in Table 1 reports the losses, while column CP in Table 2 expresses the loss relative to the case of full optimization with commitment in terms of permanent consumption losses. Hence, the benefit from using public spending for stabilization amounts to a permanent consumption gain of over 0.6% for the benchmark case. This figure may give an indication of the potential costs of the Stability and Growth Pact when its deficit upperbound is reached and it is no longer possible to stimulate the economy with a fiscal expansion. Note that because monetary policy does not suffer from a credibility problem in the benchmark, a passive fiscal policy leads to equal losses under commitment and discretion (see Table 1, with the loss under discretion in column L^{dp}).

The third variation on the benchmark case allows for asymmetry in price rigidity between the countries. Now, monetary policy *is* subject to a stabilization trade-off and commitment of monetary policy *does* yield welfare gains.[13] The reason is that monetary policy now not only affects world variables, but also the terms of trade. Hence, monetary policy will no longer be exclusively focussed on stabilizing world inflation, but also on reducing movements in national inflation and the terms-of-trade gap. More specifically, if Foreign prices are relatively more sticky, the optimal policy setting allows Home inflation to be more variable than Foreign inflation. With Foreign prices being more sticky, it is optimal to direct monetary policy at trying to keep Foreign inflation closer to zero, so that losses resulting from persistent relative price differences within Foreign are reduced. This is analogous to Benigno's (2001) result that under a strict inflation targeting rule, the highest relative weight should be attached to the inflation rate of the country with the highest degree of price rigidity. Optimal fiscal policymaking results in a Home public spending gap that is more variable than the Foreign public spending gap. The reason is that Home's higher inflation variability forces its fiscal policy to assume a relatively larger role in stabilizing national inflation.

We now vary the correlation between the shocks. Here, we ignore the case of perfectly correlated supply shocks, because by Proposition 3, we know that it leads to zero welfare

[13] This can directly be seen by comparing the losses under commitment versus discretion when fiscal policy is restricted to be passive (see the columns L^{cp} and L^{dp} in Table 1).

losses. Remember from (38) that it is *only* the relative supply shock (entering via the term $\widetilde{T}_t - \widetilde{T}_{t-1}$) that determines the fluctuations in the gaps of all variables. Hence, when the correlation of the supply shocks falls, the variance of the relative supply shock rises and the losses increase (as the figures in Table 1 confirm). The commonly-held view that in a monetary union the benefits from fiscal stabilization policy at the national level become proportionally larger when the shock correlations fall is nevertheless not correct for the current model. Table 1 shows that the ratios L^c/L^{cp} and L^d/L^{dp} remain unchanged when we vary the correlation of the supply shocks. The explanation for this finding is that the relative supply shocks effectively act as a *common* shock. Further, the welfare loss in this linear-quadratic framework is always proportional to the variance of this shock. Hence, the relative advantage of having recourse to fiscal stabilization is invariant to the correlation of the supply shocks. Nevertheless, it is interesting to vary the correlation of the supply shocks in the model, because we do not have a precise idea about their empirical correlation, while in this way we can see whether the gains from commitment and an active fiscal policy remain relevant when the correlation is positive. Holding everything else fixed at the benchmark setting, with a supply-shock correlation of 0.5, the gain from commitment amounts roughly to a 0.4% permanent improvement in consumption, while the gain from an active fiscal policy is slightly larger (see Table 2).

We have also varied the $AR(1)$ coefficient of the supply shocks. In particular, we ran numerical simulations with $AR(1)$ coefficients of 0.9 and 0.75. In both cases, we adjusted the variance of the innovations $\mu^i_{S,t}$, so as to keep the unconditional variance of S^i_t unchanged. The gain from commitment amounts to a permanent consumption gain of 0.6% and 0.3%, respectively, while the gain from using fiscal policy for stabilization amounts to a permanent consumption gain of 0.6% and 0.4%, respectively. Hence, although smaller, the gains from commitment and an active fiscal policy remain non-trivial.

The next experiment concerns the variation of the coefficients λ_{GH} and λ_{GF} of the public spending gaps in the loss function. The reason for varying this coefficient is that we are ignorant about the appropriate size of this coefficient. As expected, increasing the coefficient leads to higher losses and lower variability in public spending. However, quantitatively, the gains from commitment and having access to fiscal stabilization remain relevant (see Table 2).

Finally, we explore the effects of changing the inverse of the elasticity of the labor supply, η. The appropriate size of this parameter is typically surrounded with a lot of uncertainty, so that it is sensible to consider this variation. Tables 1 and 2 report the results for $\eta = 5$, thus assuming a labor-supply elasticity which is twice as large as the baseline elasticity. Although somewhat smaller than under the benchmark, the gains from commitment and fiscal stabilization remain non-negligible, as Table 2 shows.

5.2 The rules

As mentioned earlier, the advantage of a rule is that it may be easier to commit to than to the optimal policy, because a rule is often simpler and more transparent. The first combination of rules is suggested by the optimal solutions above. The monetary policy rule is chosen such that it (almost) closes the consumption gap and (almost) leads to zero world inflation. Of course, perfect elimination of the consumption gap and, hence, zero world inflation would be optimal, but would require some infinitely-large coefficients in the monetary policy rule. We approximate this situation by setting $b_H = b_F = b_T = 0$ and choosing large values of d_H, $d_F = d_H(1-n)/n$ and b_C in (36).[14] With the consumption gap virtually eliminated, the public spending gap can be restricted to react to the terms-of-trade gap, so that $g_{CH} = g_{CF} = 0$ in (37). Table 1 reports the optimal coefficients of the public spending rules for the parameter combinations considered earlier. The optimal rules are characterized by $g_{TH} = g_{TF} > 0$. We observe that in all the cases reported, the optimal fiscal rule leads to a welfare loss (denoted L^r) below the loss under the full-optimization discretionary policy. We note also that, for the baseline case, the loss from having passive fiscal policies (i.e., also $g_{TH} = g_{TF} = 0$, with the loss denoted by L^{rp}), is (virtually) equal to that under passive fiscal policies when monetary policy is optimally conducted under commitment (compare columns CP and RP in Table 2).[15] As before, fiscal policy is employed to reduce the effect of the terms of trade on local inflation and, with differences in price rigidity, the more flexible country employs a more active fiscal policy. Finally, the rule coefficients are unaffected by the shock correlations. This mirrors the result that the relative losses under optimal policymaking with or without active fiscal policy are invariant to the shock correlations.

The second combination of rules is based on output gaps. Monetary policy follows a standard Taylor rule, with the original coefficients proposed by Taylor (1993):

$$\widehat{R}_t - \widetilde{R}_t = 1.5\pi_t^W + 0.5\left(\widehat{Y}_t^W - \widetilde{Y}_t^W\right). \tag{41}$$

This is sometimes seen as a reasonable description of how monetary policy has been conducted in the past, in particular in the U.S. Because fiscal policy is often discussed in terms of its pro- or countercyclicality (that is, the degree to which it is correlated with

[14] When the parameters d_H and d_F are chosen too large, a unique saddlepath solution no longer exists. This reflects a well-known feature of this type of model: to ensure determinacy, the nominal interest rule should be "active," but not too active (see, e.g., Woodford, 2002). Raising b_C reduces the consumption gap further and forces world inflation closer to zero.

[15] If we restrict ourselves to an analysis of only rule-based policies, a measure of the loss caused by this fiscal restriction would be a comparison of L^r and L^{rp}. For the benchmark case, the difference corresponds to a permanent drop in consumption of around 0.5 percentage points.

the output gap), the public spending gaps are set according to:[16]

$$\widehat{G}_t^H - \widetilde{G}_t^H = -g_{YH}\left(\widehat{Y}_t^H - \widetilde{Y}_t^H\right), \quad \widehat{G}_t^F - \widetilde{G}_t^F = -g_{YF}\left(\widehat{Y}_t^F - \widetilde{Y}_t^F\right). \tag{42}$$

We report the results for the combination of rules (41) and (42) in Table 3. The losses with completely passive fiscal policies (i.e., $g_{YH} = g_{YF} = 0$) are close to the corresponding losses under the (approximate) optimal monetary policy rule (compare the losses reported in the columns under L^{rp} in Tables 1 and 3). Hence, a Taylor rule as such performs well in this model. To explore the contribution to stabilization of output-gap based fiscal rules we find the optimal coefficients g_{YH} and g_{YF}, while monetary policy follows the standard Taylor rule. The optimal fiscal rules are always countercyclical. For the baseline parameter combination, a 1 percentage point increase in the output gap leads to a reduction in the spending gap of about 1.3 percentage point. In welfare terms, this combination of rules performs well, as it attains welfare levels close to those for the optimal fiscal rule combined with the (approximate) optimal monetary policy as reported in Table 1.

We may compare the fiscal rules based on the output gap with what the empirical literature finds for the correlation between public spending and the business cycle. Several authors have recently investigated this for European countries and/or OECD countries. In his study of Irish fiscal policy, Lane (1998) finds evidence that aggregate public spending has been acyclical. Lane (2002) explores the cyclicality of fiscal policy for OECD countries and concludes that aggregate public spending is mildly countercyclical. The degree of countercyclicality varies across countries and across spending categories, though countries with more volatile output and dispersed political power are the most likely ones to run a countercyclical fiscal policy. Fatás and Mihov (2000, 2001) explore the propagation of fiscal policy changes and conclude that they have strong and persistent effects on economic activity and consumption.

Under the optimal policies we analyzed earlier, we found that with differences in price stickiness, monetary policy induced relatively more stable prices in the country with the higher degree of price rigidity. Here, we investigate this policy implication in the context of the Taylor rule for monetary policy. In (41), we therefore replace $\pi_t^W = n\pi_t^H + (1-n)\,\pi_t^H$ by $\pi_t^{W*} \equiv \delta_H \pi_t^H + \delta_H \pi_t^F$, and we compute the optimal combination of relative weights $\left(\delta_H^{opt}, \delta_F^{opt}\right)$ assuming that fiscal policies follow the output gap-based rules (42). Again, this yields a special case of the combination (36) and (37). Based on the asymmetric case of $\left(\alpha^H, \alpha^F\right) = (0.5, 0.75)$, Table 4 reports the results for different degrees of correlation of the supply shocks and different weights on public spending in the loss function. Except for the 2nd and 3rd lines of the table, which assume a passive fiscal policy, in the other

[16] Note that the combination (41) and (42) is a special case of the combination (36) and (37), because $\left(\widehat{Y}_t^H - \widetilde{Y}_t^H\right)$ and $\left(\widehat{Y}_t^F - \widetilde{Y}_t^F\right)$ can be expressed in terms of consumption, public spending and terms-of-trade gaps. For example, if $g_{YH} = g_{YF} \equiv g_Y$, we can rewrite (41) and (42) into the format (36) and (37), with coefficient restrictions $g_{CH} = g_{CF} = \frac{g_Y \xi_c}{1+g_Y(1-\xi_c)}$, $g_{TH} = \frac{g_Y \xi_c (1-n)}{1+g_Y(1-\xi_c)}$, $g_{TF} = \frac{g_Y \xi_c n}{1+g_Y(1-\xi_c)}$, $b_H = 1.5n$, $b_F = 1.5\,(1-n)$, $b_C = \frac{\xi_c b_Y}{1+g_Y(1-\xi_c)}$, $b_T = 0$ and $d_H = d_F = 0$.

lines we take for the coefficients g_{YH} and g_{YF} the optimal ones that are reported in Table 3 for the corresponding parameter setting. Table 4 shows that it is indeed optimal in all cases to give a higher relative weight to the stickier price country. However, the optimal relative weights are very close to the original weights $(n, 1-n)$ for π_t^H and π_t^F, respectively. Accordingly, the welfare losses are very close to the corresponding losses found in Table 3. Therefore, it seems that if the central bank of a monetary union follows a policy that is close to the standard Taylor rule, there is actually little reason to adjust the relative weights of the individual components of the union-wide inflation measure for asymmetries in nominal rigidities. The gains would only be small, while the political resistance to such a reweighting would most likely be substantial.[17] In addition, having more rigid countries enter with a larger relative weight could weaken their incentive to make their product markets more flexible (as argued by Benigno, 2002).

Countries sometimes call upon each other to take fiscal measures that get the (world) economy out of recession.[18] One such type of "cooperative rule" would be to have fiscal policy depend (linearly) on the world output gap, rather than the national output gap. If the world output gap is negative, fiscal policy would be expansionary, and vice versa. Because these fiscal rules do not react to national circumstances and are, therefore, unable to affect country-specific fluctuations in inflation, their contribution to reducing welfare losses will be marginal. In particular, when monetary policy is able to close the consumption gap, such fiscal rules are redundant. Hence, we do not report results for these rules.

6 Conclusion

This paper has explored the interactions between monetary and fiscal policy in a micro-founded model of a monetary union with sticky prices. We explored the contribution of public purchases in economic stabilization in the presence of supply and demand shocks. This is an important issue in EMU, given that monetary policy is constrained to be attuned to European-wide economic developments. This is often considered to be the main drawback of EMU. In selecting fiscal policies, either optimal or through a rule, we took a European-wide perspective. This is the relevant perspective to be taken by supranational European institutions, in particular the ECB and the European Commission, the latter of which has to take initiatives on economic policies that promote welfare across the European Union. It is also the relevant perspective for the ECOFIN Council (or the Eurogroup) in case it moves towards more explicit coordination of fiscal policies. Our results suggest that there are non-negligible gains from fiscal stabilization and commitment.

[17] We experimented with an increase in the coefficient on π_t^{W*} in the central bank's interest rate rule. This raised the optimal relative weight of the more rigid country in π_t^{W*}, which corresponds to what Benigno's (2001) finds for a strict inflation targeting rule (i.e., such that $\pi_t^{W*} = 0$).

[18] An example is the Bonn Agreement of 1978 in which the G5 countries intended to give a coordinated fiscal stimulus to a stagnant world economy (without aggravating external imbalances).

While there is a pressure for more fiscal coordination in Europe, actual fiscal policies are primarily conducted with the objective of serving national interests rather than union-wide interests. Therefore, further research could extend the current framework into one where national fiscal policies interact strategically. A relevant question then is whether current union-wide institutions, in particular the Stability and Growth Pact, suffice to induce fiscal policymakers to internalize the union-wide implications of their policies.[19] More generally, one would want to assess more firmly the gains from fiscal policy coordination in a monetary union.

The analysis in this paper can be extended into various other directions. One is to relax the assumption of Ricardian equivalence and allow for a richer menu of fiscal policies. In particular, public debt can be employed as an instrument to intertemporally smooth out the effects of shocks. It will be interesting to investigate how this combines with the use of public spending to stabilize current demand. Deficit ceilings, like those imposed under the Stability and Growth Pact will then also become relevant from a welfare perspective. Further, one would expect that the interaction between monetary and fiscal policy strengthens and that time consistency problems may deepen when the time profile of the taxes and/or transfers is no longer irrelevant and debt is nominal. Also issues arise that pertain to the fiscal restrictions needed to provide the central bank with control over the price level (Sims, 1999). Another extension would abolish the assumption of internationally complete markets. When centralized to a sufficient extent, fiscal policies could then be employed to provide for the sharing of country-specific risks. A third extension would allow not only for sticky prices, but also for sticky wages (e.g., Erceg et al., 2000). As a result, optimal policies would need to address more distortions. As a fourth elaboration on the current setup, one could introduce a time-varying mark up (along the lines of Giannoni, 2000), thereby giving rise to a "cost-push" shock in the Phillips curves, which again would imply more distortions to be addressed. Finally, the model can be made more realistic by introducing lags in the transmission of policy, which is especially relevant for the implementation of fiscal policy. There is a strong consensus that implementing fiscal policy actions takes much more time than changing monetary policy. For example, measures have to be designed, presented to the parliament and to be voted on. Thus, there is doubt about the extent to which fiscal policy can be used to fine-tune the economy.

The suggested extensions will all affect the usefulness of fiscal policy as an instrument for macroeconomic stabilization. While the last extension may reduce the gains from fiscal stabilization, the combination of incomplete markets and asymmetric demand shocks could provide an additional role for fiscal stabilization policies. We leave these extensions for future research and view our analysis as a potentially useful benchmark for further analyses of the monetary and fiscal policy mix in a monetary union.

[19] Benigno and Benigno (2001) explore a similar issue for monetary policy coordination.

Appendices

A Derivation of the efficient flex-price equilibrium

Log-linearizing (15) around the steady state, and using the relevant definitions from the main text, we have:

$$-\rho\left(\widetilde{C}_t^H + D_t^H\right) = (1-n)\,\widetilde{T}_t + \eta\left[(1-n)\,\xi_c \widetilde{T}_t + \xi_c \widetilde{C}_t^W + (1-\xi_c)\,\widetilde{G}_t^H\right] - \eta S_t^H, \tag{43}$$

and an analogous equation for the Foreign country:

$$-\rho\left(\widetilde{C}_t^F + D_t^F\right) = -n\widetilde{T}_t + \eta\left[-n\xi_c \widetilde{T}_t + \xi_c \widetilde{C}_t^W + (1-\xi_c)\,\widetilde{G}_t^F\right] - \eta S_t^F. \tag{44}$$

Taking a weighted average (with weights n and $1-n$) of the latter two equations, we obtain $-\rho\left(\widetilde{C}_t^W + D_t^W\right) = \eta\left[\xi_c \widetilde{C}_t^W + (1-\xi_c)\,\widetilde{G}_t^W\right] - \eta S_t^W$. Hence,

$$\widetilde{C}_t^W = \frac{\eta}{\rho + \eta\xi_c}\left[S_t^W - \frac{\rho}{\eta} D_t^W - (1-\xi_c)\,\widetilde{G}_t^W\right]. \tag{45}$$

Subtracting (44) from (43) and using that $\widetilde{C}_t^H + D_t^H = \widetilde{C}_t^F + D_t^F$ [as follows by linearizing (8)] we obtain $0 = \widetilde{T}_t + \eta\left[\xi_c \widetilde{T}_t - (1-\xi_c)\,\widetilde{G}_t^R\right] + \eta S_t^R$ and thus

$$\widetilde{T}_t = \frac{\eta}{1 + \eta\xi_c}\left[(1-\xi_c)\,\widetilde{G}_t^R - S_t^R\right]. \tag{46}$$

Further, because $\widetilde{Y}_t^H = \left[(1-n)\,\overline{T}^{1-n}\overline{C}\widetilde{T}_t + \overline{T}^{1-n}\overline{C}\widetilde{C}_t^W + \overline{G}^H \widetilde{G}_t^H\right]/\overline{Y}^H$, we can also write (43) as $-\rho\left(\widetilde{C}_t^H + D_t^H\right) = (1-n)\,\widetilde{T}_t + \eta\widetilde{Y}_t^H - \eta S_t^H$ and (44) as $-\rho\left(\widetilde{C}_t^F + D_t^F\right) = -n\widetilde{T}_t + \eta\widetilde{Y}_t^F - \eta S_t^F$. Taking a weighted average (with weights n and $1-n$) of these two equations, we then obtain

$$-\rho\left(\widetilde{C}_t^W + D_t^W\right) = \eta\widetilde{Y}_t^W - \eta S_t^W. \tag{47}$$

Combining this with (45), we find that:

$$\widetilde{Y}_t^W = \frac{\eta\xi_c}{\rho + \eta\xi_c} S_t^W - \frac{\rho\xi_c}{\rho + \eta\xi_c} D_t^W + \frac{\rho\,(1-\xi_c)}{\rho + \eta\xi_c}\widetilde{G}_t^W. \tag{48}$$

We solve now for $\widetilde{G}_t^H$ and $\widetilde{G}_t^F$, thereby completing the solution of the efficient flex-price equilibrium. The fiscal authorities maximize (20) over G_t^H and G_t^F, where it is understood that the values of C_t^H, Y_t^H, C_t^F, and Y_t^F satisfy the private-sector optimality conditions (15) and (16). Differentiating (20) with respect to G_t^H yields the first-order condition:

$$\begin{aligned}
&\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t}\left[nU_C\left(C_s^H, \epsilon_s^H\right)\frac{\partial C_s^H}{\partial G_t^H} + (1-n)\,U_C\left(C_s^F, \epsilon_s^F\right)\frac{\partial C_s^F}{\partial G_t^H}\right] + nV_G\left(G_t^H\right) \\
&-\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t}\left\{nv_y\left(Y_s^H, z_s^H\right)\left[(1-n)\,T_s^{-n} C_s^W \frac{\partial T_s}{\partial G_t^H} + T_s^{1-n}\frac{\partial C_s^W}{\partial G_t^H}\right]\right\} + nv_y\left(Y_t^H, z_t^H\right) \\
&-\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t}\left\{(1-n)\,v_y\left(Y_s^F, z_s^F\right)\left[(-n)\,T_s^{-(n+1)} C_s^W \frac{\partial T_s}{\partial G_t^H} + T_s^{-n}\frac{\partial C_s^W}{\partial G_t^H}\right]\right\} \\
= \;& 0.
\end{aligned} \tag{49}$$

Combining (8), (15), (16) and (17), we have that $T_s v_y\left(Y_s^H, z_s^H\right) = v_y\left(Y_s^F, z_s^F\right)$, for all $s \geq t$. Using this along with the fact that $\partial C_t^W / \partial G_t^H = n\left(\partial C_t^H / \partial G_t^H\right) + (1-n)\left(\partial C_t^F / \partial G_t^H\right)$, for all t, and again (15) and (16), with (17) imposed, we can simplify (49) to

$$V_G\left(G_t^H\right) = v_y\left(Y_t^H, z_t^H\right).$$

We log-linearize this and find $-\rho_g \widetilde{G}_t^H = \eta\left[(1-n)\,\xi_c \widetilde{T}_t + \xi_c \widetilde{C}_t^W + (1-\xi_c)\,\widetilde{G}_t^H\right] - \eta S_t^H$, from which we obtain

$$\widetilde{G}_t^H = \frac{\eta}{\rho_g + \eta\,(1-\xi_c)}\left[S_t^H - \xi_c\left((1-n)\,\widetilde{T}_t + \widetilde{C}_t^W\right)\right]. \tag{50}$$

For Foreign spending we similarly find

$$\widetilde{G}_t^F = \frac{\eta}{\rho_g + \eta\,(1-\xi_c)}\left[S_t^F - \xi_c\left(-n\widetilde{T}_t + \widetilde{C}_t^W\right)\right]. \tag{51}$$

Together with (45) and (46), we then have four equations in four unknowns: $\widetilde{G}_t^H$, $\widetilde{G}_t^F$, $\widetilde{T}_t$ and $\widetilde{C}_t^W$. Using (50) and (51), we get $\widetilde{G}_t^R = \frac{\eta}{\rho_g+\eta(1-\xi_c)}\left(S_t^R + \xi_c \widetilde{T}_t\right)$. By substituting this into (46), one then recovers (25). Next, combining (50) and (51) with weights n and $(1-n)$, respectively, gives $\widetilde{G}_t^W = \frac{\eta}{\rho_g+\eta(1-\xi_c)}\left(S_t^W - \xi_c \widetilde{C}_t^W\right)$. Combining this with (45) and solving gives (23). Substituting (23) back into (45) and working out yields (22).

B Derivation of (30)

We can rewrite (11), for $i = H$ and $j = h$, as

$$0 = \mathrm{E}_t \sum_{k=0}^{\infty}\left(\alpha^H \beta\right)^k \left\{\left[\lambda_{t+k} p_t(h) + v_y\left(y_{t,t+k}(h), z_{t+k}^H\right)\right] y_{t,t+k}(h)\right\},$$

where we have imposed (17). After substituting for λ_{t+k} we obtain

$$\mathrm{E}_t \sum_{k=0}^{\infty}\left(\alpha^H \beta\right)^k \left\{\left[U_C\left(C_{t+k}^H, \epsilon_{t+k}^H\right) \frac{p_t(h)}{P_{H,t+k}} T_{t+k}^{n-1} + v_y\left(y_{t,t+k}(h), z_{t+k}^H\right)\right] y_{t,t+k}(h)\right\} = 0.$$

We log-linearize this condition around the steady state and, using the relevant definitions from the main text, we obtain

$$0 = \mathrm{E}_t \sum_{k=0}^{\infty}\left(\alpha^H \beta\right)^k \left\{\begin{array}{c} \widehat{p}_{t,t+k} - (1-n)\,\widehat{T}_{t+k} - \rho\left(\widehat{C}_{t+k}^W + D_{t+k}^W\right) \\ -\eta\left[-\sigma \widehat{p}_{t,t+k} + \xi_c\left((1-n)\,\widehat{T}_{t+k} + \widehat{C}_{t+k}^W\right) + (1-\xi_c)\,\widehat{G}_{t+k}^H - S_{t+k}^H\right] \end{array}\right\},$$

where $\widehat{p}_{t,t+k} \equiv \ln\left(p_t(h)/P_{H,t+k}\right)$ and where we have used that $\widetilde{C}_t^H + D_t^H = \widetilde{C}_t^W + D_t^W$ by (8). We rewrite this expression, using that $\widehat{p}_{t,t+k} = \widehat{p}_{t,t} - \sum_{s=1}^{k} \pi_{t+s}^H$, as:

$$\begin{aligned} \frac{\widehat{p}_{t,t}}{1-\alpha^H\beta} \quad = \quad & \mathrm{E}_t \sum_{k=0}^{\infty}\left(\alpha^H \beta\right)^k \left\{\begin{array}{c} \frac{1+\eta\xi_c}{1+\eta\sigma}(1-n)\,\widehat{T}_{t+k} + \frac{\rho+\eta\xi_c}{1+\eta\sigma}\widehat{C}_{t+k}^W + \frac{\rho}{1+\eta\sigma} D_{t+k}^W \\ + \frac{\eta}{1+\eta\sigma}\left((1-\xi_c)\,\widehat{G}_{t+k}^H - S_{t+k}^H\right) \end{array}\right\} \\ & + \mathrm{E}_t \sum_{k=0}^{\infty}\left(\alpha^H \beta\right)^k \left[\sum_{s=1}^{k} \pi_{t+s}^H\right]. \end{aligned}$$

Log-linearizing (12), we obtain $\widehat{p}_{t,t} = \frac{\alpha^H}{1-\alpha^H}\pi_t^H$, which we use to simplify the previous expression:

$$\begin{aligned} \frac{\pi_t^H}{1-\alpha^H\beta}\frac{\alpha^H}{1-\alpha^H} &= \mathrm{E}_t\sum_{k=0}^{\infty}\left(\alpha^H\beta\right)^k\left\{\begin{array}{c} \frac{1+\eta\xi_c}{1+\eta\sigma}(1-n)\widehat{T}_{t+k}+\frac{\rho+\eta\xi_c}{1+\eta\sigma}\widehat{C}_{t+k}^W+\frac{\rho}{1+\eta\sigma}D_{t+k}^W \\ +\frac{\eta}{1+\eta\sigma}\left((1-\xi_c)\widehat{G}_{t+k}^H-S_{t+k}^H\right) \end{array}\right\} \\ &\quad +\mathrm{E}_t\sum_{k=1}^{\infty}\left(\alpha^H\beta\right)^k\frac{\pi_{t+k}^H}{1-\alpha^H\beta}. \end{aligned}$$

Finally, we then obtain

$$\pi_t^H = \frac{\left(1-\alpha^H\beta\right)\left(1-\alpha^H\right)}{\alpha^H}\left[\begin{array}{c} \frac{1+\eta\xi_c}{1+\eta\sigma}(1-n)\widehat{T}_t+\frac{\rho+\eta\xi_c}{1+\eta\sigma}\widehat{C}_t^W+\frac{\eta(1-\xi_c)}{1+\eta\sigma}\widehat{G}_t^H \\ +\frac{\rho}{1+\eta\sigma}D_t^W-\frac{\eta}{1+\eta\sigma}S_t^H \end{array}\right]+\beta\mathrm{E}_t\pi_{t+1}^H. \tag{52}$$

Combine (47) and (48) to find that $\widetilde{C}_t^W = \frac{\eta}{\rho+\eta\xi_c}S_t^W - \frac{\rho}{\rho+\eta\xi_c}D_t^W - \frac{\eta(1-\xi_c)}{\rho+\eta\xi_c}\widetilde{G}_t^W$. Using this expression and (46), it is straightforward to show that $-(1+\eta\xi_c)(1-n)\widetilde{T}_t - (\rho+\eta\xi_c)\widetilde{C}_t^W - \eta(1-\xi_c)\widetilde{G}_t^H = \rho D_t^W - \eta S_t^H$. Hence, (52) can be rewritten as (30). In a similar way we derive (31).

C Characterization of optimal policies

To solve for the optimal policies under commitment we set up the relevant Lagrangian (see, e.g., Woodford, 1999a):

$$\begin{aligned} \mathcal{L} &= \mathrm{E}_t\sum_{s=t}^{\infty}\beta^{s-t}\Big\{L_s+2\phi_{1,s}\left[\pi_s^H-\beta\pi_{s+1}^H-k_T^H\left(\widehat{T}_s-\widetilde{T}_s\right)-k_C^H\left(\widehat{C}_s^W-\widetilde{C}_s^W\right)-k_G^H\left(\widehat{G}_s^H-\widetilde{G}_s^H\right)\right] \\ &\quad +2\phi_{2,s}\left[\pi_s^F-\beta\pi_{s+1}^F+k_T^F\left(\widehat{T}_s-\widetilde{T}_s\right)-k_C^F\left(\widehat{C}_s^W-\widetilde{C}_s^W\right)-k_G^F\left(\widehat{G}_s^F-\widetilde{G}_s^F\right)\right] \\ &\quad +2\phi_{3,s}\left[\left(\widehat{T}_s-\widetilde{T}_s\right)-\left(\widehat{T}_{s-1}-\widetilde{T}_{s-1}\right)-\pi_s^F+\pi_s^H-\left(\widetilde{T}_s-\widetilde{T}_{s-1}\right)\right]\Big\}, \end{aligned}$$

where $k_T^H \equiv k^H(1+\eta\xi_c)(1-n)$, $k_C^H \equiv k^H(\rho+\eta\xi_c)$, $k_G^H \equiv k^H\eta(1-\xi_c)$, $k_T^F \equiv k^F(1+\eta\xi_c)n$, $k_C^F \equiv k^F(\rho+\eta\xi_c)$, $k_G^F \equiv k^F\eta(1-\xi_c)$ and where $2\phi_{1,s}$, $2\phi_{2,s}$, and $2\phi_{3,s}$ are the multipliers on (30), (31), and (32), respectively. Optimizing over $\widehat{C}_s^W-\widetilde{C}_s^W$, π_s^H, π_s^F, $\widehat{G}_s^H-\widetilde{G}_s^H$, $\widehat{G}_s^F-\widetilde{G}_s^F$, and $\widehat{T}_s-\widetilde{T}_s$ yields six necessary first-order conditions, which after some manipulation imply the following optimality conditions (or targeting rules):

$$\lambda_C\left(\widehat{C}_t^W-\widetilde{C}_t^W\right) = \frac{\lambda_{GH}k_C^H}{k_G^H}\left(\widehat{G}_t^H-\widetilde{G}_t^H\right)+\frac{\lambda_{GF}k_C^F}{k_G^F}\left(\widehat{G}_t^F-\widetilde{G}_t^F\right), \tag{53}$$

$$\lambda_{\pi^H}\pi_t^H = -\frac{\lambda_{GH}}{k_G^H}\left[\left(\widehat{G}_t^H-\widetilde{G}_t^H\right)-\left(\widehat{G}_{t-1}^H-\widetilde{G}_{t-1}^H\right)\right]-\phi_{3,t}, \tag{54}$$

$$\lambda_{\pi^F}\pi_t^F = -\frac{\lambda_{GF}}{k_G^F}\left[\left(\widehat{G}_t^F-\widetilde{G}_t^F\right)-\left(\widehat{G}_{t-1}^F-\widetilde{G}_{t-1}^F\right)\right]+\phi_{3,t}, \tag{55}$$

$$\phi_{3,t} = \beta\mathrm{E}_t\phi_{3,t+1}-\lambda_T\left(\widehat{T}_t-\widetilde{T}_t\right)+\frac{\lambda_{GH}k_T^H}{k_G^H}\left(\widehat{G}_t^H-\widetilde{G}_t^H\right)-\frac{\lambda_{GF}k_T^F}{k_G^F}\left(\widehat{G}_t^F-\widetilde{G}_t^F\right). \tag{56}$$

At any period t, equations (53)-(56) and (30)-(32) determine the optimal evolution of the variables with commitment under the "timeless principle" (Woodford, 1999b); i.e., the Lagrange multipliers are not set at zero at $t-1$, which would render the solution dependent upon the particular date the commitment plan is implemented. Equation (53) resembles a standard public finance efficiency condition. Equations (54) and (55), which provide the optimal trade-offs among national inflation, government spending gaps and the terms-of-trade gap,[20] reveal the *inertia* of the public spending gaps. Without commitment, the lagged spending gaps would be absent from these equations. Inflationary pressures are thus met with a prolonged fiscal contraction, which helps to dampen inflation via the effect on expected future inflation.[21]

Now, consider the case of complete symmetry, so that $\alpha^H = \alpha^F$ and $n = 1/2$. Hence, $k^H = k^F$ and, hence, $k_T^H = k_T^F \equiv k_T$, $k_G^H = k_G^F \equiv k_G$ and $k_C^H = k_C^F \equiv k_C$. Further, let $\lambda_{GH} = \lambda_{GF} \equiv \lambda_G$. Then, (53) becomes $\lambda_C(\widehat{C}_t^W - \widetilde{C}_t^W) = \frac{\lambda_G k_C}{k_G}[(\widehat{G}_t^H - \widetilde{G}_t^H) + (\widehat{G}_t^F - \widetilde{G}_t^F)]$. This confirms that, when monetary policy closes the consumption gap, then $(\widehat{G}_t^H - \widetilde{G}_t^H) = -(\widehat{G}_t^F - \widetilde{G}_t^F)$. With equal rigidities, $\lambda_{\pi^H} = n$ and $\lambda_{\pi^F} = 1-n$, and from (54) and (55), we then obtain an equation for world inflation:

$$\pi_t^W = -\frac{\lambda_G}{k_G}\left\{\left[\left(\widehat{G}_t^H - \widetilde{G}_t^H\right) - \left(\widehat{G}_{t-1}^H - \widetilde{G}_{t-1}^H\right)\right] + \left[\left(\widehat{G}_t^F - \widetilde{G}_t^F\right) - \left(\widehat{G}_{t-1}^F - \widetilde{G}_{t-1}^F\right)\right]\right\}.$$

This confirms that, when $(\widehat{G}_t^H - \widetilde{G}_t^H) = -(\widehat{G}_t^F - \widetilde{G}_t^F)$, $\pi_t^W = 0$ at all dates. However, from the above system of equations, we observe that national inflation rates cannot be stabilized when supply shocks move $\widetilde{T}_t$. (A proof by contradiction can be constructed along the lines of that of Proposition 4.)

[20] The latter affects the trade off via $\phi_{3,t}$, the marginal loss of the terms-of-trade gap. Due to the dynamics of the latter, $\phi_{3,t}$ is a discounted sum of all current and expected future terms-of-trade and public spending gaps; cf. (56). (Spending gaps enter as they are proportional to the marginal losses of the terms of trade in terms of local inflation, i.e., the multipliers $\phi_{1,t}$ and $\phi_{2,t}$, respectively.)

[21] This is analogous to the targeting rule under commitment obtained in the closed-economy model without fiscal policy (e.g., see Clarida et al., 1999): $\pi_t = -\chi(x_t - x_{t-1})$, $\chi > 0$, where x_t is the output gap.

D Tables

Table 1: Expected welfare losses and optimal rule coefficients.

$(\alpha^H, \rho_S, \eta, \lambda_G)$	L^c	L^d	L^{cp}	L^{dp}	L^r	L^{rp}	$(g_{TH}^{opt}, g_{TF}^{opt})$
baseline	0.6691	0.7248	0.7417	0.7417	0.6943	0.7417	(0.37,0.37)
$(0.75, 0.5, 10, \lambda_G^B)$	0.3345	0.3624	0.3708	0.3708	0.3472	0.3708	(0.37,0.37)
$(0.75, -1, 10, \lambda_G^B)$	1.3381	1.4497	1.4834	1.4834	1.3886	1.4834	(0.37,0.37)
$(0.5, 0, 10, \lambda_G^B)$	0.8042	0.8575	0.8747	0.8864	0.8382	0.8911	(0.41,0.30)
$(0.5, -1, 10, \lambda_G^B)$	1.6084	1.7150	1.7494	1.7727	1.6764	1.7821	(0.41,0.30)
$(0.75, 0, 10, \frac{1}{2}\lambda_G^B)$	0.6263	0.7091	0.7417	0.7417	0.6567	0.7417	(0.62,0.62)
$(0.75, -1, 10, \frac{1}{2}\lambda_G^B)$	1.2525	1.4181	1.4834	1.4834	1.3133	1.4834	(0.62,0.62)
$(0.5, 0, 10, \frac{1}{2}\lambda_G^B)$	0.7609	0.8329	0.8747	0.8864	0.7998	0.8911	(0.64,0.55)
$(0.5, -1, 10, \frac{1}{2}\lambda_G^B)$	1.5217	1.6659	1.7494	1.7727	1.5996	1.7821	(0.64,0.55)
$(0.75, 0, 10, 2\lambda_G^B)$	0.6999	0.7331	0.7417	0.7417	0.7167	0.7417	(0.20,0.20)
$(0.75, -1, 10, 2\lambda_G^B)$	1.3999	1.4663	1.4834	1.4834	1.4334	1.4834	(0.20,0.20)
$(0.5, 0, 10, 2\lambda_G^B)$	0.8346	0.8713	0.8747	0.8864	0.8623	0.8911	(0.24,0.15)
$(0.5, -1, 10, 2\lambda_G^B)$	1.6692	1.7426	1.7494	1.7727	1.7245	1.7821	(0.24,0.15)
$(0.75, 0, 5, \lambda_G^B)$	0.6013	0.6415	0.6533	0.6533	0.6205	0.6533	(0.33,0.33)
$(0.75, -1, 5, \lambda_G^B)$	1.2026	1.2830	1.3067	1.3067	1.2411	1.3067	(0.33,0.33)

Legend: ρ_S = correlation between the supply shocks, λ_G^B = baseline value for λ_G, L^c = loss under commitment with full optimization, L^d = idem for discretion, L^{cp} = loss under commitment with fiscal policy restricted to $\widehat{G}_t^i = \widetilde{G}_t^i$ $(i = H, F)$, L^{dp} = idem for discretion, L^r = loss under indicated monetary rule (see below) and fiscal rule (37) with $g_{CH} = g_{CF} = 0$ imposed; L^{rp} = loss under indicated monetary rule with passive fiscal policy; $(g_{TH}^{opt}, g_{TF}^{opt})$ = optimal combination of fiscal policy coefficients under this rule. All losses have been multiplied by 10000.

Note: the results for the rules all assume that monetary policy is characterized by the rule (36) with parameter values $(b_H, b_F, b_C, b_T, d^H, d^F) = (0, 0, 75, 0, 125, 125)$.

Table 2: Expected welfare losses relative to commitment with full optimization. Measured as corresponding permanent change in the consumption gap (in %).

$(\alpha^H, \rho_S, \eta, \lambda_G)$	D	CP	DP	R	RP
baseline	0.56	0.63	0.63	0.37	0.63
$(0.75, 0.5, 10, \lambda_G^B)$	0.39	0.45	0.45	0.26	0.45
$(0.75, -1, 10, \lambda_G^B)$	0.77	0.90	0.90	0.52	0.90
$(0.5, 0, 10, \lambda_G^B)$	0.42	0.48	0.52	0.33	0.53
$(0.5, -1, 10, \lambda_G^B)$	0.59	0.68	0.73	0.47	0.75
$(0.75, 0, 10, \frac{1}{2}\lambda_G^B)$	0.68	0.80	0.80	0.41	0.80
$(0.75, -1, 10, \frac{1}{2}\lambda_G^B)$	0.96	1.13	1.13	0.58	1.13
$(0.5, 0, 10, \frac{1}{2}\lambda_G^B)$	0.48	0.61	0.64	0.35	0.65
$(0.5, -1, 10, \frac{1}{2}\lambda_G^B)$	0.68	0.86	0.90	0.50	0.92
$(0.75, 0, 10, 2\lambda_G^B)$	0.43	0.48	0.48	0.31	0.48
$(0.75, -1, 10, 2\lambda_G^B)$	0.61	0.68	0.68	0.43	0.68
$(0.5, 0, 10, 2\lambda_G^B)$	0.34	0.36	0.41	0.30	0.43
$(0.5, -1, 10, 2\lambda_G^B)$	0.49	0.51	0.58	0.42	0.60
$(0.75, 0, 5, \lambda_G^B)$	0.43	0.49	0.49	0.30	0.49
$(0.75, -1, 5, \lambda_G^B)$	0.61	0.70	0.70	0.42	0.70

Legend: D = full optimization under discretion, CP = optimal monetary policy under commitment and passive fiscal policy, DP = optimal monetary policy under discretion and passive fiscal policy, R = monetary policy rule aimed at closing world consumption gap and zero world inflation (see Table 1), while fiscal policy is set optimally according to (37) with $g_{CH} = g_{CF} = 0$ imposed. RP = idem for monetary policy, but with passive fiscal policy.

Table 3: Results for the combination of rules (41) and (42).

$(\alpha^H, \rho_S, \eta, \lambda_G)$	L^r	R	$(g_{YH}^{opt}, g_{YF}^{opt})$	L^{rp}	RP
baseline	0.6947	0.38	(1.29,1.29)	0.7421	0.64
$(0.75, 0.5, 10, \lambda_G^B)$	0.3478	0.27	(1.29,1.29)	0.3714	0.45
$(0.75, -1, 10, \lambda_G^B)$	1.3886	0.53	(1.29,1.29)	1.4834	0.90
$(0.5, 0, 10, \lambda_G^B)$	0.8510	0.39	(2.14,0.94)	0.9149	0.60
$(0.5, -1, 10, \lambda_G^B)$	1.6813	0.49	(2.14,0.96)	1.8096	0.81
$(0.75, 0, 10, \frac{1}{2}\lambda_G^B)$	0.6571	0.41	(2.83,2.83)	0.7421	0.80
$(0.75, -1, 10, \frac{1}{2}\lambda_G^B)$	1.3133	0.58	(2.83,2.83)	1.4834	1.13
$(0.5, 0, 10, \frac{1}{2}\lambda_G^B)$	0.8055	0.38	(4.49,2.02)	0.9149	0.71
$(0.5, -1, 10, \frac{1}{2}\lambda_G^B)$	1.5896	0.47	(4.49,2.06)	1.8096	0.97
$(0.75, 0, 10, 2\lambda_G^B)$	0.7171	0.31	(0.61,0.61)	0.7421	0.48
$(0.75, -1, 10, 2\lambda_G^B)$	1.4334	0.43	(0.61,0.61)	1.4834	0.68
$(0.5, 0, 10, 2\lambda_G^B)$	0.8802	0.38	(1.03,0.44)	0.9149	0.51
$(0.5, -1, 10, 2\lambda_G^B)$	1.7400	0.48	(1.03,0.45)	1.8096	0.67
$(0.75, 0, 5, \lambda_G^B)$	0.6209	0.30	(1.11,1.11)	0.6537	0.50
$(0.75, -1, 5, \lambda_G^B)$	1.2411	0.42	(1.11,1.11)	1.3067	0.70

Legend: L^r = welfare loss under optimal fiscal rule, R = welfare loss under optimal fiscal rule relative to full commitment optimal policy expressed as a permanent change in the consumption gap (in %-points), $(g_{YH}^{opt}, g_{YF}^{opt})$ = optimal combination of (g_{YH}, g_{YF}), L^{rp} = welfare loss when fiscal policy is passive ($g_{YH} = g_{YF} = 0$) and RP = welfare loss relative to full commitment optimal policy expressed as a permanent change in the consumption gap (in %-points) when fiscal policy is passive. (All losses have been multiplied by 10000.)

Table 4: Results for the combination of rules (41) and (42): allowing for different weights on Home and Foreign inflation.

$(\alpha^H, \rho_S, \lambda_G)$	(g_{YH}, g_{YF})	$(\delta_H^{opt}, \delta_F^{opt})$	L^{dw}
$(0.5, 0, \lambda_G^B)$	$(0,0)^a$	(0.490,0.510)	0.9148
$(0.5, -1, \lambda_G^B)$	$(0,0)^a$	(0.491,0.509)	1.8094
$(0.5, 0, \lambda_G^B)$	$(2.14,0.94)^b$	(0.493,0.507)	0.8510
$(0.5, -1, \lambda_G^B)$	$(2.14,0.96)^b$	(0.494,0.506)	1.6812
$(0.5, 0, \frac{1}{2}\lambda_G^B)$	$(4.49,2.02)^b$	(0.490,0.510)	0.8054
$(0.5, -1, \frac{1}{2}\lambda_G^B)$	$(4.49,2.06)^b$	(0.490,0.510)	1.5894
$(0.5, 0, 2\lambda_G^B)$	$(1.03,0.44)^b$	(0.493,0.507)	0.8802
$(0.5, -1, 2\lambda_G^B)$	$(1.03,0.45)^b$	(0.494,0.506)	1.7399

Legend: (g_{YH}, g_{YF}) = coefficients in (42), $(\delta_H^{opt}, \delta_F^{opt})$ = optimized coefficients in (41), L^{dw} = associated welfare loss (multiplied by 10000).

Notes: a: Coefficients constrained to zero; b: optimized coefficients taken from corresponding parameter setting in Table 3.

References

[1] Alesina, A., S. Ardagna, R. Perotti and F. Schiantarelli, 1999, Fiscal Policy, Profits, and Investment, *NBER Working Paper* No. 7207.

[2] Andrés, J., J.D. López-Salido and J. Vallés, 2001, Money in an Estimated Business Cycle Model of the Euro Area, *Documento de Trabajo* no. 0121, Banco de España.

[3] Aoki, K., 2002, Optimal Monetary Policy Responses to Relative-Price Changes, *Journal of Monetary Economics* 48, 55-80.

[4] Backus, D.B. and J. Driffill, 1986, The Consistency of Optimal Policy in Stochastic Rational Expectations Models, *CEPR Discussion Paper*, No. 124, London.

[5] Beetsma, R.M.W.J. and P.C. Schotman, 2001, Measuring Risk Attitudes in a Natural Experiment: Data from the Television Game Show LINGO, *Economic Journal* 111, 474, 821-848.

[6] Benigno, P., 2001, Optimal Monetary Policy in a Currency Area, *mimeo*, Princeton University.

[7] Benigno, P., 2002, Appropriate Country Weights for Inflation Targeting in the European Monetary Union, *C.V. Starr Center Newsletter* 18, 11-12.

[8] Benigno, G. and P. Benigno, 2001, Implementing Monetary Policy Cooperation through Inflation Targeting, *mimeo*, Bank of England/New York University.

[9] Calvo, G., 1983, Staggered Prices in a Utility-Maximizing Framework, *Journal of Monetary Economics* 12, 383-98.

[10] Canzoneri, M.B., R.E. Cumby and B.T. Diba, 2002, The Need for International Policy Coordination: What's Old, What's New, What's yet to Come?, *NBER Working Paper*, No. 8765.

[11] Clarida, R., J. Galí and M. Gertler, 1999, The Science of Monetary Policy: A New Keynesian Perspective, *Journal of Economic Literature* 27, 1661-1707.

[12] Clarida, R., J. Galí and M. Gertler, 2002, A Simple Framework for International Monetary Policy Analysis, *Journal of Monetary Economics* 49, 879-904.

[13] Coenen, G. and V. Wieland, 2000, A Small Estimated Euro Area Model with Rational Expectations and Nominal Rigidities, European Central Bank, Working Paper No. 30, Frankfurt.

[14] Cooley, T. F. and E. Prescott, 1995, Economic Growth and Business Cycles, in T. F. Cooley (ed.), *Frontiers of Business Cycle Research*, Princeton University Press, Princeton, NJ.

[15] Corsetti, G. and P. Pesenti, 2001a, Welfare and Macroeconomic Interdependence, *Quarterly Journal of Economics* 116, 2, 421-446.

[16] Corsetti, G. and P. Pesenti, 2001b, The International Dimension of Optimal Monetary Policy, *NBER Working Paper*, No. 8230.

[17] Devereux, M. B., 1991, The Terms of Trade and the International Coordination of Fiscal Policy, *Economic Inquiry* 29, 720-36.

[18] Dixit, A. and J. E. Stiglitz, 1977, Monopolistic Competition and Optimum Product Diversity, *American Economic Review* 67, 297-308.

[19] Erceg, C.J., D.W. Henderson and A.T. Levin, 2000, Optimal Monetary Policy with Staggered Wage and Price Contracts, *Journal of Monetary Economics* 46, 281-313.

[20] Fatás, A. and I. Mihov, 2000, Fiscal Policy and Business Cycles: An Empirical Investigation, *mimeo*, INSEAD.

[21] Fatás, A. and I. Mihov, 2001, The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence, *CEPR Discussion Paper*, No. 2760.

[22] Finn, M. G., 1998, Cyclical Effects of Government's Employment and Goods Purchases, *International Economic Review* 39, 635-57.

[23] Galí, J. and M. Gertler, 1999, Inflation Dynamics: A Structural Econometric Analysis, *Journal of Monetary Economics* 44, 195-222.

[24] Galí, J., M. Gertler and J.D. López-Salido, 2001, European Inflation Dynamics, *European Economic Review* 45, 1237-1270.

[25] Giannoni, M.P., 2000, Optimal Interest-Rate Rules in a Forward-Looking Model, and Inflation Stabilization versus Price-Level Stabilization, *mimeo*, Federal Reserve Bank of New York.

[26] Ireland, P., 2000, Money's Role in the Monetary Business Cycle, *mimeo*, Boston College.

[27] Lane, P.R., 1998, On the Cyclicality of Irish Fiscal Policy, *The Economic and Social Review* 29, 1-16.

[28] Lane, P.R., 2002, The Cyclical Behaviour of Fiscal Policy: Evidence from the OECD, *Journal of Public Economics,* forthcoming.

[29] Neiss, K. and E. Nelson, 2002, Inflation Dynamics, Marginal Cost, and the Output Gap: Evidence from Three Countries, *mimeo*, Bank of England.

[30] Obstfeld, M. and K. Rogoff, 2002, Global Implications of Self-Oriented National Monetary Rules, *Quarterly Journal of Economics* 117, 503-535.

[31] Roberts, J. M., 1995, New Keynesian Economics and the Phillips Curve, *Journal of Money, Credit, and Banking* 27, 975-84.

[32] Sbordone, A.G., 2002, Prices and Unit Labor Costs: A New Test of Price Stickiness, *Journal of Monetary Economics* 49, 265-292.

[33] Schmitt-Grohé, S. and M. Uribe, 2001, Optimal Fiscal and Monetary Policy under Sticky Prices, *CEPR Discussion Paper*, No. 2942.

[34] Sims, C., 1999, The Precarious Fiscal Foundations of EMU, *De Economist* 147, 415-36.

[35] Söderlind, P., 1999, Solution and Estimation of RE Macromodels with Optimal Policy, *European Economic Review* 43, 813-23.

[36] Sutherland, A., 2002, Cost-Push Shocks and the Optimal Choice of Monetary Target in an Open Economy, *mimeo*, University of St. Andrews.

[37] Svensson, L.E.O., 1994, Why Exchange Rate Bands? Monetary Independence in Spite of Fixed Exchange Rates, *Journal of Monetary Economics* 33, 157-199.

[38] Svensson, L.E.O., 2001, What Is Wrong with Taylor Rules? Using Judgement in Monetary Policy through Targeting Rules, *mimeo*, Princeton University.

[39] Taylor, J. B., 1993, Discretion versus Rules in Practice, *Carnegie-Rochester Series on Public Policy* 39, 195-214.

[40] Taylor, J. B. (ed.), 1999, *Monetary Policy Rules* (University of Chicago Press).

[41] Turnovsky, S. J., 1988, The Gains from Fiscal Cooperation in the Two-Commodity Real Trade Model, *Journal of International Economics* 25, 111-27.

[42] Woodford, M., 1999a, Optimal Monetary Policy Inertia, *NBER Working Paper*, No. 7261.

[43] Woodford, M., 1999b, Commentary: How Should Monetary Policy Be Conducted in an Era of Price Stability?, in *New Challenges for Monetary Policy*, A symposium sponsored by the Federal Reserve Bank of Kansas City, 277-316.

[44] Woodford, M., 2002, *Interest and Prices: Foundations of a Theory of Monetary Policy*, book manuscript, Princeton University.

[45] Wynne, M. A., 1996, Balanced Budget Multipliers, *Journal of Macroeconomics* 18, 197-211.