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

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Abstract

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 a 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 compare the performance of various types of monetary and fiscal policy rules in the presence of supply and demand shocks, and investigate the extent to which these rules can approximate the optimal cooperative solution.

Keywords: Policy mix; monetary policy rules; fiscal policy rules; monetary union.

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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 fiscal policy and monetary 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 important for a variety of reasons, such as the question to what extent the burden on fiscal policy will increase in dealing with country-specific shocks, whether fiscal constraints hamper stabilization and whether there is a need for the coordination of monetary and fiscal policies.

In this paper, we 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] The model is an extension of the models developed by Benigno (1999) and Benigno and Benigno (2001). We derive the log-linearized 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 through public spending variations. The resulting demand side is the usual world consumption Euler equation, whereas the supply side features forward-looking Phillips curves, with inflation driven by deviations of the terms-of-trade, consumption and public spending from their respective stochastic natural rates (i.e., their efficient flex-price levels).

Throughout the paper we take the perspective of welfare at the level of the union. This is obvious for the common central bank. However, given that in Europe there is increasing discussion about the need to coordinate (fiscal) policies, it is interesting to take a supranational perspective when evaluating the performance of fiscal policies and see how one could design policies that serve best the common interest. First, we study the optimal commitment and discretionary policies both when we allow for full optimization over all instruments (monetary and fiscal) and when we restrict fiscal policies to be "passive" (in a sense to be explained below).

The optimal policies are characterized by some interesting features. First, (and in congruence with the case in which fiscal policy is absent from the model) in the absence of

[1] For example, see the volume edited by Taylor (1999) or the Special Issue of *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. (2001), Canzoneri et al. (2002) and Sutherland (2002).

asymmetries in price rigidity, the optimal monetary policy closes the world consumption gap and forces world inflation to be zero.[3] While world inflation is zero, supply shocks generally cause national producer inflation rates to differ from zero. The role of the optimal fiscal policy is then to trade off the resulting terms-of-trade gap against national inflation rates *per se* and government spending gaps. Only in the special case of perfectly correlated supply shocks can the optimal policy mix replicate the efficient flex-price allocation. In that case, the natural rate of the terms of trade is constant, thereby leaving national inflation rates perfectly stable with public spending at the natural rates. Second, with equal degrees of price rigidity throughout the monetary union, monetary policy is not subject to a time-consistency problem, while fiscal policy does suffer from such a problem. As a result, there are welfare gains to be obtained from the commitment of fiscal policy. In particular, by committing to a public spending pattern that is more "active," the policymaker influences inflation expectations in a way that improves the inflation/public spending trade off, thereby securing more stable national inflation rates and a more stable terms-of-trade gap.[4] Finally, with differences in price rigidity, the optimal common monetary policy puts a relatively large emphasis on stabilizing the inflation of the country with the highest degree of price rigidity (in conformity with what Benigno, 1999, finds). Hence, the other country is characterized by more variable inflation and employs a more active fiscal policy.

From the analysis of the optimal policies it turns out that fiscal policy as an instrument for stabilization does not provide a relative advantage when the correlation of the supply shocks decreases. While welfare losses increase, because optimal monetary policy on average can address only a smaller component of the supply shocks, the optimal fiscal policies do not absorb a larger share of the increased economic variability. Expected losses are determined by the variability of the relative supply shock, which affects the economies via the terms of trade gap. Given the linear-quadratic structure of the optimization problem, the public spending gap offsets a given fraction of the relative supply shock on national inflation. This is the case irrespective of the degree of correlation of the supply shock and also of the asymmetry in price stickiness. From a welfare point of view, the use of fiscal policy for stabilization appears to be of relevance. Restricting fiscal policy to be equal to its natural level leads to welfare losses that, under our parameterizations, are equal to a permanent reduction in consumption of the order of 0.5 to 1 percentage point.

Next, we explore several types of simple policy rules. The advantage of such rules 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.[5] We explore rules that have monetary policy close the world consumption gap as much as possible and keep world

[3] Generally, "gap" refers to the deviation of a variable from its stochastic natural rate.

[4] 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 (1999).

[5] 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.

inflation as close as possible to zero (so as to approximate the properties of the optimal monetary policy). Then, the expected welfare losses can be reduced by having the public spending gap respond to the terms-of-trade gap, thereby stabilizing national inflation. In particular, a terms-of-trade deterioration should lead to a contractionary fiscal policy. This combination of simple policy rules is able to reduce the expected loss below that under full optimization with discretion. It cannot, however, attain the loss under the optimal commitment policy. The "distance" to the optimal loss is equivalent to a permanent reduction in consumption ranging from 0.3 to 0.6 percentage points.

We also explore the case of a standard Taylor-rule for monetary policy combined with fiscal policy rules for which the public spending gap is linear in the output gap. Such a combination of rules generally performs well and produces expected losses below those under full discretionary optimization. In fact, the expected losses are surprisingly close to those obtained under the set of rules described in the previous paragraph (i.e., those approximately featuring the optimal monetary policy). The optimal fiscal rules are countercyclical and for our baseline parameter combination a 1%-point increase in the output gap causes a fall in the spending gap of somewhat more than 1%-point. The final set of rules combines the standard monetary policy Taylor rule with "cooperative" public spending rules, in which the spending gap depends on the world output gap. The problem with this type of spending rules is that they fail to address country-specific developments. They complement monetary policy in closing the world consumption gap, but they never produce losses that are lower than those obtained under the optimal monetary policy combined with completely passive fiscal policies.

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 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 optimal policies and the rules that we consider. Finally, Section 6 concludes the main body of the paper.

2 The model

The model extends the basic model developed by Benigno (1999) by introducing public spending as an instrument for stabilization and by introducing demand shocks. The following presentation of the model and the notation parallels closely that of Benigno (1999).

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, P_s^i is the price level and y_s^j is the amount of goods that household j produces. The functions U and V are strictly increasing and strictly concave in their first arguments. The function 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 [the final term in (1)]. Further, ϵ_s^i is a shock which affects the demand for consumption goods, and z_s^i is a supply shock.[6]

The consumption index C^j is defined as:

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

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

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

where $c^j\left(h\right)$ and $c^j\left(f\right)$ 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 defined by:

$$P^i = \left(P_H^i\right)^n \left(P_F^i\right)^{1-n},$$

where

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

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. 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).

[6]We could have introduced real money balances as an argument in (1). However, if it enters additively [as, e.g., empirical evidence for the US suggests; see Ireland (2000)], 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.

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 the restriction provided by (3). The implied demands for individual good h, produced in country H, and individual good f, produced in country F, are, respectively:

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

Public spending in countries H and F is given by the following indices:

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

Minimization of $P_H G^H$ and $P_F G^F$ under restriction (5) yields the governments' demands for 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 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. Household j's budget constraint in country i is:

$$q_t^i B_t^{ij} + \frac{B_t^j}{P_t(1+R_t)} = W_{t-1}^j + \left(1-\tau^i\right)\frac{p_t(j)\, y_t(j)}{P_t} - C_t^j + \frac{Q_t^{ij}}{P_t},$$

where $B_t^{ij} = \left[B_{t,1}^{ij}, .., B_{t,S_{t+1}}^{ij}\right]'$ are the holdings of Arrow-Debreu securities paying off in period $t+1$ one unit of the composite consumption good in state $1, .., S_{t+1}$, respectively, and zero otherwise. Further, $q_t^i = \left[q_{t,1}^i, .., q_{t,S_{t+1}}^i\right]$ is the vector of prices of these securities, B_t^j is the holding of the nominal one-period non-contingent bond, Q_t^{ij} is a nominal lump-sum transfer from the government of the country i in which j resides and τ^i is a proportional tax on nominal income. Finally,

$$W_{t-1}^j \equiv B_{t-1,s_t}^{ij} + \frac{B_{t-1}^j}{P_t}.$$

The period-t budget constraint of the government of country i is:

$$\tau^i \int_{j\in i} p_t(j)\, y_t(j)\, dj = G_t^i + \int_{j\in i} Q_t^{ij} dj.$$

We assume that each individual's initial asset holdings of any type are zero: $\left[B^{ij}_{-1,1}, .., B^{ij}_{-1,S_0}\right]' = [0, .., 0]'$ and $B^j_{-1} = 0$ for all $j \in [0,1]$. Market completeness, combined with identical preferences and equal initial wealth implies perfect consumption risk-sharing within each country. International asset market completeness combined with equal initial wealth implies that the marginal utilities of consumption are equalized between countries:

$$U_C\left(C^H_t, \epsilon^H_t\right) = U_C\left(C^F_t, \epsilon^F_t\right), \tag{8}$$

Further, the Euler equations are:

$$U_C\left(C^i_t, \epsilon^i_t\right) = (1+R_t)\,\beta \mathrm{E}_t\left[U_C\left(C^i_{t+1}, \epsilon^i_{t+1}\right)(P_t/P_{t+1})\right], \quad i = H, F, \tag{9}$$

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. The household optimality conditions are completed by the resource constraint and the appropriate transversality conditions.

Finally, using the appropriate aggregators, aggregate demand in both countries is found as

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

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 relative to the entire economy, 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:

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

where $y_{t,t+k}(j)$ is given by (7), and where $\lambda_{t+k} = U_C(C_{t+k}, \epsilon_{t+k})/P_{t+k}$ is the marginal utility of nominal income. This yields:

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

Realizing that, in equilibrium, each producer in a given country in a given period will set the same price when given the chance to change his 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 Efficient steady state and flexible price equilibrium

Under flexible prices, (11) is replaced by:

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

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

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

and that $p_t(j) = P^F_t$ for all j living in Foreign, so that:

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

In the sequel, we confine ourselves to efficient equilibria. That is, the tax rates τ^H and τ^F are set such that they 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 (efficient) steady-state values $\overline{C}$ 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 $\overline{T} = 1$. The steady state values $\overline{G}^H$ and $\overline{G}^F$ are obtained 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, the steady-state nominal (=real) interest rate is obtained from (9) as:

$$1 + \overline{R} = 1/\beta. \tag{20}$$

For the (efficient) flexible price equilibrium that we consider, we assume that the fiscal authorities coordinate. Hence, they choose G^H_t and G^F_t to maximize

$$\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left\{ \begin{array}{c} n\left[U\left(C_t, \epsilon^H_t\right) + V\left(G^H_t\right) - v\left(Y^H_t, z^H_t\right)\right] \\ +(1-n)\left[U\left(C_t, \epsilon^F_t\right) + V\left(G^F_t\right) - v\left(Y^F_t, z^F_t\right)\right] \end{array} \right\}.$$

again subject to (15) and (16), with (17) imposed. Because there are no distortions, this programme gives the highest possible weighted welfare level. It implies the following optimality conditions (see Appendix A for the details):

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

Before we continue, we introduce some notation. Following Benigno (1999), 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 efficient flex-price log-deviation from the steady state, i.e., $\widetilde{X} \equiv \ln\left(X/\overline{X}\right)$. In Appendix A we derive the following flex-price dynamics:

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

$$\widetilde{C}_t^H = \widetilde{C}_t^W + (1-n) D_t^R, \tag{23}$$

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

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

$$\widetilde{T}_t = -\frac{\eta\rho_g}{\rho_g(1+\eta\xi_c) + \eta(1-\xi_c)} S_t^R, \tag{26}$$

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 $(i = H, F)$ such that $U_{C\epsilon}\epsilon_t^i = \overline{C}U_{CC}\left(\overline{C},0\right)D_t^i$. Hence, S_t^i and D_t^i are proportional to the supply and demand shocks, respectively.

The dynamics of the terms of trade are explained as follows. Because of perfect consumption risk sharing, the marginal utilities of consumption are equated across countries. Moreover, the marginal utilities of consumption are equated to the implied marginal disutility of additional production effort [see (15) and (16)]. A positive supply shock in Home relative to Foreign reduces the effort needed to produce a given amount of output. Production of Home needs to increase relative to production of Foreign to ensure that the disutilities of effort are equated again. Hence, the Home terms-of-trade need to depreciate (i.e., $\widetilde{T}_t$ should fall). Finally, assuming that the inflation rate in the flex-price equilibrium is zero, we derive the natural rate of the nominal interest rate as

$$\widetilde{R}_t = \rho \mathrm{E}_t\left[\left(\widetilde{C}_{t+1}^W - \widetilde{C}_t^W\right) + \left(D_{t+1}^W - D_t^W\right)\right]. \tag{27}$$

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., $\widehat{X} \equiv \ln\left(X/\overline{X}\right)$:

$$\mathrm{E}_t\left(\widehat{C}_{t+1}^W - \widetilde{C}_{t+1}^W\right) = \left(\widehat{C}_t^W - \widetilde{C}_t^W\right) + \rho^{-1}\left[\left(\widehat{R}_t - \widetilde{R}_t\right) - \mathrm{E}_t\left(\pi_{t+1}^W\right)\right], \tag{28}$$

$$\widehat{C}_t^H + D_t^H = \widehat{C}_t^F + D_t^F = \widehat{C}_t^W + D_t^W, \tag{29}$$

$$\widehat{Y}_{H,t} = \xi_c\left[(1-n)\,\widehat{T}_t + \widehat{C}_t^H\right] + (1-\xi_c)\,\widehat{G}_t^H, \tag{30}$$

$$\widehat{Y}_{F,t} = \xi_c\left[-n\widehat{T}_t + \widehat{C}_t^F\right] + (1-\xi_c)\,\widehat{G}_t^F, \tag{31}$$

$$\begin{aligned}\pi_t^H &= \beta\mathrm{E}_t\pi_{t+1}^H + k^H(1+\eta\xi_c)(1-n)\left(\widehat{T}_t - \widetilde{T}_t\right) + k^H(\rho+\eta\xi_c)\left(\widehat{C}_t^W - \widetilde{C}_t^W\right) \\ &\quad + k^H\eta(1-\xi_c)\left(\widehat{G}_t^H - \widetilde{G}_t^H\right),\end{aligned} \tag{32}$$

$$\begin{aligned}\pi_t^F &= \beta\mathrm{E}_t\pi_{t+1}^F - k^F(1+\eta\xi_c)\,n\left(\widehat{T}_t - \widetilde{T}_t\right) + k^F(\rho+\eta\xi_c)\left(\widehat{C}_t^W - \widetilde{C}_t^W\right) \\ &\quad + k^F\eta(1-\xi_c)\left(\widehat{G}_t^F - \widetilde{G}_t^F\right),\end{aligned} \tag{33}$$

$$\widehat{T}_t = \widehat{T}_{t-1} + \pi_t^F - \pi_t^H, \tag{34}$$

where,

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

Here, equation (28) is the consumption Euler equation expressed in terms of the world consumption gap and the world real interest rate gap. Equation (29) highlights the implications of full consumption risk sharing, as it implies that the consumption gaps are equalized, i.e., $\widehat{C}_t^W - \widetilde{C}_t^W = \widehat{C}_t^H - \widetilde{C}_t^H = \widehat{C}_t^F - \widetilde{C}_t^F$. Equations (30) and (31) are the log-linearized counterparts of (10). Equation (32) 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 (33) is the analogous foreign inflation adjustment equation. Finally, equation (34) is the definition of the terms of trade expressed through the inflation differential. In sum, equations (28), (30), (31), (32), (33), (34), 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 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 whether a replication of the (efficient) flex-price equilibrium is feasible in the model. By considering the Phillips curves (32) and (33), the following proposition is immediate:

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

By (committing to) setting (for all t) $\widehat{R}_t = \widetilde{R}_t$, $\widehat{G}_t^H = \widetilde{G}_t^H$ and $\widehat{G}_t^F = \widetilde{G}_t^F$ and observing that $\widetilde{T}_t = 0$ 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 and of potential asymmetries in the demand shock, because $\widetilde{T}_t$ only depends on the relative supply shock. Hence, in this special case policy can be designed so as to replicate the efficient equilibrium.

Now, suppose that the supply shocks are imperfectly correlated. Is it still always possible to attain the efficient equilibrium through appropriate instrument settings? The answer is no. We formally state this result in the following proposition:

Proposition 2 *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 $\widehat{C}_s = \widetilde{C}_s$, 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 $\widehat{C}_s = \widetilde{C}_s$, 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. This proposition confirms Benigno's (1999) finding for the case in which fiscal policy is absent. Hence, it is clear that 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:

$$L = \sum_{t=1}^{\infty} \beta^{t-1} \mathrm{E}_1 \left[L_t \right], \tag{35}$$

where

$$\begin{aligned} L_t &= \lambda_C \left(\widehat{C}_t^W - \widetilde{C}_t^W \right)^2 + \lambda_T \left(\widehat{T}_t - \widetilde{T}_t \right)^2 + \lambda_{GH} \left(\widehat{G}_t^H - \widetilde{G}_t^H \right)^2 \\ &\quad + \lambda_{GF} \left(\widehat{G}_t^F - \widetilde{G}_t^F \right)^2 + \lambda_{\pi^H} \left(\pi_t^H \right)^2 + \lambda_{\pi^F} \left(\pi_t^F \right)^2, \end{aligned} \tag{36}$$

with all weights non-negative. That is, any deviation of endogenous variables from their efficient flex-price level constitutes a welfare loss. The loss function generalizes the loss function that Benigno (1999) 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 reduces to Benigno's (1999) 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 (36) are functions of the "deep" parameters in 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.[7] 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

[7]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).

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 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 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. 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 5).

We consider rules that are functions of the terms-of-trade gap and the consumption gap. This provides us with a rather general class of rules, which contains as a special case (see below) rules based on output gaps that are often considered in the literature. Thus, a rather general formulation of the rule that the central bank might follow is:

$$\widehat{R}_t - \widetilde{R}_t = \left(b_H \pi_t^H + b_F \pi_t^F\right) + b_C \left(\widehat{C}_t^W - \widetilde{C}_t^W\right) + b_T \left(\widehat{T}_t - \widetilde{T}_t\right) + \left[d_H \mathrm{E}_t \left(\pi_{t+1}^H\right) + d_F \mathrm{E}_t \left(\pi_{t+1}^F\right)\right]. \tag{37}$$

An increase in inflation or expected inflation in either one of the countries or a rise in the consumption gap, $\widehat{C}_t^W - \widetilde{C}_t^W$, leads the monetary authority to contract its policy in an attempt to slow down the economy. As Benigno (1999) shows, it may be optimal for the central bank to attach weights b_H and b_F that differ from the relative weights n and $1-n$. In particular, the relative weight attached to the stickier-price country should be higher so as to reduce losses from an inadequate response of prices to the shocks buffeting the economies. Finally, we also include the terms-of-trade gap in the interest rate rule.

The most general formulation of our fiscal policy rules is:

$$\begin{aligned} \widehat{G}_t^H - \widetilde{G}_t^H &= -g_{CH}\left(\widehat{C}_t^W - \widetilde{C}_t^W\right) - g_{TH}\left(\widehat{T}_t - \widetilde{T}_t\right), \\ \widehat{G}_t^F - \widetilde{G}_t^F &= -g_{CF}\left(\widehat{C}_t^W - \widetilde{C}_t^W\right) + g_{TF}\left(\widehat{T}_t - \widetilde{T}_t\right), \end{aligned} \tag{38}$$

where we recall that $\widehat{C}_t^W - \widetilde{C}_t^W = \widehat{C}_t^H - \widetilde{C}_t^H = \widehat{C}_t^F - \widetilde{C}_t^F$, so that we directly formulate the rules in terms of the world consumption gap. The situation in which fiscal policy is completely passive will, of course, in terms of the rules, amount to setting $g_{CH} = g_{CF} = g_{TH} = g_{TF} = 0$. This will provide us with a benchmark against which we can compare the usefulness of fiscal policy as a stabilization tool. This benchmark may also capture some of the effects of the Stability and Growth Pact (SGP), which may effectively limit the use of fiscal policy as an instrument for stabilizing individual economies. With $g_{CH} > 0$ and

$g_{TH} > 0$, we have that a positive consumption gap or a terms-of-trade deterioration (Home becomes cheaper relative to Foreign and, hence, the demand for its products increases) leads to a more contractionary fiscal policy, so that demand is reduced and the economy slows down.

In the following, we will not optimize the combination of policy rules over all parameters. Firstly, it would require an immense amount of computing time, but more importantly it will in some instances lead to coefficients of infinity (as will be explained below), which essentially make no sense. We therefore consider simple rules, where some parameters are constrained and a relevant subset is chosen optimally.

As mentioned, policy rules discussed in the literature are often (partly) based on the output gap. This is certainly the case for monetary policy rules, but also public spending is often discussed in terms of its pro- or countercyclicality. That is, the degree to which fiscal policy is correlated with the output gap. Therefore, an obvious class of rules involving the output gap is:

$$\begin{aligned} \widehat{R}_t - \widetilde{R}_t &= \left(b_H \pi_t^H + b_F \pi_t^F\right) + b_Y \left(\widehat{Y}_t^W - \widetilde{Y}_t^W\right) + \left[d_H \mathrm{E}_t\left(\pi_{t+1}^H\right) + d_F \mathrm{E}_t\left(\pi_{t+1}^F\right)\right], \quad (39) \\ \widehat{G}_t^H - \widetilde{G}_t^H &= -g_{YH}\left(\widehat{Y}_t^H - \widetilde{Y}_t^H\right), \quad \widehat{G}_t^F - \widetilde{G}_t^F = -g_{YF}\left(\widehat{Y}_t^F - \widetilde{Y}_t^F\right). \end{aligned}$$

If $g_{YH} = g_{YF} \equiv g_Y$, and 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, we can rewrite the combination of policy rules into the format (37) and (38), with the following restrictions imposed on the coefficients in (37) and (38):

$$\begin{aligned} g_{CH} &= g_{CF} = \frac{g_Y \xi_c}{1 + g_Y (1 - \xi_c)}, \quad g_{TH} = \frac{g_Y \xi_c (1 - n)}{1 + g_Y (1 - \xi_c)}, \\ g_{TF} &= \frac{g_Y \xi_c n}{1 + g_Y (1 - \xi_c)}, \quad b_C = \frac{\xi_c b_Y}{1 + g_Y (1 - \xi_c)}, \quad b_T = 0. \end{aligned}$$

When g_{YH} and g_{YF} differ from each other, the interest rate rule can be written in terms of the world consumption gap and the terms-of-trade gap, so that $b_T \neq 0$. Thus, asymmetries between countries, potentially giving rise to different degrees of cyclicality of government spending, also indirectly lead to asymmetric reactions in the interest rate rule towards local developments in the union. An obvious source of asymmetry within this model framework is a different degree of price rigidity in the two countries.

A variation on the above class of rules would be to have fiscal policy depend on the world output gap, rather than the national output gap:

$$\widehat{G}_t^H - \widetilde{G}_t^H = -g_{YHW}\left(\widehat{Y}_t^W - \widetilde{Y}_t^W\right), \quad \widehat{G}_t^F - \widetilde{G}_t^F = -g_{YFW}\left(\widehat{Y}_t^W - \widetilde{Y}_t^W\right). \quad (40)$$

These fiscal rules might be viewed as a "cooperative rules." At summits countries sometimes call upon each other to take fiscal measures that get the (world) economy out of recession.[8] These rules would resemble such measures. Because $\widehat{Y}_t^W - \widetilde{Y}_t^W = \xi_c\left(\widehat{C}_t^W - \widetilde{C}_t^W\right) +$

[8] 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).

$(1-\xi_c)\left(\widehat{G}_t^W - \widetilde{G}_t^W\right)$, one can rewrite the pair of rules (40) as

$$\widehat{G}_t^H - \widetilde{G}_t^H = -\left[\frac{\xi_c g_{YHW}}{1+(1-\xi_c)(n g_{YHW} + (1-n) g_{YFW})}\right]\left(\widehat{C}_t^W - \widetilde{C}_t^W\right), \qquad (41)$$

and a similar expression for $\widehat{G}_t^F - \widetilde{G}_t^F$. Combining these expressions with an interest rate rule of the type (39), which is also based on the world output gap, produces an interest rate rule of the format (37), with the restriction that

$$b_C = \frac{\xi_c b_Y}{1+(1-\xi_c)(n g_{YHW} + (1-n) g_{YFW})}, \quad b_T = 0.$$

Obviously, in cases where monetary policy is able to close the consumption gap, "cooperative" fiscal rules of the form (40) are redundant.

4.3 The benchmark parameter combination

We largely follow Benigno (1999) 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 (1999) in our assumptions about the coefficient of relative risk aversion (RRA) for private consumption and the elasticity of labor supply. Regarding the former, we assume that $\rho = 2.5$.[9] We set the RRA coefficient for government spending, ρ_g, also at 2.5. Further, we set the elasticity of 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.

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 (1999) — in the absence of government spending — derives for these parameters as functions of the "deep" model parameters. This yields the following expressions (up to an irrelevant proportionality factor):

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

[9] For example, see Beetsma and Schotman, 2001, and the references therein.

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

The final step involves the choices about the shocks. The shocks are assumed to follow $AR(1)$ processes:

$$
\begin{aligned}
S_t^i &= 0.97 S_{t-1}^i + \mu_{S,t}^i, \ i = H, F, \\
D_t^i &= 0.30 D_{t-1}^i + \mu_{D,t}^i, \ i = H, F,
\end{aligned}
$$

where the $\mu_{D,t}^i$ and $\mu_{S,t}^i$ are white noise shocks. We assume that demand shocks are not correlated with supply shocks. We notice that the chosen degree of autocorrelation is higher for the supply shocks. This seems reasonable if we assume that supply shocks are thought to represent technology shocks. We set the standard deviation of the innovations in the process for demand shocks is 2.5%, while the corresponding one for the supply shocks is 0.7%. This provides a reasonable unconditional standard deviation of the supply shocks. We may already note that the particular process chosen for the demand shocks play no role (see below). The baseline parameter combination assumes that the correlation between $\mu_{S,t}^H$ and $\mu_{S,t}^F$ is zero.

In the sequel, we consider a number of variations on the benchmark 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 Europe 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. However, as we will see, this strengthens the robustness of our results, which remain qualitatively unaltered when introducing asymmetries in rigidity. Another variation is that we allow for different shock correlations. Again, to capture a range of possible situations that is as large as possible, we also consider cases in which the (contemporaneous) correlation of the supply shocks differs from zero. Finally, given our ignorance about the appropriate 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 results of the numerical analysis, we narrow down the set of possible parameters combinations that we need to investigate by observing that:

Proposition 3 *The demand shocks are irrelevant for the optimal policies, the optimal rules and the equilibrium welfare losses associated with the optimal policies and the optimal rules.*

For the optimal policies one can immediately see this result, if one realizes that the system (36), (28), (32), (33) and (34), with the latter rewritten as

$$
\widehat{T}_t - \widetilde{T}_t = \widehat{T}_{t-1} - \widetilde{T}_{t-1} + \pi_t^F - \pi_t^H - \left(\widetilde{T}_t - \widetilde{T}_{t-1}\right), \tag{42}
$$

is exhaustively expressed as a set of relations among gaps of variables, national inflation rates and $\widetilde{T}_t - \widetilde{T}_{t-1}$, without demand shocks explicitly entering the system. Here, using (26), we have observed that $\widetilde{T}_t - \widetilde{T}_{t-1}$ depends only on the (current and one-period lagged) relative supply shock. Hence, this also explains why supply shocks in general *do* matter. As regards to the irrelevance of the demand shocks for the rules that we consider, we observe that the demand shocks do not explicitly enter any of the rules discussed in Subsection 4.2.

5.1 The optimal policies

Table 1 presents, for a number of situations, the equilibrium expected losses for the optimal policies conducted under commitment and discretion and under full and constrained optimization, where recall that under the latter we set $\widehat{G}_t^H = \widetilde{G}_t^H$ and $\widehat{G}_t^F = \widetilde{G}_t^F$. In cases where price rigidities are equal between the two countries, the monetary authority commits to setting the interest rate at the natural rate and the equilibrium is characterized by a closed consumption gap and zero world inflation at all dates. Thus, the optimal monetary policy corresponds to the optimal commitment policy in a closed economy without public spending where there is no trade-off in optimal monetary policymaking and all gaps can be closed. Now, the "world" Phillips curve in the absence of asymmetries can be written as:

$$\pi_t^W = \beta \mathrm{E}_t \pi_{t+1}^W + k \left[(\rho + \eta \xi_c) \left(\widehat{C}_t^W - \widetilde{C}_t^W \right) + \eta (1 - \xi_c) \left(\widehat{G}_t^W - \widetilde{G}_t^W \right) \right], \tag{43}$$

where $k \equiv k^H = k^F$. Of course, under constrained optimization we trivially have $\widehat{G}_t^W = \widetilde{G}_t^W$, so that monetary policy trade-offs are absent and one would indeed expect monetary policy to close all remaining gaps. However, also when fiscal policy is unconstrained, because the model is symmetric, the spending gaps in the expression for the world Phillips curve cancel. Given that the terms-of-trade gap exerts the same, but opposite, effect on local inflation in the two countries and given that the spending gaps (when corrected for the relative country weights) are of equal size, but of opposite sign, the national inflation rates are indeed perfectly negatively correlated and world inflation is always zero. Public spending in each country is used to (partially) offset the effect of the terms-of-trade on national producer inflation. Hence, when the terms-of-trade gap is positive, causing upward pressure on Home inflation, Home fiscal policy should be contractionary, and vice versa for the other country.

In all the cases with full optimization there are welfare gains from commitment relative to discretion. To assess what these welfare gains mean 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 percentage change for 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 precommitment with full optimization, and L^i is the loss under the regime that we want to compare with L^c in terms of "consumption equivalents". Table 2 reports this measure for the various regimes that we consider. The table shows that the gains from commitment are of a nontrivial magnitude, as they are equivalent to a permanent consumption gain ranging from 0.4 to 1 percent.

When the economies feature an equal degree of price rigidity, the commitment problem arises exclusively in fiscal policy, as there — as explained above — are no trade-offs in monetary policy. However, the fiscal authorities can gain if they commit to more aggressive and persistent policy responses towards shocks. This will affect inflation expectations, and thus help to stabilize current inflation. 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 is the case under commitment.

Table 1 also reports the welfare losses (L^{cm} for commitment and L^{dm} for discretion) when fiscal policy is restricted to be passive (i.e., $\widehat{G}_t^H = \widetilde{G}_t^H$ and $\widehat{G}_t^F = \widetilde{G}_t^F$), while Table 2 expresses the welfare effects in terms of consumption equivalents. The table shows that the costs of restricting fiscal policy are nontrivial, as they are equivalent to permanent changes in consumption in the range of 0.5 to 1 percent.

Now, consider the situation in which there is asymmetry in price rigidity ($\alpha^H = 0.5$, $\alpha^F = 0.75$). The optimal policy allows Home inflation to be more variable than Foreign inflation. With the higher degree of stickiness in Foreign price setting, 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 in Foreign are reduced. Optimal fiscal policymaking results in a Home public spending gap that is more variable than the Foreign public spending gap. The reason is that the relatively higher inflation variability forces Home fiscal policy to assume a relatively larger role in stabilizing national inflation.

Let us now vary the correlation between the shocks. The case of perfectly correlated supply shocks is not reported in Table 1, because as shown earlier, in this case all gaps can be closed and national producer inflation rates are kept at zero. Changing the correlation of the supply shocks produces a finding that runs counter to the view that fiscal policy can stabilize the effects of idiosyncratic shocks on the national economy. When the correlation of the supply shocks falls, the variance of the relative supply shock rises and, thus, the expected losses increase. However, the use of fiscal policy for stabilization does not improve the situation relative to the baseline case of uncorrelated supply shocks: more precisely, the ratios L^c/L^{cm} and L^d/L^{dm} remain unaltered when we reduce (or raise) the correlation of the supply shocks. Here, L^d is the full optimization loss under discretion. The intuition for this result is easiest when we consider the situation of equal price rigidities. While the optimal monetary policy closes the consumption gap, the best that fiscal policy can do is to (partially) offset the effect of the terms-of-trade gap on national inflation. Given that the loss function is quadratic and the Phillips curves are linear in the gaps, fiscal policy offsets a fixed share of the volatility inserted by the relative supply shock (via the terms-of-trade gap) into the economy. This finding is preserved when we allow for different degrees of price stickiness. As we can observe from Table 1 (e.g., the 4th and 5th line), the ratios of the losses with and without active fiscal policy remain unaffected by the correlation of the supply shocks.

The final experiment concerns the variation of the coefficient on 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 expected losses and to lower variability in public spending. Note, however, that results are qualitatively unchanged when we vary this coefficient, while, quantitatively speaking the effects are not substantial for the variations that we consider (see Table 2).

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. With both monetary and fiscal policy present, an "assignment problem" arises. The reason is that both types of policy instruments can be used to address the suboptimal deviations of inflation from its steady state value. In particular, as (32) and (33) make clear, if the governments adopt the following rules on public spending:

$$g_{CH} = g_{CF} = \frac{\rho + \eta\xi_c}{\eta\left(1-\xi_c\right)}, \quad g_{TH} = \frac{\left(1+\eta\xi_c\right)\left(1-n\right)}{\eta\left(1-\xi_c\right)}, \quad g_{TH} = \frac{-\left(1+\eta\xi_c\right)n}{\eta\left(1-\xi_c\right)},$$

they are able to eliminate movements in both Home and Foreign inflation. The monetary authority could then close consumption gap, employing a rule $\widehat{R}_t - \widetilde{R}_t = \rho \mathrm{E}_t \left(\widehat{C}^W_{t+1} - \widetilde{C}^W_{t+1}\right) + \mathrm{E}_t \left(\pi^W_{t+1}\right)$. Then, the only remaining source of losses are the fluctuations in the public spending and terms of trade gaps. However, this combination of policy rules can lead to relatively large welfare losses, as fluctuations in these gaps can be large.

In the sequel, we consider different rules. 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. We do this by choosing large values of d_H and $d_F = d_H\left(1-n\right)/n$ and, if necessary, b_C.[10] With the consumption gap virtually eliminated, the public spending gap is restricted to react to the terms-of-trade gap:

$$\begin{aligned}\widehat{G}^H_t - \widetilde{G}^H_t &= -g_{TH}\left(\widehat{T}_t - \widetilde{T}_t\right), \\ \widehat{G}^F_t - \widetilde{G}^F_t &= g_{TF}\left(\widehat{T}_t - \widetilde{T}_t\right). \end{aligned} \qquad (44)$$

[10] 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.

Table 1 reports the optimal coefficients of the public spending rules for the parameter combinations considered earlier. In all the cases reported, the optimal fiscal rule gets the expected welfare loss below the expected loss under the full-optimization discretionary policy. In all these cases, we have — not surprisingly — that the optimal fiscal policy rules set $g_{TH} = g_{TF} > 0$. As before, fiscal policy is employed to reduce the effect of the terms-of-trade on local inflation, while the country with the lower degree of price rigidity 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 are invariant to the shock correlations.

The second combination of rules assumes that monetary policy follows a standard Taylor rule, with the original coefficients proposed by Taylor (1993):

$$\widehat{R}_t - \widetilde{R}_t = 1.5\pi_t^W + 0.5\left(\widehat{Y}_t^W - \widetilde{Y}_t^W\right). \tag{45}$$

This is sometimes seen as a reasonable description of how monetary policy has been conducted in the past, in particular in the US. In view of the earlier discussion, we assume the fiscal policies follow a rule in which the public spending gap is a function of the output gap:

$$\begin{aligned} \widehat{G}_t^H - \widetilde{G}_t^H &= -g_{YH}\left(\widehat{Y}_t^H - \widetilde{Y}_t^H\right), \\ \widehat{G}_t^F - \widetilde{G}_t^F &= -g_{YF}\left(\widehat{Y}_t^F - \widetilde{Y}_t^F\right). \end{aligned} \tag{46}$$

Our goal is find the optimal coefficients g_{YH} and g_{YF} and see to what extent such a fiscal policy rule can improve upon the situation in which it is completely passive ($g_{YH} = g_{YF} = 0$), while monetary policy is restricted to follow a Taylor rule. We report the results for this rule in Table 3. The optimal fiscal rules are always countercyclical. When all parameters, including the public spending weight in the loss function, are at their baseline values, a 1%-point increase in the output gap leading to reduction in the spending gap of about 1.3% - point. Note that in welfare terms, this combination of rules performs surprisingly well, as it almost replicates the welfare level attained under the rules with the (approximate) optimal monetary policy.

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. Fatas 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.

As mentioned earlier, Benigno (1999) finds that it is optimal to design monetary policy in such a way that a relatively higher weight is given to countries that exhibit more price stickiness. This is also in accordance with the optimal policies we analyzed earlier. Here, we evaluate such a policy in the context of the Taylor rule for monetary policy. In (45), 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 (46). 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 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. Note, however, that 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 follows a policy that is close to the standard Taylor rule, there is actually little reason to reweigh the individual components of the world inflation rate in face of differences in nominal rigidities across countries. The results presented here suggest that the gains would only be small, while one could imagine that the cost could be major political upheaval in the case of EMU.

The final set of rules we investigate involves the combination of a standard Taylor rule for monetary policy, (45), and fiscal policy rules of the format (40). As demonstrated in the previous section, fiscal policy only plays a role to the extent that the Taylor rule does not fully close the consumption gap. Hence, the contribution of fiscal policy is marginal, given that it is limited to addressing a union-wide objective, which is also already addressed by the common monetary policy. For this reason, we do not report numerical results for this case.

6 Conclusion

This paper has explored the interactions between monetary and fiscal policy in a microfounded model of a monetary union with sticky prices. We explored the contribution of public spending in economic stabilization in the presence of demand and supply shocks and under different assumptions about their correlations. 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 Europe. It is also the relevant perspective for the

ECOFIN Council (or the Eurogroup) in case it moves towards more explicit coordination of fiscal policies.

The analysis in this paper can be extended into various 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. Another extension would abolish the assumption of complete markets. When centralized to a sufficient extent, fiscal policies could then be employed to provide for the sharing of country-specific risks. This seems to be of particular importance in the presence of price rigidities, so that it takes long for economies to attain the steady state. Finally, the model can be made more realistic by allowing for 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 stabilization gains found in this paper from the use of fiscal policy form an upper bound on what might be gained when the model includes a lag in the implementation of fiscal policy. We leave these extensions for future research.

Appendices

A Derivation of the efficient flex-price equilibrium

We first derive the outcomes conditional on the public spending policies. Rewrite (14) (for Home) as:

$$\frac{p_t\left(j\right)}{P_t}U_C\left(C_t^H,\epsilon_t^H\right)\left(T_t^{1-n}C_t^H+G_t^H\right)=\frac{\sigma}{\left(\sigma-1\right)\left(1-\tau^H\right)}v_y\left(T_t^{1-n}C_t^H+G_t^H,z_t^H\right)\left(T_t^{1-n}C_t^H+G_t^H\right).$$

Because under flexible prices each agent in Home chooses the same price, hence $p_t\left(j\right)=P_t^H$, we can simplify this to (15). Log-linearizing (15), we obtain:

$$\begin{aligned}\frac{U_{CC}\left(\overline{C},0\right)\overline{C}}{U_C\left(\overline{C},0\right)}\frac{dC_t^H}{\overline{C}}+\frac{U_{C\epsilon}\left(\overline{C},0\right)}{U_C\left(\overline{C},0\right)}\epsilon_t^H \quad &= \quad \left(1-n\right)\frac{dT_t}{\overline{T}}+\frac{v_{yy}\left(\overline{Y}^H,0\right)\overline{Y}^H}{v_y\left(\overline{Y}^H,0\right)}\left[\frac{(1-n)T_t^{-n}C_t^H dT_t+T_t^{1-n}dC_t^H+dG_t^H}{\overline{Y}^H}\right]\\ &\quad +\frac{v_{yz}\left(\overline{Y}^H,0\right)}{v_y\left(\overline{Y}^H,0\right)}z_t^H.\end{aligned}$$

Hence,

$$-\rho\left(\widetilde{C}_t^H+D_t^H\right)=\left(1-n\right)\widetilde{T}_t+\eta\left[\left(1-n\right)\frac{\overline{T}^{1-n}\overline{C}}{\overline{Y}^H}\frac{dT_t}{\overline{T}}+\frac{\overline{T}^{1-n}\overline{C}}{\overline{Y}^H}\frac{dC_t^H}{\overline{C}}+\frac{\overline{G}^H}{\overline{Y}^H}\frac{dG_t^H}{\overline{G}^H}\right]+\frac{v_{yy}\overline{Y}^H}{v_y}\frac{v_{yz}}{v_{yy}}\frac{1}{\overline{Y}^H}z_t^H.$$

Hence,

$$-\rho\left(\widetilde{C}_t^H + D_t^H\right) = (1-n)\,\widetilde{T}_t + \eta\left[(1-n)\,\xi_c\widetilde{T}_t + \xi_c\widetilde{C}_t^H + (1-\xi_c)\,\widetilde{G}_t^H\right] - \eta S_t^H. \quad (47)$$

We derive an analogous equation for the other country:

$$-\rho\left(\widetilde{C}_t^F + D_t^F\right) = -n\widetilde{T}_t + \eta\left[-n\xi_c\widetilde{T}_t + \xi_c\widetilde{C}_t^F + (1-\xi_c)\,\widetilde{G}_t^F\right] - \eta S_t^F. \quad (48)$$

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,

$$\widetilde{C}_t^W = \tfrac{\eta}{\rho+\eta\xi_c}\left[S_t^W - \tfrac{\rho}{\eta}D_t^W - (1-\xi_c)\,\widetilde{G}_t^W\right]. \quad (49)$$

Subtracting (48) from (47), we obtain:

$$0 = \widetilde{T}_t + \eta\left[\xi_c\widetilde{T}_t + \xi_c D_t^R - (1-\xi_c)\,\widetilde{G}_t^R\right] + \eta S_t^R.$$

Hence,

$$\widetilde{T}_t = \tfrac{\eta}{1+\eta\xi_c}\left[(1-\xi_c)\,\widetilde{G}_t^R - \xi_c D_t^R - S_t^R\right]. \quad (50)$$

One observes that the terms-of-trade are insulated from monetary policy. They are not insulated from fiscal policy, though: an increase in $\widetilde{G}_t^R$ raises the demand for Home goods relative to Foreign goods. To avoid an equal disparity in production, the terms-of-trade of Home improves (i.e., $\widetilde{T}_t$ falls). The relative increase in public spending is partly absorbed by a relative decrease in consumption and a relative increase in production.

Further, because $\widetilde{Y}_t^H = \frac{dY_t^H}{\overline{Y}^H} = \frac{(1-n)T_t^{-n}C_t^H dT_t + T_t^{1-n}dC_t^H + dG_t^H}{\overline{Y}^H}$, we can also write (47) 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 (48) 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 the latter two equations, we obtain:

$$-\rho\left(\widetilde{C}_t^W + D_t^W\right) = \eta\widetilde{Y}_t^W - \eta S_t^W. \quad (51)$$

Combining this with (49), we find:

$$\widetilde{Y}_t^W = \tfrac{\eta\xi_c}{\rho+\eta\xi_c}S_t^W - \tfrac{\rho\xi_c}{\rho+\eta\xi_c}D_t^W + \tfrac{\rho(1-\xi_c)}{\rho+\eta\xi_c}\widetilde{G}_t^W. \quad (52)$$

Finally, we linearize the Euler equation, assuming that the inflation rate in the flexible price equilibrium is zero. This yields:

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

where we have used that $\widetilde{C}^H_t + D^H_t = \widetilde{C}^F_t + D^F_t$, $\widetilde{C}^W_t + D^W_t = \widetilde{C}^H_t + D^H_t$.

We solve now for $\widetilde{G}^H_t$ and $\widetilde{G}^F_t$, thereby completing the solution of the (efficient) flexible price equilibrium. The fiscal authorities maximize over G^H_t and G^F_t:

$$\mathrm{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\begin{array}{c} n \left(U \left(C^H_t, \epsilon^H_t \right) + V \left(G^H_t \right) - v \left(Y^H_t, z^H_t \right) \right) + \\ (1-n) \left(U \left(C^F_t, \epsilon^F_t \right) + V \left(G^F_t \right) - v \left(Y^F_t, z^F_t \right) \right) \end{array} \right].$$

Because G^H_t and G^F_t affect only the period-t values of C^H_t, C^F_t, T_t, Y^H_t and Y^F_t as (49) and (50) reveal, the problem reduces to a series of one-period optimization problems. Hence, the first-order condition with respect to G^H_t is:

$$\begin{aligned} & nU_C \left(C^H_t, \epsilon^H_t \right) \frac{\mathrm{d}C^H_t}{\mathrm{d}G^H_t} + (1-n) U_C \left(C^F_t, \epsilon^F_t \right) \frac{\mathrm{d}C^F_t}{\mathrm{d}G^H_t} + nV_G \left(G^H_t \right) \\ & -nv_y \left(Y^H_t, z^H_t \right) \left[(1-n) T_t^{-n} C^H_t \frac{\mathrm{d}T_t}{\mathrm{d}G^H_t} + T_t^{1-n} \frac{\mathrm{d}C^H_t}{\mathrm{d}G^H_t} + 1 \right] \\ & - (1-n) v_y \left(Y^F_t, z^F_t \right) \left[(-n) T_t^{-(n+1)} C^F_t \frac{\mathrm{d}T_t}{\mathrm{d}G^H_t} + T_t^{1-n} \frac{\mathrm{d}C^F_t}{\mathrm{d}G^H_t} \right] \\ = \; & 0. \end{aligned}$$

An analogous first-order condition is obtained for G^F_t. Using (15) and (16) with (17) (efficiency) we can simplify the preceding equation to:

$$\begin{aligned} nV_G \left(G^H_t \right) &= nv_y \left(Y^H_t, z^H_t \right) \left[(1-n) T_t^{-n} C_t \frac{\mathrm{d}T_t}{\mathrm{d}G^H_t} + 1 \right] \\ &\quad + (1-n) v_y \left(Y^F_t, z^F_t \right) \left[(-n) T_t^{-(n+1)} C_t \frac{\mathrm{d}T_t}{\mathrm{d}G^H_t} \right]. \end{aligned}$$

Combining (15), (16), (8) and (17), we have that $T_t v_y \left(Y^H_t, z^H_t \right) = v_y \left(Y^F_t, z^F_t \right)$. Using this in the preceding equation, the latter simplifies to:

$$V_G \left(G^H_t \right) = v_y \left(Y^H_t, z^H_t \right).$$

We linearize this:

$$\begin{aligned} d \log V_G \left(G^H_t \right) &= d \log v_y \left(Y^H_t, z^H_t \right) \Rightarrow \\ \tfrac{V_{GG} \overline{G}^H}{V_G} \tfrac{\mathrm{d}G^H_t}{\overline{G}^H} &= \tfrac{v_{yy} \overline{Y}^H}{v_y} \left[\tfrac{\overline{T}^{1-n} \overline{C}}{\overline{Y}^H} \left((1-n) \tfrac{\mathrm{d}T_t}{\overline{T}} + \tfrac{\mathrm{d}C^H_t}{\overline{C}} \right) + \tfrac{\overline{G}^H}{\overline{Y}^H} \tfrac{\mathrm{d}G^H_t}{\overline{G}^H} \right] + \tfrac{v_{yz}}{v_y} z^H_t \Rightarrow \\ -\rho_g \widetilde{G}^H_t &= \eta \left[(1-n) \xi_c \widetilde{T}_t + \xi_c \widetilde{C}^H_t + (1-\xi_c) \widetilde{G}^H_t \right] + \tfrac{v_{yy} \overline{Y}^H}{v_y} \tfrac{v_{yz}}{v_{yy}} \tfrac{z^H_t}{\overline{Y}^H} \Rightarrow \\ - \left[\rho_g + \eta (1-\xi_c) \right] \widetilde{G}^H_t &= \eta \left[(1-n) \xi_c \widetilde{T}_t + \xi_c \widetilde{C}^H_t \right] - \eta S^H_t \Rightarrow \\ \widetilde{G}^H_t &= \tfrac{\eta}{\rho_g + \eta (1-\xi_c)} \left[S^H_t - \xi_c \left((1-n) \widetilde{T}_t + \widetilde{C}^H_t \right) \right]. \end{aligned}$$

For Foreign we have

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

Together with (49) and (50), for the flexible equilibrium, we then have four equations in four unknowns: $\widetilde{G}_t^H$, $\widetilde{G}_t^F$, $\widetilde{T}_t$ and $\widetilde{C}_t$. Using the expressions for $\widetilde{G}_t^H$ and $\widetilde{G}_t^F$ we get:

$$\widetilde{G}_t^R = \tfrac{\eta}{\rho_g+\eta(1-\xi_c)} \left[S_t^R + \xi_c\widetilde{T}_t + \xi_c\widetilde{D}_t^R\right].$$

Substitute this into (50) and solve to yield:

$$\widetilde{T}_t = -\tfrac{\eta\rho_g}{\rho_g(1+\eta\xi_c)+\eta(1-\xi_c)} \left(S_t^R + \xi_c\widetilde{D}_t^R\right), \tag{53}$$

Next, combining the earlier expressions for $\widetilde{G}_t^H$ and $\widetilde{G}_t^F$ with weights n and $(1-n)$, respectively, gives $\widetilde{G}_t^W = \tfrac{\eta}{\rho_g+\eta(1-\xi_c)} \left[S_t^W - \xi_c\widetilde{C}_t^W\right]$. Combining this with (49) and solving gives (24). Substituting (24) back into (49) and working out yields (22). Finally, we obtain (27).

B Derivation of (32)

We start from (11), for $i = H$ and $j = h$, (12) and

$$\widetilde{y}_{t,t+k}(h) = \left(\frac{\widetilde{p}_t(h)}{P_{H,t+k}}\right)^{-\sigma} \left[T_{t+k}^{1-n}C_{t+k}^H + G_{t+k}^H\right]. \tag{54}$$

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

$$0 = \mathrm{E}_t \sum_{k=0}^{\infty} \left(\alpha^H\beta\right)^k \left\{\left[(1-\sigma)\left(1-\tau^H\right)\lambda_{t+k}\widetilde{p}_t(h) + \sigma v_y\left(\widetilde{y}_{t,t+k}(h), z_{t+k}^H\right)\right]\widetilde{y}_{t,t+k}(h)\right\}.$$

After substituting for λ_{t+k} we obtain:

$$\mathrm{E}_t \sum_{k=0}^{\infty} \left(\alpha^H\beta\right)^k \left\{\left[\begin{array}{c}(1-\sigma)\left(1-\tau^H\right)U_C\left(C_{t+k}^H, \epsilon_{t+k}^H\right)\frac{\widetilde{p}_t(h)}{P_{t+k}} \\ +\sigma v_y\left(\widetilde{y}_{t,t+k}(h), z_{t+k}^H\right)\end{array}\right]\widetilde{y}_{t,t+k}(h)\right\} = 0,$$

or

$$\mathrm{E}_t \sum_{k=0}^{\infty} \left(\alpha^H\beta\right)^k \left\{\left[\begin{array}{c}(1-\sigma)\left(1-\tau^H\right)U_C\left(C_{t+k}^H, \epsilon_{t+k}^H\right)\frac{\widetilde{p}_t(h)}{P_{H,t+k}}T_{t+k}^{n-1} \\ +\sigma v_y\left(\widetilde{y}_{t,t+k}(h), z_{t+k}^H\right)\end{array}\right]\widetilde{y}_{t,t+k}(h)\right\} = 0.$$

We take a log-linear approximation of this equilibrium condition around a steady state in which $C_t = \overline{C}^H = \overline{C}$, $T_t = 1$, $\widetilde{p}_t(h)/P_{H,t} = 1$, $G_t^H = \overline{G}^H$ and $\left(1-\tau^H\right)U_C\left(\overline{C},0\right) = \frac{\sigma}{\sigma-1}v_y\left(\overline{C}+\overline{G}^H,0\right)$ at all times, obtaining:

$$0 = \mathrm{E}_t \sum_{k=0}^{\infty} \left(\alpha^H\beta\right)^k \left\{\left[\begin{array}{c}(1-\sigma)\left(1-\tau^H\right)U_C\left(\overline{C},0\right)\left(\widehat{p}_{t,t+k} - (1-n)\widehat{T}_{t+k}\right) \\ +(1-\sigma)\left(1-\tau^H\right)\left[U_{CC}\left(\overline{C},0\right)\overline{C}\widehat{C}_{t+k}^H + U_{C\epsilon}\left(\overline{C},0\right)\epsilon_{t+k}^H\right] \\ +\sigma\overline{Y}^H v_{yy}\left(\overline{Y}^H,0\right)\left[\begin{array}{c}-\sigma\widehat{p}_{t,t+k} + \xi_c\left((1-n)\widehat{T}_{t+k} + \widehat{C}_{t+k}^H\right) \\ +(1-\xi_c)\widehat{G}_{t+k}^H\end{array}\right] \\ +\sigma v_{yz}\left(\overline{Y}^H,0\right)z_{t+k}^H\end{array}\right]\right\},$$

or, using the definitions of S_{t+k}^H and D_{t+k}^H in the main text,

$$0=\mathrm{E}_t\sum_{k=0}^{\infty}\left(\alpha^H\beta\right)^k\left\{\left[\begin{array}{c}\widehat{p}_{t,t+k}-(1-n)\widehat{T}_{t+k}+\frac{U_{CC}\left(\overline{C},0\right)\overline{C}}{U_C\left(\overline{C}\right)}\left(\widehat{C}_{t+k}^H+D_{t+k}^H\right)\\ \frac{\sigma\overline{Y}^H v_{yy}\left(\overline{Y}^H,0\right)}{(1-\sigma)(1-\tau^H)U_C\left(\overline{C},0\right)}\left[\begin{array}{c}-\sigma\widehat{p}_{t,t+k}+\xi_c\left((1-n)\widehat{T}_{t+k}+\widehat{C}_{t+k}^H\right)\\+(1-\xi_c)\widehat{G}_{t+k}^H-S_{t+k}^H\end{array}\right]\end{array}\right]\right\},$$

or, using (18) and the definitions of ρ and η from the main text:

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

We observe that:

$$\widehat{p}_{t,t+k}=\widehat{p}_{t,t}-\sum_{s=1}^{k}\pi_{t+s}^H.$$

Using this, we simplify the next to last expression to:

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

Log-linearizing (12) we obtain:

$$\widehat{p}_{t,t}=\frac{\alpha^H}{1-\alpha^H}\pi_t^H.$$

Using this, we can further simplify the next-to-last expression to:

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

We then obtain:

$$\pi_t^H=\frac{\left(1-\alpha^H\beta\right)\left(1-\alpha^H\right)}{\alpha^H}\left[\begin{array}{c}\frac{1+\eta\xi_c}{1+\eta\sigma}(1-n)\widehat{T}_t+\frac{\rho+\eta\xi_c}{1+\eta\sigma}\widehat{C}_t^H+\frac{\eta(1-\xi_c)}{1+\eta\sigma}\widehat{G}_t^H\\+\frac{\rho}{1+\eta\sigma}D_t^H-\frac{\eta}{1+\eta\sigma}S_t^H\end{array}\right]+\beta\mathrm{E}_t\pi_{t+1}^H. \quad (55)$$

Combine (51), (52) and the fact that $\widetilde{C}_t^W+D_t^W=\widetilde{C}_t^H+D_t^H$, to find that $\widetilde{C}_t^H=\frac{\eta}{\rho+\eta\xi_c}S_t^W+\frac{\eta\xi_c}{\rho+\eta\xi_c}D_t^W-\frac{\eta(1-\xi_c)}{\rho+\eta\xi_c}\widetilde{G}_t^W-D_t^H$. Using this expression and (50), it is straightforward to show (without working out the expressions for the efficient flex-price public spending levels) that $-(1+\eta\xi_c)(1-n)\widetilde{T}_t-(\rho+\eta\xi_c)\widetilde{C}_t^H-\eta(1-\xi_c)\widetilde{G}_t^H=\rho D_t^H-\eta S_t^H$. Hence, also using that $\widehat{C}_t^W-\widetilde{C}_t^W=\widehat{C}_t^H-\widetilde{C}_t^H$, (55) can be rewritten as (32). For Foreign, we can derive a similar expression.

C Tables

Table 1: Welfare losses under optimal policies and optimal rule coefficients

$(\alpha^H, \rho_S, \lambda_G)$	L^c	L^d	L^{cm}	L^{dm}	L^{rp}	L^r	$(g_{TH}^{opt}, g_{TF}^{opt})$
baseline	0.6691	0.7248	0.7444^a	0.7444^a	0.7417^b	0.6943^b	(0.37,0.37)
$(0.75, -1, \lambda_G^B)$	1.3381	1.4497	1.4889^a	1.4889^a	1.4834^b	1.3886^b	(0.37,0.37)
$(0.5, 0, \lambda_G^B)$	0.8042	0.8575	0.8747	0.8864	0.8911^c	0.8382^c	(0.41,0.30)
$(0.5, -1, \lambda_G^B)$	1.6084	1.7150	1.7494	1.7727	1.7821^c	1.6764^c	(0.41,0.30)
baseline $(\lambda_G = \frac{1}{2}\lambda_G^B)$	0.6263	0.7091	0.7444^a	0.7444^a	0.7417^b	0.6567^b	(0.62,0.62)
$(0.75, -1, \frac{1}{2}\lambda_G^B)$	1.2525	1.4181	1.4889^a	1.4889^a	1.4834^b	1.3131^b	(0.62,0.62)
$(0.5, 0, \frac{1}{2}\lambda_G^B)$	0.7609	0.8329	0.8747	0.8864	0.8911^c	0.7998^c	(0.64,0.55)
$(0.5, -1, \frac{1}{2}\lambda_G^B)$	1.5217	1.6659	1.7494	1.7727	1.7821^c	1.5996^c	(0.64,0.55)
baseline $(\lambda_G = 2\lambda_G^B)$	0.6999	0.7331	0.7444^a	0.7444^a	0.7417^b	0.7167^b	(0.20,0.20)
$(0.75, -1, 2\lambda_G^B)$	1.3999	1.4663	1.4889^a	1.4889^a	1.4834^b	1.4334^b	(0.20,0.20)
$(0.5, 0, 2\lambda_G^B)$	0.8346	0.8713	0.8747	0.8864	0.8911^c	0.8623^c	(0.24,0.15)
$(0.5, -1, 2\lambda_G^B)$	1.6692	1.7426	1.7494	1.7727	1.7821^c	1.7245^c	(0.24,0.15)

Legend: ρ_S = correlation between the supply shocks, λ_G^B = baseline value for λ_G, L^c = expected loss under commitment, L^d = expected loss under discretion, L^{cm} = expected loss under commitment with fiscal policy restricted to $\widehat{G}_t^i = \widetilde{G}_t^i$ $(i = H, F)$, L^{dm} = idem for discretion, L^{rp} = expected loss under indicated monetary rule with passive fiscal policy, L^r = idem, but with fiscal rule of type (44), $(g_{TH}^{opt}, g_{TF}^{opt})$ = optimal combination of fiscal policy coefficients. All expected losses have been multiplied by 10000.

Notes: a: $\alpha^H = 0.749$ (this minor deviation from the baseline was needed to secure convergence of the solution algorithms); b: $(b_C, d^H, d^F) = (0, 250, 250)$; c: $(b_C, d^H, d^F) = (75, 125, 125)$.

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

$(\alpha^H, \rho_S, \lambda_G)$	D	CM	DM	RP	R
baseline	0.56	0.65	0.65	0.63	0.37
$(0.75, -1, \lambda_G^B)$	0.77	0.91	0.91	0.90	0.52
$(0.5, 0, \lambda_G^B)$	0.42	0.48	0.52	0.53	0.33
$(0.5, -1, \lambda_G^B)$	0.59	0.68	0.73	0.75	0.47
baseline $(\lambda_G = \frac{1}{2}\lambda_G^B)$	0.68	0.81	0.81	0.80	0.41
$(0.75, -1, \frac{1}{2}\lambda_G^B)$	0.96	1.14	1.14	1.13	0.58
$(0.5, 0, \frac{1}{2}\lambda_G^B)$	0.48	0.61	0.64	0.65	0.35
$(0.5, -1, \frac{1}{2}\lambda_G^B)$	0.68	0.86	0.90	0.92	0.50
baseline $(\lambda_G = 2\lambda_G^B)$	0.43	0.50	0.50	0.48	0.31
$(0.75, -1, 2\lambda_G^B)$	0.61	0.70	0.70	0.68	0.43
$(0.5, 0, 2\lambda_G^B)$	0.34	0.36	0.41	0.43	0.30
$(0.5, -1, 2\lambda_G^B)$	0.49	0.51	0.58	0.60	0.42

Legend: D = full optimization under discretion, CM = optimal monetary policy under commitment and passive fiscal policy, DM = optimal monetary policy under discretion and passive fiscal policy, RP = monetary policy rule aimed at closing world consumption gap and zero world inflation (see Table 1), but with passive fiscal policy, R = idem, but with fiscal rule of type (44)

Table 3: Welfare losses under the combination of rules (45) and (46)

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

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

Table 4: Welfare losses under the combination of rules (45) and (46): allowing for different weights on Home and Foreign inflation

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

Legend: (g_{YH}, g_{YF}) = coefficients in (46), $\left(\delta_H^{opt}, \delta_F^{opt}\right)$ = optimized coefficients in (45), 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.

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