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Source: *Journal of Money, Credit and Banking*, Oct., 2007, Vol. 39, No. 7 (Oct., 2007), pp. 1759-1784

Published by: Wiley

Stable URL: <https://www.jstor.org/stable/4494319>

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## Optimal Fiscal Policy Rules in a Monetary Union

This paper investigates the importance of fiscal policy in providing macroeconomic stabilization in a monetary union. We use a microfounded New Keynesian model of a monetary union, which incorporates persistence in inflation and non-Ricardian consumers, and derive optimal simple rules for fiscal authorities. We find that fiscal policy can play an important role in reacting to inflation, output, and the terms of trade, but that not much is lost if national fiscal policy is restricted to react, on the one hand, to *national differences* in inflation and, on the other hand, to either national differences in output or changes in the terms of trade. However, welfare is reduced if national fiscal policy responds only to output, ignoring inflation.

JEL codes: E52, E61, E63, F41

Keywords: optimal monetary and fiscal policies, monetary union, simple rules.

IN THIS PAPER, we show how national fiscal policy can help to stabilize individual economies within a monetary union. While the vulnerability of monetary unions to asymmetric shocks is well known, there has been little analysis of the extent to which fiscal policy can overcome these problems within the framework of the new international macroeconomics (see Lane 2001, Ganelli and Lane 2003

We are grateful to Christopher Allsopp, Tommaso Monacelli, an anonymous referee, and participants at a conference at the University of Siena for helpful comments on this paper. David Vines and Mathan Satchi are grateful to the Leverhulme Trust for financial support under grant no. F/108 519A, "EMU and European Macroeconomic Policy in a Global Context." All opinions and any mistakes are our own.

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Received February 1, 2006; and accepted in revised form September 20, 2006.

*Journal of Money, Credit and Banking*, Vol. 39, No. 7 (October 2007)

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for a survey of this literature). This is despite the fact that policy makers in potential members of the European Monetary Union (EMU) have actively discussed the possibility of using fiscal policy in this way (Swedish Committee 2002, Treasury 2003).

Since the work of Mundell (1961) and the subsequent Optimum Currency Area literature, it has been recognized that members of a monetary union would be vulnerable to asymmetric shocks. It has also been recognized that union members could in principle reduce this vulnerability by using fiscal policy in a countercyclical manner. While earlier studies have suggested that fiscal policy could be effective in this role (see, e.g., Hughes Hallett and Vines 1991, Driver and Wren-Lewis 1999), they have tended to use models without explicit microfoundations. The value of clear microfoundations when analyzing fiscal policy is apparent: it is important to consider the impact of fiscal actions on agents' lifetime income, on labor supply as well as consumption, and on the solvency of the government. We can use a setup with these features to conduct a rigorous analysis of whether the requirement that fiscal policy ensures debt stability conflicts with the use of fiscal policy for macroeconomic stabilization. A microfounded model can also allow us to derive a social welfare metric (see Woodford 2003), which can be used to rank policy outcomes.

A number of recent papers have examined joint stabilization by monetary and fiscal authorities acting optimally in the context of microfounded models with derived social welfare in a closed economy setting; see Benigno and Woodford (2004), Dixit and Lambertini (2003), Schmitt-Grohe and Uribe (2004), among many others. This approach can be extended to analyze a monetary union, with a union-wide monetary authority and individual national fiscal authorities. A natural setup to adopt here is a two-country framework, where the union as a whole is a closed economy, and we follow this approach. (In contrast, Gali and Monacelli 2005b assume the union is made up of a number of economies that are "small" in relation to the union, which reduces the extent of interaction between economies.)

Our analytical framework is perhaps closest to that of a recent paper by Beetsma and Jensen (2005), whose model is in turn based on a model developed in Benigno and Benigno (2000). However our analysis is more general than theirs in three important respects.<sup>1</sup> First, while their representative consumers are identical across countries (and therefore consume an identical basket), we allow for some home bias in consumption, along lines that are familiar from Gali and Monacelli (2005a), for example.<sup>2</sup> Second, while both papers embody nominal inertia in the form of Calvo contracts, we also allow for some additional inflation inertia, using a setup outlined in Steinsson (2003). This not only makes our model more realistic<sup>3</sup> but it also creates a greater potential need for fiscal policy to moderate the dynamic response to shocks. Inflation inertia introduces a key potential instability into the economies of the union,<sup>4</sup> and

1. In some respects our set up is more restrictive than Beetsma and Jensen (2005): for example, we assume that our two economies are of equal size whereas they do not do this.

2. See also Duarte and Wolman (2002).

3. See Mankiw (2001), Benigno and Lopez-Salido (2006), among many others.

4. See Kirsanova, Vines, and Wren-Lewis (2006), which looks at the stability issues in a monetary union but which ignores welfare analysis.

so a stabilizing fiscal policy may become vital. Third, we introduce the government solvency constraint in the model. As a result, we can directly study the potential conflict between the short-run task of macroeconomic stabilization and the long-run task of debt stabilization of the fiscal authorities. In our main case, we follow most of the literature in assuming consumers are infinitely lived. However, in examining the robustness of our results we also adopt in Section 4 the constant probability of death model due to Blanchard (1985), which provides a source of non-Ricardian consumer behavior that is in addition to the distortionary taxes already present in the model. Allowing for this may also be important when looking at the interrelationships between debt management and macroeconomic stabilization.

Our focus is on simple fiscal policy rules rather than completely optimal fiscal policy (although we do compute the latter as a benchmark). This seems justified given the institutional constraints that would prevent the “fine tuning” that is associated with a fully optimal policy. (In contrast, we allow full optimization by the union wide monetary policy.) We show that rules that relate government spending to lagged inflation, output, and the terms of trade can significantly **reduce the impact of asymmetric shocks**.<sup>5</sup> We also show that these rules can be restricted, with only a small welfare loss, to rules that relate government spending, on the one hand, to **differences between countries in inflation** and, on the other hand, to **either national differences between countries in output or changes in the terms** of trade. This result is important for the political economy debate on using fiscal policy as a countercyclical tool within EMU (see, e.g., Calmfors 2003). However, if, as some have suggested, fiscal policy reacts merely to output, or to output differences, without being concerned with inflation, then it is much less effective at reducing the welfare consequences of asymmetric shocks, a result that has important implications for some practical proposals for stabilization within EMU (Swedish Committee 2002, Westaway 2003).

The paper is laid out as follows. Section 1 describes the theoretical structure of the model. The calibration of the model is discussed in Section 2. The main results, which were summarized in the previous paragraph, are presented in Section 3. Then, in Section 4, we introduce Blanchard–Yaari consumers into the model. We do this in order to show that this important additional channel of fiscal influence, present in a model with this feature, does not greatly influence our results. In particular we show that, even in this more general model, the use of fiscal policy for short-run macroeconomic stabilization need not harm the medium-to-long-run objective of keeping public debt under control. Section 5 concludes.

## 1. THE MODEL

### 1.1 The Setup

Our monetary union consists of **two symmetric economies, labeled *a* and *b***. Each of these is inhabited by a large number of individuals and firms. Each representative

5. See Lombardo and Sutherland (2004) for an analysis of stabilization policies against asymmetric shocks using a static two-country model.

individual specializes in the production of one differentiated good, denoted by  $z$ , and spends  $h(z)$  of effort on its production. The household consumes a consumption basket  $C$ , and also derives utility from per capita government consumption  $G$ . Private and public consumption are not perfect substitutes.

In each of the two economies the consumption basket consists of two composite goods: the domestic composite good (produced in the home country) and the foreign composite good from the other open economy. Each composite good in turn consists of a continuum of produced goods  $z \in [0, 1]$ . In order not to repeat symmetric equations, we will use the index  $k$  for a single country in the union, and the index  $j$  for the other country, such that if  $k = a$  then  $j = b$ , or if  $k = b$  then  $j = a$ .

Preferences of individuals are assumed to be ( $\mathcal{E}_t$  is an expectation operator, conditional on information available at time  $t$ ):

$$\max_{\{C_{h,s}, h_{k,s}\}_{s=t}^{\infty}} \mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t} [u(C_{k,s}, \xi_{k,s}) + f(G_{k,s}, \xi_{k,s}) - v(h_{k,s}(z), \xi_{k,s})], \quad (1)$$

where we allow for taste/technology shocks  $\xi$ . Domestically produced goods may be consumed either at home or abroad and so:

$$y_k(z) = c_k^k(z) + c_j^k(z) + g_k(z), \quad (2)$$

where the superscript denotes the source of goods, so that  $c_j^k$  denotes goods produced in country  $k$  but consumed in the other country, and where the common time index is suppressed for notational convenience. We assume that government consumption  $g_k(z)$  only involves domestically produced goods.

All goods are aggregated into a Dixit and Stiglitz (1977) consumption index with the elasticity of substitution between any pair of goods given by  $\epsilon_t > 1$  (which is a stochastic elasticity<sup>6</sup> with mean  $\epsilon$ ):

$$C_{k,t}^k = \left[ \int_0^1 (c_{k,t}^k(z))^{\frac{\epsilon_t-1}{\epsilon_t}} dz \right]^{\frac{\epsilon_t}{\epsilon_t-1}}. \quad (3)$$

Every household consumes both domestic and foreign goods with the elasticity of substitution between them given by  $\eta > 0$ . Therefore, the consumption basket in country  $k$  is

$$C_k = \left[ (\alpha_d)^{\frac{1}{\eta}} (C_k^k)^{\frac{\eta-1}{\eta}} + (\alpha_n)^{\frac{1}{\eta}} (C_k^j)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (4)$$

where  $\alpha_d$  is the share of consumption of domestic goods,  $\alpha_n = 1 - \alpha_d$ .

6. We make this parameter stochastic to allow us to generate shocks to the mark-up of firms.

## 1.2 Demand: Optimal Consumption Decisions

An individual chooses optimal consumption and work effort to maximize the criterion (1) subject to the demand system and the budget constraint:

$$P_{k,t}C_{k,t} + \mathcal{E}_t(Q_{t,t+1}A_{k,t+1}) \leq A_{k,t} + (1 - \tau)(w_{k,t}(z)h_{k,t}(z) + \Pi_{k,t}(z)) + T_{k,t},$$

where  $P_{k,t}$  is a CPI price index defined below,  $A_t$  are nominal financial assets of a household, and  $\Pi_t$  is profit. Here  $w$  is the wage rate,  $\tau$  is a tax rate on income, and  $T$  are lump-sum government subsidies.  $Q_{t,t+1}$  is the stochastic discount factor, which is identical for all individuals, which determines the price in period  $t$  to the individual of being able to carry a state-contingent amount  $A_{t+1}$  of wealth into period  $t + 1$ . The riskless short-term nominal interest rate  $i_t$  has the following representation in terms of the stochastic discount factor:

$$\mathcal{E}_t(Q_{t,t+1}) = \frac{1}{(1 + i_t)}.$$

We assume no Ponzi schemes and that the net present value of individual's future income is bounded. We also assume that the nominal interest rate is positive at all times. These assumptions rule out infinite consumption (either because of infinite future income or because money would pay a higher return than bonds) and allow us to replace the infinite sequence of flow budget constraints of the individual by a single intertemporal constraint,

$$\begin{aligned} & \mathcal{E}_t \sum_{v=t}^{\infty} Q_{t,v} C_{k,v} P_{k,v} \\ &= A_{k,t} + \mathcal{E}_t \sum_{v=t}^{\infty} Q_{t,v} \left( T_{k,v} + \int_0^1 (1 - \tau)(w_{k,v}(z)h_{k,v}(z) + \Pi_{k,v}(z)) dz \right). \end{aligned} \quad (5)$$

The household optimization problem is standard (Woodford 2003) and, after linearization, it leads to the following first-order condition for country  $k$ , written in terms of deviations from the steady state (for each variable  $X_t$  with steady-state value  $X$ , we use the notation  $\hat{X}_t = \ln(X_t/X)$ ):

$$\hat{C}_{k,t} = \mathcal{E}_t \hat{C}_{k,t+1} - \sigma(\hat{i}_t - \mathcal{E}_t \hat{\pi}_{k,t+1}) + \hat{\xi}_{k,t}, \quad (6)$$

where  $\sigma = -u_C(C, 1)/u_{CC}(C, 1)$  is the elasticity of intertemporal substitution.

The optimal allocation of any given expenditure within each category of goods yields the demand functions:

$$c_k^k(z) = \left( \frac{P_{Hk}(z)}{P_{Hk}} \right)^{-\epsilon} C_k^k, \quad (7)$$

where the price of goods produced in country  $k$ ,  $P_{Hk} = [\int_0^1 P_{Hk}^{1-\epsilon}(z) dz]^{\frac{1}{1-\epsilon}}$ , and we suppress the common time subscript.

The optimal allocation of expenditures between domestic and foreign goods implies:

$$C_k^k = \alpha_d \left( \frac{P_{Hk}}{P_k} \right)^{-\eta} C_k, \quad C_k^j = \alpha_n \left( \frac{P_{Hj}^*}{P_k} \right)^{-\eta} C_k, \quad (8)$$

where  $P_{Hj}^*$  is the price of goods produced in country  $j$  in country  $k$ 's currency. The consumer price index for country  $k$  is:

$$P_k = (\alpha_d P_{Hk}^{1-\eta} + \alpha_n (P_{Hj}^*)^{1-\eta})^{\frac{1}{1-\eta}}. \quad (9)$$

We define the terms of trade  $S_k$ , the nominal exchange rate  $E_k$ , and the real exchange rate  $\Theta_k$  as follows:

$$S_k = \frac{P_{Hj}^*}{P_{Hk}}, \quad E_k = \frac{P_{Hj}}{P_{Hk}}, \quad \Theta_k = \frac{E_k P_j}{P_k}. \quad (10)$$

### 1.3 Supply: Pricing Decisions by Firms

In order to describe price setting decisions we split firms into two groups according to their pricing behavior, following Steinsson (2003). In each period, each firm is able to reset its price with probability  $1 - \gamma$ , and otherwise, with probability  $\gamma$ , its price will rise at the steady-state rate of domestic inflation. Among those firms, which are able to reset their price, a proportion  $1 - \omega$  are forward looking and set prices optimally, while a fraction  $\omega$  are backward looking and set their prices according to a rule of thumb.

Forward-looking firms are profit maximizing, and reset prices ( $P_{Hk,t}^F$ ) optimally, which in terms of log deviations from the steady state (see Appendix<sup>7</sup> A.2) implies:

$$\begin{aligned} \hat{P}_{Hk,t}^F &= \gamma \beta \mathcal{E}_t \hat{P}_{Hk,t+1}^F + \gamma \beta \mathcal{E}_t \pi_{Hk,t+1} \\ &+ \frac{(1 - \gamma \beta) \psi}{\psi + \epsilon} \left( \alpha_n \hat{S}_{k,t} + \frac{1}{\psi} \hat{Y}_{k,t} + \frac{1}{\sigma} \hat{C}_{k,t} + \left( \frac{v_{y\xi}}{v_y} - \frac{u_{C\xi}}{u_C} \right) \hat{\xi}_{k,t} + \hat{\mu}_{k,t} \right), \end{aligned} \quad (11)$$

where  $\pi_{Hk,t}$  is domestic inflation in country  $k$ ,  $\hat{\mu}_{k,t}$  is a mark-up shock, and  $\psi$  is elasticity of labor supply.

The rule of thumb used by a backward-looking firm to set its price  $P_{Hk,t}^B$  is

$$P_{Hk,t}^B = P_{Hk,t-1}^r \Pi_{Hk,t-1} \left( \frac{Y_{k,t-1}}{Y_{k,t-1}^n} \right)^\delta, \quad (12)$$

7. Here and below all references to appendices refer to the technical appendix to this paper, which is available from the authors upon request and also from [www.people.ex.ac.uk/tkirsano/AppendixRULES.pdf](http://www.people.ex.ac.uk/tkirsano/AppendixRULES.pdf).

where  $P_{Hk,t-1}^f$  is the average domestic price in the previous period,  $\Pi_{Hk,t} = P_{Hk,t}/P_{Hk,t-1}$  is the past period's growth rate of prices, and  $Y_{k,t}/Y_{k,t}^n$  is output relative to the flexible-price equilibrium. For the economy as a whole, the price equation can be written as:

$$P_{H,t} = [\gamma(\Pi P_{H,t-1})^{1-\epsilon_t} + (1-\gamma)(1-\omega)(P_{H,t}^F)^{1-\epsilon_t} + (1-\gamma)\omega(P_{H,t}^B)^{1-\epsilon_t}]^{\frac{1}{1-\epsilon_t}}. \quad (13)$$

Following Steinsson (2003) and allowing for government consumption terms in the utility function, we can derive the following Phillips curve for our economy, written in terms of log deviations from the steady state:<sup>8</sup>

$$\begin{aligned} \hat{\pi}_{Hk,t} = & \chi^f \beta \mathcal{E}_t \hat{\pi}_{Hk,t+1} + \chi^b \hat{\pi}_{Hk,t-1} + \kappa_c \hat{C}_{k,t} + \kappa_s \hat{S}_{k,t} \\ & + \kappa_{y0} \hat{Y}_{k,t} + \kappa_{y1} \hat{Y}_{k,t-1} + \left( \frac{v_{y\xi}}{v_y} - \frac{u_{C\xi}}{u_C} \right) \hat{\xi}_{k,t} + \hat{\mu}_{k,t}, \end{aligned} \quad (14)$$

where coefficients  $\chi$  and  $\kappa$ s are

$$\begin{aligned} \chi^f &= \frac{\gamma}{\gamma + \omega(1-\gamma + \gamma\beta)}, \quad \chi^b = \frac{\omega}{\gamma + \omega(1-\gamma + \gamma\beta)}, \\ \delta &= \frac{(1-\gamma\beta)(\psi + \sigma)}{\gamma\sigma(\psi + \epsilon)}, \\ \kappa_c &= \frac{(1-\gamma\beta)(1-\gamma)(1-\omega)\psi}{(\gamma + \omega(1-\gamma + \gamma\beta))(\psi + \epsilon)\sigma}, \quad \kappa_{y1} = \frac{(1-\gamma)\omega}{\gamma + \omega(1-\gamma + \gamma\beta)}\delta, \\ \kappa_{y0} &= \frac{(1-\gamma\beta)(1-\gamma)(1-\omega)}{(\gamma + \omega(1-\gamma + \gamma\beta))(\psi + \epsilon)} - \frac{(1-\gamma)\gamma\beta\omega}{\gamma + \omega(1-\gamma + \gamma\beta)}\delta, \\ \kappa_s &= \frac{(1-\gamma\beta)(1-\gamma)(1-\omega)\psi\alpha_n}{(\gamma + \omega(1-\gamma + \gamma\beta))(\psi + \epsilon)}. \end{aligned}$$

The *constant* income tax rate  $\tau$  does not appear in formula (14) because we have used the first-order condition (see (18) below) to substitute for the equilibrium post-tax real wage. Although the constant income tax rate has no effect on the dynamic equations for log deviations from the flexible price equilibrium, it alters the equilibrium choice between consumption and leisure for the consumer. The Phillips curve (14) has a structure in which both current and past output have an effect on inflation. The presence of the terms of trade in the Phillips curve is due to the fact that people consume a basket of goods that includes imports but, of course, produce only domestic goods.

8. The derivation is identical to that in Steinsson (2003), amended by the introduction of mark-up shocks as in Beetsma and Jensen (2004) and by accounting for the open economy. A detailed derivation is given in Appendix A.2.



#### 1.4 The Economy as a Whole

*Aggregate demand.* Market-clearing condition (2) can be aggregated across all goods to yield the condition that output produced in country  $k$  is consumed by either the domestic or foreign private sector and by the government in country  $k$ :

$$Y_k = C_k^k + C_k^j + G_k.$$

Substituting consumption from the demand system (20) and log linearizing, we obtain the following relationship (see Appendix A.5 for the derivation):

$$\hat{Y}_{k,t} = \theta \alpha_d \hat{C}_{k,t} + \theta \alpha_n \hat{C}_{j,t} + (1 - \theta) \hat{G}_{k,t} + 2\theta \eta \alpha_n \alpha_d \hat{S}_{k,t}. \quad (15)$$

The demand for the home country's products depends on consumption at home and overseas, but only on home government spending by assumption. The parameter  $\theta$  denotes the share of private consumption in output, so  $1 - \theta$  is the share of the government sector in the economy. The presence of the terms of trade reflects the direct effect of competitiveness on demand: with an increase in the terms of trade home goods become more competitive, and therefore it leads to an increase in the demand for home-produced goods.

*Aggregate supply.* The Phillips curve equation (14) contains terms in the preference shock  $\xi$ . It will be convenient to replace them by consumption, output and the terms of trade at their "natural" level (superscript  $n$ ), which is the level of these variables that would occur in an economy with flexible prices and no markup shocks. Consumer optimization implies that the real post-tax wage is equal to the ratio of marginal utilities in the usual way (we assume the production function  $y_t = h_t$ ):

$$(1 - \tau) \frac{w_{k,t}}{P_{k,t}} = \frac{v_y(y_{k,t}(z), \xi_{k,t})}{u_C(C_{k,t}, \xi_{k,t})}. \quad (16)$$

As discussed in Appendix A.2, we assume an employment subsidy  $\mu^w$ , paid for by lump-sum taxes  $T$ , of the size necessary to entirely remove all the distortions resulting from both the monopoly power of producers and the effect of taxes.

Profit maximization relates the real product wage to the monopolistic markup  $\mu_t = -(1 - \epsilon_t)/\epsilon_t$  and labor subsidy, if prices are flexible:

$$\frac{w_{k,t}}{P_{Hk,t}} = \frac{\mu^w}{\mu_t}. \quad (17)$$

Taking the relationship (16) in the flexible-price equilibrium with no markup shocks, and using relationship (17), we obtain

$$\frac{P_{k,t}}{P_{Hk,t}} \frac{v_y(y_{k,t}^n(z), \xi_{k,t})}{(1 - \tau) u_C(C_{k,t}^n, \xi_{k,t})} = \frac{\mu^w}{\mu}. \quad (18)$$

Linearization of (18) yields:

$$\hat{Y}_k^n \frac{1}{\psi} + \hat{C}_k^n \frac{1}{\sigma} + \alpha_n \hat{S}_k^n + \left( \frac{v_{y\xi}}{v_y} - \frac{u_{C\xi}}{u_C} \right) \hat{\xi}_k = 0. \quad (19)$$

We use this formula to substitute out the taste shock from the Phillips curve (14).

*Fiscal constraint.* We assume that the government buys goods ( $G$ ), taxes income (with tax rate  $\tau$ ), and issues nominal debt  $\mathcal{B}$ . The evolution of the nominal debt stock can be written as:

$$\mathcal{B}_{k,t+1} = (1 + i_t)(\mathcal{B}_{k,t} + G_{k,t}P_{Hk,t} - \tau Y_{k,t}P_{Hk,t}). \quad (20)$$

This equation can be linearized as (defining  $B_t = \mathcal{B}_t/P_{t-1}$ ):

$$\hat{B}_{k,t+1} = \hat{i}_t + (1 + i) \left( \hat{B}_{k,t} - \hat{\pi}_{Hk,t} + \frac{1 - \theta}{\rho} \hat{G}_{k,t} - \frac{\tau}{\rho} \hat{Y}_{k,t} \right), \quad (21)$$

where  $\rho$  is the steady-state level of real bonds as a share of  $Y$  and  $i$  is the steady-state level of the interest rate. If consumers live forever,  $(1 + i) = 1/\beta$ .

There is no capital in this model, so

$$\mathcal{A}_{a,t} + \mathcal{A}_{b,t} = \mathcal{B}_{a,t} + \mathcal{B}_{b,t}.$$

*Financial markets.* Monetary union implies a common nominal interest rate in the two countries. We assume that there exists a complete set of financial markets, so there is complete international risk sharing. In these circumstances, the first-order conditions of the household optimization problem imply

$$\beta \frac{u_C(C_{a,t+1})}{u_C(C_{a,t})} \frac{P_{a,t}}{P_{a,t+1}} = Q_{t,t+1}, \quad \beta \frac{u_C(C_{b,t+1})}{u_C(C_{b,t})} \frac{P_{b,t}E_t}{P_{b,t+1}E_{t+1}} = Q_{t,t+1}.$$

Combining them together with the definition of the real exchange rate introduced in (10), we obtain

$$\frac{u_C(C_{b,t}, \xi_{b,t})}{\Theta_t u_C(C_{a,t}, \xi_{a,t})} = \frac{u_C(C_{b,t+1}, \xi_{b,t+1})}{u_C(C_{a,t+1}, \xi_{a,t+1}) \Theta_{t+1}}.$$

Following Gali and Monacelli (2005a), we iterate this formula forward and substitute the real exchange rate as a function of the terms of trade, log linearize, and obtain the following relationship (detailed derivation is given in Appendix A.4):

$$\hat{C}_{a,t} = \hat{C}_{b,t} + \sigma(\alpha_d - \alpha_n) \hat{S}_{a,t} - (1 - \sigma)(\xi_{a,t} - \xi_{b,t}). \quad (22)$$

Risk sharing allows consumers to insure against individual country income risk. Thus consumption is equal in both countries, aside from changes in the cost of consumption reflected in movements in the terms of trade. If the terms of trade in country  $a$  increase,

this implies the cost of consumption in  $a$  relative to  $b$  falls (providing  $\alpha_d - \alpha_n > 0$ ), leading to higher consumption in  $a$  relative to  $b$ .

Under a fixed exchange rate regime

$$\hat{S}_{a,t} = \pi_{Hb,t} - \pi_{Ha,t} + \hat{S}_{a,t-1}. \quad (23)$$

### 1.5 Putting Things Together

We now write down the final system of equations for the “law of motion” of the out-of-steady-state economy. We simplify notation by denoting gap variables with lowercase letters: for any variable  $x_t = \hat{X}_t - \hat{X}_t^n$ . We use relationship (19) to substitute out the  $\xi$ -shock term in the Phillips curve, which enables us to rewrite some of the dynamic system in “gap” form. We denote  $s = s_a = -s_b$ . We also substitute for consumer price inflation so as to obtain all equations in terms of domestic inflation and the terms of trade. We omit the expectational superscript, assuming rational expectations,  $\mathcal{E}_t X_{t+1} = X_{t+1}$  for any variable  $X$ . As a result the complete system is

$$c_{a,t} = c_{a,t+1} - \sigma(i_t - \alpha_d \pi_{Ha,t+1} - \alpha_n \pi_{Hb,t+1}) + \hat{\zeta}_{a,t}, \quad (24)$$

$$c_{b,t} = c_{b,t+1} - \sigma(i_t - \alpha_d \pi_{Hb,t+1} - \alpha_n \pi_{Ha,t+1}) + \hat{\zeta}_{b,t}, \quad (25)$$

$$\begin{aligned} \pi_{Ha,t} = & \chi^f \beta \pi_{Ha,t+1} + \chi^b \pi_{Ha,t-1} + \kappa_c c_{a,t} + \kappa_y y_{a,t} \\ & + \kappa_{y1} y_{a,t-1} + \kappa_s s_t + \hat{\mu}_{a,t}, \end{aligned} \quad (26)$$

$$\begin{aligned} \pi_{Hb,t} = & \chi^f \beta \pi_{Hb,t+1} + \chi^b \pi_{Hb,t-1} + \kappa_c c_{b,t} + \kappa_y y_{b,t} \\ & + \kappa_{y1} y_{b,t-1} - \kappa_s s_t + \hat{\mu}_{b,t}, \end{aligned} \quad (27)$$

$$y_{a,t} = (1 - \theta)g_{a,t} + \theta\alpha_d c_{a,t} + \theta\alpha_n c_{b,t} + 2\theta\eta\alpha_d\alpha_n s_t, \quad (28)$$

$$y_{b,t} = (1 - \theta)g_{b,t} + \theta\alpha_d c_{b,t} + \theta\alpha_n c_{a,t} - 2\theta\eta\alpha_d\alpha_n s_t, \quad (29)$$

$$\begin{aligned} \hat{B}_{a,t+1} = & i_t + (1 + i) \left( \hat{B}_{a,t} - \alpha_d \pi_{Ha,t} - \alpha_n \pi_{Hb,t} + \frac{(1 - \theta)}{\rho} g_{a,t} - \frac{\tau}{\rho} y_{a,t} \right) \\ & + i(1 - \alpha_D)s_t + \hat{\kappa}_{a,t}, \end{aligned} \quad (30)$$

$$\begin{aligned} \hat{B}_{b,t+1} = & i_t + (1 + i) \left( \hat{B}_{b,t} - \alpha_d \pi_{Hb,t} - \alpha_n \pi_{Ha,t} + \frac{(1 - \theta)}{\rho} g_{b,t} - \frac{\tau}{\rho} y_{b,t} \right) \\ & - i(1 - \alpha_D)s_t + \hat{\kappa}_{b,t}, \end{aligned} \quad (31)$$

$$\begin{aligned} \hat{A}_{a,t+1} = & i_t + (1 + i) \left( a_{a,t} - \alpha_d \pi_{Ha,t} - \alpha_n \pi_{Hb,t} \right. \\ & \left. + \frac{(1 - \tau)}{\rho} (y_{a,t} - (1 - \alpha_D)s_t) - \frac{\theta}{\rho} c_{a,t} \right) + \hat{\eta}_{a,t}, \end{aligned} \quad (32)$$

$$\hat{A}_{b,t} = \hat{B}_{a,t} + \hat{B}_{b,t} - \hat{A}_{a,t}, \quad (33)$$

$$s_t = \pi_{Hb,t} - \pi_{Ha,t} + s_{t-1} + \hat{v}_t. \quad (34)$$

Equations (24) and (25) are the consumption equations for each country from (6), written in terms of domestic inflation. Equations (28) and (29) are aggregate demand equations from (15). Equation (34) is equation (23) written in gap variables; see Appendix A.7. The terms  $\hat{\zeta}$ ,  $\hat{v}$ ,  $\hat{\kappa}$ , and  $\hat{\eta}$  are composite shocks that are combinations of the taste shock  $\hat{\xi}$  and the natural variables, as shown in Appendix A.7. In an open economy with a flexible exchange rate, taste shocks need not influence gap variables as monetary policy can ensure that any real adjustment will occur without the need for nominal prices to change. However, an asymmetric taste shock in an economy in a monetary union will require nominal prices to change (e.g., to achieve any change in the real exchange rate), and so taste shocks will influence gap variables in the analysis presented here. The cost-push shocks  $\hat{\mu}$  are distortionary and are uncorrelated with taste shocks and thus with any of  $\hat{\zeta}$ ,  $\hat{v}$ ,  $\hat{\kappa}$ , and  $\hat{\eta}$ .

### 1.6 Policy Framework

In this paper, we study simple and potentially implementable fiscal rules. We postulate that fiscal authorities operate with rules of the following general form:

$$g_{k,t} = \theta_{\pi k} \pi_{k,t-1} + \theta_{\pi j} \pi_{j,t-1} + \theta_{y k} y_{k,t-1} + \theta_{y j} y_{j,t-1} + \theta_s s_{k,t-1} + \theta_{b k} \hat{B}_{k,t}. \quad (35)$$

Government spending in country  $k$  can potentially react to both home and overseas inflation and output, the terms of trade, and its own government debt, although we also investigate restricted versions of this rule where some of the  $\theta_k$  parameters are set to zero. For all these variables, we assume a one-period lag (one quarter) before spending can react, reflecting institutional delays in fiscal decision making. In practice, delays in fiscal policy decision making may be longer than this: fiscal budgets are generally approved on an annual basis and budget execution is often subject to rigidities and/or cyclical patterns. However, we have not imposed longer lags for three reasons. First, institutional practice varies considerably among countries. Second, these lags may not be immutable, particularly if fiscal policy starts being used for stabilization purposes among EMU countries. Third, it seems appropriate in the context of policy optimization to investigate, at least as a first step, what fiscal policy could potentially do in the most favorable institutional circumstances. Further work could then introduce additional constraints associated with particular fiscal instruments in particular institutional contexts. (Leith and Wren-Lewis 2006b show in the context of a small open economy that additional lags do reduce the effectiveness of fiscal actions, but fiscal stabilization can still have significant welfare benefits, particularly if shocks are persistent.)

Monetary policy, in contrast, is considered to be optimal and not subject to implementation lags, and will take into account all available information. We assume monetary policy is formulated under commitment (i.e., it is time inconsistent). We have checked that the results are similar if we assume a discretionary (time consistent) policy.

If the fiscal authorities are given such rules, and monetary authorities use optimal policy, this leads to stochastic equilibria that should be compared across a suitable metric. The coefficients  $\theta_k$  are then chosen such that they would optimize the chosen welfare criterion. Clearly, setting some  $\theta_k$  to zero reduces the information set that the fiscal authorities can respond to, so worse outcomes will be achieved. In this paper, we examine the magnitude of the cost of these restrictions.

The social loss is an aggregation of individual losses, taken across all individuals. As all individuals are identical, and live forever, the aggregate loss for each country is simply the individual loss of the representative, infinitely lived agent. For the union that consists of two identical countries, the social loss is a sum of the two losses for each country and it takes the form

$$\mathcal{L} = \mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t} (\mathcal{U}_{a,s} + \mathcal{U}_{b,s}) = \mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \mathcal{U}_s, \quad (36)$$

where the intraperiod loss  $\mathcal{U}_s$  takes the form (see Rotemberg and Woodford 1997, Beetsma and Jensen 2004, Steinsson 2003, and Appendix B for this derivation):

$$\begin{aligned} \mathcal{U}_s = & \lambda_{\pi} (\pi_{Ha,s}^2 + \pi_{Hb,s}^2) + \lambda_c (c_{a,s}^2 + c_{b,s}^2) + \lambda_y (y_{a,s}^2 + y_{b,s}^2) + \lambda_s s_s^2 \\ & + \lambda_g (g_{a,s}^2 + g_{b,s}^2) + \lambda_{sc} s_s c_{a,s} - \lambda_{sc} s_s c_{b,s} + \mu_y (y_{a,s-1}^2 + y_{b,s-1}^2) \\ & + \mu_{\Delta\pi} ((\Delta\pi_{Ha,s})^2 + (\Delta\pi_{Hb,s})^2) + \mu_{y\Delta\pi} (y_{a,s-1} \Delta\pi_{Ha,s} + y_{b,s-1} \Delta\pi_{Hb,s}) \\ & + v_{cn} c_{a,s} [\hat{Y}_{a,s}^n - \hat{C}_{a,s}^n + v_{cs} \hat{S}_s^n] + v_{cn} c_{b,s} [\hat{Y}_{b,s}^n - \hat{C}_{b,s}^n - v_{cs} \hat{S}_s^n] \\ & + v_{xn} y_{a,s} [\hat{C}_{a,s}^n - \hat{Y}_{a,s}^n + v_{xs} \hat{S}_s^n] + v_{xn} y_{b,s} [\hat{C}_{b,s}^n - \hat{Y}_{b,s}^n - v_{xs} \hat{S}_s^n] \\ & + v_{gn} g_{a,s} [\hat{Y}_{a,s}^n - \hat{G}_{a,s}^n + v_{gs} \hat{S}_s^n] + v_{gn} g_{b,s} [\hat{Y}_{b,s}^n - \hat{G}_{b,s}^n - v_{gs} \hat{S}_s^n] \\ & + v_{sn} s_s [v_{ss} \hat{S}_s^n + (\hat{Y}_{a,s}^n - \hat{Y}_{b,s}^n) - (\hat{C}_{a,s}^n - \hat{C}_{b,s}^n)] + Z_s, \end{aligned} \quad (37)$$

where term  $Z_s$  collects all terms independent of policy and all terms that are higher than the second order.

There are two unconventional features of this loss function. First, terms with  $\mu$  coefficients are present only because of the persistence due to rule of thumb price setters. These terms reflect the fact that, in these circumstances, welfare will be higher if any changes to inflation and output happen gradually. Steinsson (2003) has shown that when the private sector is predominantly backward looking, these terms dominate the loss function. Second, the terms with weights denoted by  $v$  arise in an open economy. With taste/technology shocks it is in general no longer optimal in an open economy to reproduce the flexible price equilibrium because changes in the terms of

trade alter the impact of the monopoly distortion, and this introduces what Kirsanova, Leith, and Wren-Lewis (2006) describe as “linear in policy” terms.

We assume that the monetary authorities use a union-wide social welfare function. However, as monetary policy cannot react to differences between the two economies (where there is no change in aggregate union-wide variables), then this expression can be simplified to the following:

$$\begin{aligned} \mathcal{U}_s = & \lambda_c \left( \frac{c_{a,s} + c_{b,s}}{2} \right)^2 + \lambda_y \left( \frac{y_{a,s} + y_{b,s}}{2} \right)^2 + \lambda_g \left( \frac{g_{a,s} + g_{b,s}}{2} \right)^2 \\ & + \lambda_\pi \left( \frac{\pi_{Ha,s} + \pi_{Hb,s}}{2} \right)^2 + \mu_{\Delta\pi} \left( \Delta \frac{\pi_{Ha,s} + \pi_{Hb,s}}{2} \right)^2 \\ & + \mu_y \left( \frac{y_{a,s-1} + y_{b,s-1}}{2} \right)^2 + \mu_{y\Delta\pi} \left( \frac{y_{a,s-1} + y_{b,s-1}}{2} \Delta \frac{\pi_{Ha,s} + \pi_{Hb,s}}{2} \right) + Z_s. \end{aligned} \quad (38)$$

This eliminates cross-terms from (37). Alternatively, and equivalently, it is the closed economy version of (37).

To interpret the resulting values of the social loss, we can express them in terms of compensating consumption—the permanent fall in the steady-state consumption level that would balance the welfare gain from eliminating the volatility of consumption, government spending and leisure (Lucas 1987). As explained in Appendix C, the percentage change in consumption level,  $\Omega$ , that is needed to compensate differences in welfare of two regimes with social losses  $\mathcal{L}_1$  and  $\mathcal{L}_2$  is given by (37):

$$\Omega = \sigma \left( 1 - \sqrt{1 + \frac{(1-\beta)}{\sigma} (\mathcal{L}_2 - \mathcal{L}_1)} \right). \quad (39)$$

(In brief, this is the relevant solution of a quadratic equation that relates the (quadratic) gain in the steady-state level of consumption to the difference in losses due to the variability of the key macroeconomic variables under two different policy regimes.)

## 2. CALIBRATION

Because of the microfounded nature of the model, there are relatively few parameters to calibrate. One period is taken as equal to one quarter of a year. We set the discount factor of the private sector (and policy makers) to  $\beta = 0.99$ . We follow the literature in setting  $\gamma = 0.75$ , which implies that, on average, prices last for 1 year. For the parameters related to fiscal policy, we calibrate the ratio of private consumption to output as 75%, and we assume that the equilibrium ratio of domestic debt to output is 60%. Then the debt accumulation equation gives us the equilibrium level of the primary surplus and the tax rate. Parameters for the openness of the economies are  $\alpha_d = 0.7$ , the elasticity of intertemporal substitution is  $\sigma = 0.5$ , the elasticity of

labor supply is  $\psi=2$ , the elasticity of substitution between domestic goods is  $\varepsilon = 5.0$ , and the elasticity of substitution between foreign and domestic goods is  $\eta = 2$  (see Lombardo and Sutherland 2004).

Perhaps the most important parameter in our model is the proportion of rule of thumb price setters,  $\omega$ . Our knowledge regarding inflation persistence is very insecure. All empirical studies are unanimous in concluding that an empirical Phillips curve has a statistically significant backward-looking component. The estimates of the exact weights  $\chi^f$  and  $\chi^b$ , however, differ widely. Gali and Gertler (1999) and Benigno and Lopez-Salido (2006) find a predominantly forward-looking specification of the Phillips curve, while Mehra (2004) finds an extremely backward-looking specification. Mankiw (2001) argues that stylized empirical facts are inconsistent with a predominantly forward-looking Phillips Curve. As a result of this ambiguity, we look at two values of  $\omega$ :  $\omega = 0.0$ , which is the New Keynesian Phillips curve, and  $\omega = 0.75$ , which leads to an equal weight on forward and backward inflation terms, as suggested by results in Fuhrer and Moore (1995).

This calibration completely defines the coefficients of the welfare function. In order to evaluate the social loss, which results from the optimal policies that we have designed, we assume that the standard deviations of cost-push and taste/technology shocks are equal. This is common in the literature, in which a consensus number is 0.5% (e.g., Jensen and McCallum 2002, Bean, Nikolov, and Larsen 2002). All shocks are independent and not persistent.

### 3. RESULTS

#### 3.1 Key Findings

Table 1 presents some key results for the model with infinitely lived consumers and a mix of backward- and forward-looking price setters ( $\omega = 0.75$ ). The columns of the table display the results for different forms of fiscal policy rule, where in each case the parameter values shown are the optimal values computed in the face of cost-push and taste/technology shocks. We also show the feedback parameters for optimal monetary policy in each case; however, these parameters should be interpreted with caution because they are part of an optimal rule under commitment, which also involves additional Lagrange multipliers.<sup>9</sup> The social loss under each policy, measured in absolute loss units, is shown in the first row, while the second row computes the gain in consumption units relative to the first column (in which there is no fiscal stabilization). The first column of numbers (labeled “Debt only”) represents the case where there is no fiscal stabilization, although there *is* a feedback on debt.

In all cases fiscal policy stabilizes debt, but, in each case, the optimal coefficient is small. It is large enough to ensure that the government’s debt stock reaches its

9. Lagrange multipliers are integrals of the predetermined variables, so they change slowly. In this sense, the coefficients in the columns can be thought of as describing the immediate reaction of policy instruments to a shock. We do not report the reaction of monetary policy to preference shocks because cost-push shocks are quantitatively more important.

TABLE 1  
COEFFICIENTS OF FISCAL RULE (35). MODEL WITH INFINITELY LIVED CONSUMERS AND GOVERNMENT SOLVENCY CONSTRAINT, PHILLIPS CURVE WITH INFLATION INERTIA

	Feedback on country's variables			Full and shock	Feedback on differences					
	Debt only	Full rule	Home only		Differences	Excl ToT	Excl output	Inflation only	ToT only	Output only
Absolute units of loss	14.69	14.00	14.07	13.91	14.13	14.17	14.13	14.52	14.51	14.33
% of steady state consumption	0.00	0.35	0.31	0.39	0.28	0.26	0.28	0.09	0.09	0.18
Optimal coefficients for fiscal policy in country a										
Cost-push shock	$\hat{\mu}_a$	0	0	-4.98	0	0	0	0	0	0
Inflation	$\pi_a$	-2.68	-3.31	-3.76	-2.60	-2.08	-2.55	-1.65	0	0
Output	$y_a$	-1.54	-2.50	-1.43	-0.30	-1.09	0	0	0	-1.21
Debt	$\hat{B}_a$	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Cost push shock	$\hat{\mu}_b$	0	0	4.98	0	0	0	0	0	0
Inflation	$\pi_b$	0	0	3.76	2.60	2.08	2.55	1.65	0	0
Output	$y_b$	-0.94	0	1.43	0.30	1.09	0	0	0	1.21
Terms of Trade	$s$	-1.07	-0.06	-0.21	-1.09	0	-1.34	0	-0.84	0
Optimal commitment solution for monetary policy (selected feedback coefficients)										
Cost-push shock	$\frac{\hat{\mu}_a + \hat{\mu}_b}{2}$	1.19	-1.00	0.34	1.19	1.19	1.19	1.19	1.19	1.19
Inflation	$\frac{\pi_a + \pi_b}{2}$	0.24	-0.36	-0.66	0.24	0.24	0.24	0.24	0.24	0.24
Output	$\frac{y_a + y_b}{2}$	0.06	-0.81	-0.77	0.06	0.06	0.06	0.06	0.06	0.06
Debt	$\hat{B}_a, \hat{B}_b$	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Assets	$\hat{A}_a, \hat{A}_b$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For reference: minimum possible loss under fully optimal commitment solution is 13.72.

For reference: minimum possible loss under fully optimal commitment solution is 13.72.



steady-state value, but otherwise small enough to give policy the freedom to also help stabilize output and inflation. The reason why very slow adjustment of debt may be optimal is explored extensively in Kirsanova and Wren-Lewis (2006).

We begin at the right of the table. In the last three columns in the table (headed “Inflation only,” “ToT only,” and “Output only”) we allow fiscal policy to feed back only on a single variable: *national differences* in inflation, the terms of trade between the countries and *national differences* in output, respectively. There is a moderate welfare gain in each case, although the gain is twice as large when output alone is used. The column headed “Differences” has fiscal feedback on all three variables, and there is a further improvement in welfare. However, the two intermediate columns (headed “Excl ToT” and “Excl output”) suggest that the main welfare gain comes from including *both* inflation *and* one other variable, which can be either output or the terms of trade. This is an important result in the light of some proposals (Treasury 2003) that have suggested that national fiscal policy focus exclusively on output gaps, and not on inflation. Our results suggest this would be clearly suboptimal. In all cases, the signs of the fiscal feedback on inflation and output are as we would expect. The sign of the terms of trade feedback implies that government spending is reduced if  $s$  rises (i.e., there is a real depreciation), for reasons we discuss further below. The consumption equivalent gain in allowing this form of fiscal feedback is significant, at between a quarter and a third of 1% of consumption. We can also note that the optimal union-wide monetary policy appears to be “conventional” in all these cases: interest rates rise in response to a cost-push shock, an increase in output, or an increase in inflation.

How important is the restriction that fiscal policy reacts only to *national differences* in output or inflation? This is explored in the second and third columns. In the column headed “Home only,” the fiscal authority in each country reacts to the level of inflation and/or output in his or her own country rather than to differences with the other country. The column headed “Full rule” is less restrictive still, and allows the fiscal authority to react to output and inflation in the other country as well to the level of these variables in their own country. In each case there is a further gain in welfare, but it is relatively small. However, note the parameters on the monetary policy rule in each case. In “Home only,” monetary policy reacts perversely to increases in output and inflation. In “Full rule” it reacts perversely to cost-push shocks. In these cases fiscal policy is “substituting” for monetary policy in that fiscal policy is stabilizing the monetary union at the aggregate level. Many would regard such “displacement” of monetary policy by fiscal policy, in stabilizing aggregates for the union as a whole, as undesirable, and this is what motivates our focus on fiscal feedback on national differences.

A “constraint” placed on fiscal policy in all the cases discussed so far is that it does not react to contemporary shocks. While this may be realistic given institutional lags in fiscal policy, it is interesting to note the cost of this constraint. The column headed “Full and shock” illustrates the effects obtained by adding feedback to the cost-push shock to the feedback used in the “Differences” column. There is some small additional gain.

Finally, the bottom line of Table 1 reports the welfare loss that would occur if both fiscal authorities cooperate with monetary authorities and jointly stabilize the union as a whole, taking into account all available information (including contemporary shocks) and acting under commitment.

### 3.2 The Performance of Rules

A comparison of the columns headed “Differences” and “Debt only” indicates substantial welfare gains from an active fiscal policy that reacts to inflation and output differentials and the terms of trade. The consumption equivalent gain in allowing this form of fiscal feedback is around a third of 1%. (Hughes Hallett and Vines 1991 and Driver and Wren-Lewis 1999 find gains of the same order of magnitude in less microfounded models.)

Figure 1 illustrates the two cases, presenting impulse responses to an asymmetric cost-push shock. The shock raises inflation. But with interest rates given by the centralized monetary policy, this means that the real interest rate will *fall*. This violation of the Taylor principle—which is inevitable in a monetary union following an asymmetric inflation shock when there is inflation persistence—tends to cause higher demand which would further augment the shock. The feedback on inflation in the “differences” rule, and in all of the rules whose performance that we describe in Table 1, moderates this destabilizing effect.

The increase in inflation has another effect in a monetary union: it leads to a deterioration in competitiveness. This helps reduce output, which in turn brings inflation back to base. But inflation must now fall below base in order to return the terms of trade to its initial level, which is necessary in a monetary union. However, when the terms of trade has done this, inflation is still negative, so the terms of trade (the price level) will overshoot. This will lead to high demand in the future, which will cause a return of inflation and higher prices and so on. The correction mechanism is inherently cyclical. Figure 1 shows the damped cyclical response in output that occurs when there is no fiscal stabilization. This cycle is largely removed if fiscal policy not only reacts to differences in inflation—for reasons described in the previous paragraph—but is allowed to react to national differences in output. We can see that feature at work in Figure 1. Government spending initially falls following the shock in order to help counter the increase in inflation. But then, once inflation has fallen, government spending rises. We can describe this increase in government spending as “supporting” output so as to prevent cyclical behavior. If fiscal policy instead reacts to both inflation and the terms of trade the same effect can be achieved. We could redescribe what happens in Figure 1 as being that fiscal policy that “keeps output up so as prevent inflation falling so low that the price level overshoots.” That is to say, feedback on the terms of trade can be viewed, at least in part, as a substitute for feedback on output.<sup>10</sup>

10. Table 1 shows numerically that in the model with inflation inertia, if the fiscal authorities feed back on inflation, then additional feedbacks on output, and the terms of trade are close substitutes.

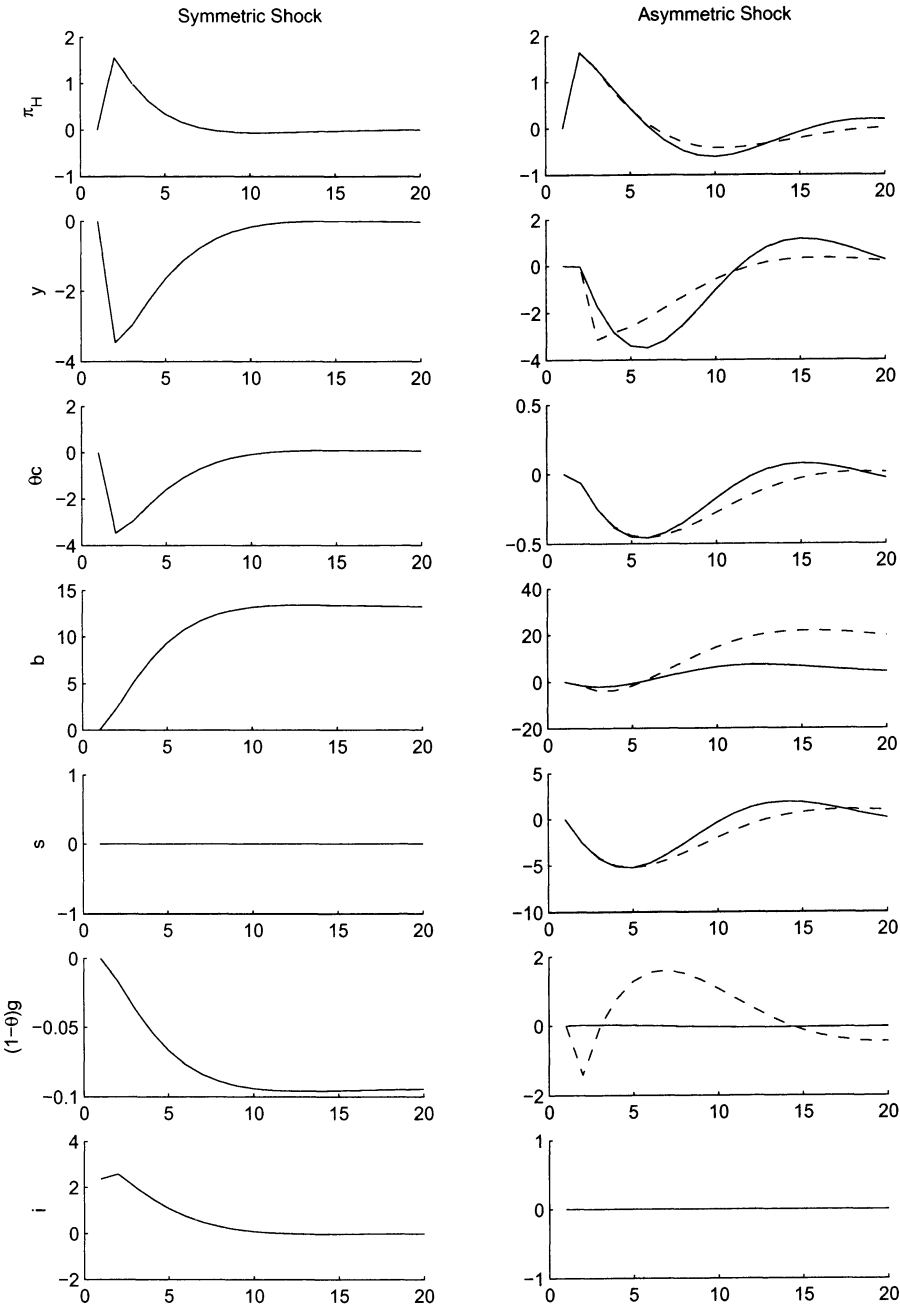


FIG. 1. Impulse Responses to a Unit Cost Push Shock.

NOTES: Solid line denotes the case "debt only," dashed line denotes the case "differences." Model with Phillips curve with inflation inertia, and infinitely lived consumers.

As a check on how stabilization works, we increased the size of the competitiveness elasticity ( $\eta$ ), which means that a unit worsening of competitiveness (caused, say, by our initial inflationary shock) would cause a larger reduction in output. We found that the optimal feedback on the terms of trade increased proportionately, as one would expect.

To understand one of the key reasons for the gains from the fiscal stabilization we can look at Table 2, which repeats the same exercise for the case where the Phillips curve is purely forward looking (i.e., New Keynesian). We observe a similar pattern, in that fiscal feedback on all three variables is preferable to the no fiscal feedback case. However, with a New Keynesian Phillips curve, feedback on inflation alone appears to be more important than feedback on either output or the terms of trade (compare columns “Inflation only” with the two next columns) and when there is joint feedback the response to output is perverse. Experimentation suggests that the reason for this is that the welfare function is very flat in relation to changes in output: big changes in fiscal feedback on output only result in small changes in welfare. The reason for this may, in turn be that, with simple Calvo contracts, control of inflation, together with its ability to jump, is sufficient to avoid the cumulative and hence cyclical movements in the terms of trade (price level), which were noted above. In all the cases in Table 2, the gains to fiscal stabilization are very much smaller than in Table 1.<sup>11</sup> This suggests that a large amount of gains to fiscal stabilization in Table 1 are due to backward-looking elements in the Phillips curve.

It is easy to understand the reasons for this. Suppose for some reason that output in one country rises and output in the other country falls, with no impact on union output. When there is inflation inertia, inflation in the country with higher output will gradually rise. As discussed above, this means that real interest rates in that country will therefore fall (because nominal interest rates are fixed at the union level and there is no reason for monetary policy to change). Lower real interest rates put further upward pressure on output and inflation. Feedback from this higher inflation to a tighter fiscal policy helps to restrain this destabilizing pressure, but even if this pressure toward instability is avoided, the adjustment mechanism is slow and cyclical.<sup>12</sup> In contrast, if inflation is entirely forward looking, as in the New Keynesian Phillips curve, it would jump up and then gradually fall, so the expected real interest rate would always be higher. This increase in the expected real interest rate will help to stabilize the economy.

11. The absolute size of the welfare loss in Table 2 compared to Table 1 is different because the models are different, even though we assume the same standard errors of shock hitting the economy. The percentage reduction in the loss when we have fiscal feedback is much smaller—it is in fact in the order of 10 times smaller in Table 2 than in Table 1. Note, however, that if there was no inflation persistence in the economy, then there would be a very strong case for examining persistent shocks, which would substantially raise the gains from fiscal stabilization. We have not done that here.

12. For detailed dynamic analysis of instability mechanisms in a monetary union when inflation is persistent, see Kirsanova, Vines, and Wren-Lewis (2006).

TABLE 2  
COEFFICIENTS OF FISCAL RULE (35). MODEL WITH INFINITELY LIVED CONSUMERS AND GOVERNMENT SOLVENCY CONSTRAINT, NEW KEYNESIAN PHILLIPS CURVE

	Feedback on country's variables				Feedback on differences					
	Debt only	Full rule	Home only	Full and shock	Differences	Excl ToT	Excl output	Inflation only	ToT only	Output only
Absolute units of loss	0.5256	0.5241	0.5250	0.5236	0.5241	0.5242	0.5248	0.5248	0.5256	0.5256
% of steady state consumption*	0.00	7.71	3.14	10.06	7.47	7.09	3.95	3.94	0.00	0.09
Optimal coefficients for fiscal policy in country a										
Cost-push shock	0	0	0	-0.38	0	0	0	0	0	0
Inflation	0	-0.53	-0.64	-0.26	-0.53	-0.55	-0.47	-0.47	0	0
Output	0	1.50	0.02	1.45	1.46	1.41	0	0	0	-0.26
Debt	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Cost push shock	0	0	0	0.38	0	0	0	0	0	0
Inflation	0	0.53	0	0.26	0.53	0.55	0.47	0.47	0	0
Output	0	-1.42	0	-1.45	-1.46	-1.41	0	0	0	0.26
Terms of Trade	0	-0.97	-0.50	-0.66	-0.96	0	-0.12	0	0.03	0
Optimal commitment solution for monetary policy (selected feedback coefficients)										
Cost-push shock	$\hat{\mu}_a + \hat{\mu}_b$	1.10	1.12	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Debt	$\hat{\mu}_a, \hat{\mu}_b$	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.06
Assets	$\hat{A}_a, \hat{A}_b$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For reference: minimum possible loss under fully optimal commitment solution is 0.5225.

For reference: minimum possible loss under fully optimal commitment solution is 0.5225.

NOTES: \* indicates that numbers presented in this line should be multiplied by 10<sup>-4</sup>.

#### 4. BLANCHARD–YAARI CONSUMERS

The model above assumes infinitely lived consumers. If taxes were lump sum, then these consumers would be unaffected by the timing of taxes and Ricardian Equivalence would hold. In our model taxes are distortionary, as we assume a constant income tax rate. Nevertheless, it is interesting to investigate how robust our results are to introducing an additional departure from Ricardian Equivalence, where we replace infinitely lived consumers by consumers with finite lives, using the framework due to Blanchard and Yaari (Blanchard 1985). (Blanchard/Yaari consumers are also modeled in Leith and Wren-Lewis 2006a who examine issues of stability and monetary/fiscal policy interaction in a monetary union, as well as Smets and Wouters 2002 and Ganelli 2005.) Introducing Blanchard–Yaari consumers does, however, introduce costs in terms of complexity, which is why we do not examine them in the base case.

##### 4.1 The Model

We need to make a number of changes to our model, described by equations (24)–(34), see Leith and Wren-Lewis (2006a), Smets and Wouters (2002), and Appendix A.1. First, as consumers have a constant probability of death,  $p$ , the discount factor in formula (1) becomes  $\beta/(1+p)$ . Second, in the household budget constraint (5), the discount factor takes account of mortality,  $\mathcal{E}_t(Q_{t,t+1}) = \frac{1}{(1+i_t)(1+p)}$ . Third, these modifications and the fact that we now have an infinite number of living cohorts at each moment of time result in a new system for aggregate variables. The first-order conditions for individual consumption, and then aggregation of all such behavioral equations, leads to a pair of equations for aggregate consumption and for the average propensity to consume, instead of the single Euler equation (6):

$$\hat{C}_{k,t} = [\beta(1+i)]^{-\sigma} \left( \mathcal{E}_t \hat{C}_{k,t+1} + \frac{p\rho}{\Phi\theta} (\mathcal{E}_t \hat{A}_{k,t+1} - \mathcal{E}_t \hat{\pi}_{k,t+1} - \mathcal{E}_t \hat{\Phi}_{k,t+1}) \right) - \sigma(\hat{i}_t - \mathcal{E}_t \hat{\pi}_{k,t+1}) + \hat{\xi}_{kt}, \quad (40)$$

$$\frac{(1+p)(1+i)}{\beta^\sigma(1+i)^\sigma} \hat{\Phi}_{k,t} = \mathcal{E}_t \hat{\Phi}_{k,t+1} - (1-\sigma)(\hat{i}_t - \mathcal{E}_t \hat{\pi}_{k,t+1}) - \hat{\xi}_{k,t}, \quad (41)$$

where, as before,  $k = \{a, b\}$ , and where  $1/\Phi_{k,t}$  is average propensity to consume out of total resources, resources that consist of nominal financial wealth and human wealth. For the derivation of this result see Appendix A.1. Financial assets, which now affect consumption, are defined as  $A_{k,t} = \mathcal{A}_{k,t}/P_{k,t-1}$ , where  $\mathcal{A}_{k,t}$  is the stock of nominal assets. Their evolution over time is described by:

$$\hat{A}_{k,t+1} = \hat{i}_t + (1+i) \left( \hat{A}_{k,t} - \hat{\pi}_{Hk,t} + \frac{(1-\tau)}{\rho} \hat{Y}_{k,t} - \frac{\theta}{\rho} (\hat{C}_{k,t} + \alpha_n \hat{S}_{k,t}) \right). \quad (42)$$

The evolution of the nominal stock of debt,  $\mathcal{B}_{k,t}$ , can be described by the following equation (denoting  $B_{k,t} = \mathcal{B}_{k,t}/P_{k,t-1}$ ):

$$\hat{B}_{k,t+1} = \hat{i}_t + (1+i) \left( \hat{B}_{k,t} - \hat{\pi}_{Hk,t} + \frac{1-\theta}{\rho} \hat{G}_{k,t} - \frac{\tau}{\rho} \hat{Y}_{k,t} \right). \quad (43)$$

The amount of bonds issued is equal to the amount of bonds held:

$$\hat{A}_{a,t} + \hat{A}_{b,t} = \hat{B}_{a,t} + \hat{B}_{b,t}. \quad (44)$$

Equations (40) and (41) can be written in terms of gap variables and for each country. The resulting four equations should now be included in a system like that shown in equations (24)–(34) instead of equations (24) and (25).

To evaluate gains and losses we need a welfare metric. In the Blanchard–Yaari case, unlike in the infinitely lived case, there is no obvious choice. Ideally, total welfare should be evaluated using a social welfare function that aggregates across generations and weights the utility of every generation. It is not clear, however, how to treat future unborn generations. Calvo and Obstfeld (1988) discuss the importance of including unborn generations in the social welfare metric. If they are excluded, we introduce an additional source of time inconsistency, as a policy that treats some particular generation differently will be necessarily time inconsistent. However, straightforward aggregating of the utilities of unborn generations is not feasible for computational reasons. One way to overcome this difficulty is to suggest that the government uses a weighting scheme that makes the aggregate welfare of overlapping generations equivalent to the welfare of one infinitely long-lived generation of consumers. A similar strategy was also adopted by Calvo and Obstfeld (1988). We therefore use formulae (36) and (37) to obtain our results.

## 4.2 Results

Table 3 repeats Table 1 for the model with Blanchard–Yaari consumers. The results are very similar to those obtained for infinitely lived consumers above. This is in part a consequence of the small degree of debt feedback. Although Blanchard–Yaari consumers allow for the additional effect of fiscal policy on consumption behavior, for realistic values of the probability of death the extent to which debt influences consumption remains small and is a similar order of magnitude to the optimal degree of fiscal feedback in Table 3. As a result, the two influences on debt are not only small but they offset each other in terms of their net influence on demand. As a result, the model with Blanchard–Yaari consumers and optimal fiscal feedback behaves in a very similar manner to the model with infinitely lived consumers.

## 5. CONCLUSION

In this paper, we have examined the potential role for fiscal policy to help stabilize individual economies within a monetary union. While the vulnerability of monetary unions to asymmetric shocks is well known, there has been surprisingly little analysis

TABLE 3  
COEFFICIENTS OF FISCAL RULE (35). MODEL WITH BLANCHARD–YAARI CONSUMERS AND GOVERNMENT SOLVENCY CONSTRAINT, PHILLIPS CURVE WITH INFLATION INERTIA

	Feedback on country's variables			Feedback on differences						
	Debt only	Full rule	Home only	Full and shock	Differences	Excl ToT	Excl output	Inflation only	ToT only	Output only
Absolute units of loss	14.67	14.00	14.07	13.91	14.12	14.17	14.12	14.50	14.50	14.33
% of steady-state consumption	0.00	0.34	0.30	0.38	0.28	0.25	0.28	0.09	0.09	0.17
Optimal coefficients for fiscal policy in country a										
Cost-push shock	0	0	0	-4.90	0	0	0	0	0	0
Inflation	0	-0.14	-3.31	-3.29	-2.55	-2.09	-2.55	-1.66	0	0
Output	0	-0.29	-2.49	-0.95	0.00	-1.07	0	0	0	-1.19
Debt	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Cost push shock	0	0	0	4.90	0	0	0	0	0	0
Inflation	0	5.01	0	3.29	2.55	2.09	2.55	1.6671	0	0
Output	0	0.04	0	0.95	-0.00	1.07	0	0	0	1.19
Terms of Trade	0	-1.21	-0.05	-0.56	-1.33	0	-1.33	0	-0.82	0
Optimal commitment solution for monetary policy (selected feedback coefficients)										
Cost-push shock	1.17	-1.21	0.34	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Inflation	0.23	0.33	-0.66	0.23	0.232	0.23	0.23	0.22	0.23	0.23
Output	0.05	-0.08	-0.77	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Debt	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Assets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For reference: minimum possible loss under fully optimal commitment solution is 13.72.

For reference: minimum possible loss under fully optimal commitment solution is 13.72.



of the extent to which fiscal policy can help to solve the resulting problems. This is despite the fact that policy makers in potential members of the EMU have actively discussed the possibility of using fiscal policy in this way (Swedish Committee 2002, Treasury 2003).

Our analysis looks at the potential welfare gains that might arise when national governments follow simple rules for fiscal policy. We find that there are substantial welfare gains if government expenditure responds to both national *differences* in inflation and one of either national differences in output or changes in the terms of trade. The more persistent is inflation, the larger are these gains. We might also expect these gains to be larger if there are other rigidities (e.g., in the labor market) in the economy that are not captured in the model. In practice, of course, it might not be possible to fully realize these gains as the level of institutional flexibility we have assumed for fiscal policy exceeds that of current arrangements. We have also shown that a fully optimal fiscal policy might achieve even larger welfare gains. But such a policy might well require even further institutional flexibility, possibly to an unrealistic degree. It might also lead to undesirable “competition” between fiscal and monetary policy at the aggregate union level.

We also find that the optimal feedback from government debt is only slightly above the minimum level required to ensure solvency. This result appears robust to replacing infinitely lived consumers with consumers of a Blanchard–Yaari type. Such a small feedback on debt is what makes it possible for fiscal policy to pursue the stabilization gains described in the previous paragraph.

These results have three important implications for the debate on how fiscal policy should be managed in a monetary union. First, we find that the potential gains from fiscal stabilization remain significant, even if we restrict fiscal policy to respond to differences between national and union wide variables. Such a restriction is important, both because it would prevent the fiscal authorities from “fighting” the monetary authority in dealing with union-wide shocks and because restricting fiscal policy in this way might help avoid some of the political economy concerns that have been expressed about fiscal stabilization. Second, these gains are very greatly reduced if fiscal policy does not react to intercountry differences in inflation but responds only to differences in output (as suggested by Treasury 2003). Third, there appears to be no conflict between stabilizing asymmetric shocks and the requirements for debt sustainability.

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