Abstract

This paper provides an overview of recent papers which use estimated New Keynesian models to study the extent to which fiscal policy can be used to stabilize the economy. We use a variety of different New Keynesian models, estimated on data for both the US and for the Euro area, and highlight the diverse transmission channels through which fiscal policy acts in these models. Although we find that fiscal policy can provide a useful complement to monetary policy, especially in models where consumers have finite horizons, there are important limitations to the value added of fiscal policy.

Analyzing the Interaction of Monetary and Fiscal Policy: Does Fiscal Policy Play a Valuable Role in Stabilisation?[1]

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1 Introduction

There is renewed interest in the role that fiscal policy can play in macroeconomic stabilization. After a decade in which the focus has mainly been on the delegation of monetary policy to independent central banks, attention is shifting to the potential role of fiscal policy. We seem to be again moving towards some of the opinions that were prevalent in the 1960s and early 1970s, which seemed to have been swept away by the monetarist-new classical revolution. Fiscal policy is again seen by some as an effective and necessary tool of stabilization policy.

In the case of EMU, the role of fiscal policy has received particular attention. Within EMU, decentralized fiscal policy is the only policy instrument that can respond to asymmetric shocks. This has led some observers to go beyond the initial suggestion that within EMU automatic fiscal stabilizers should be the main source of counter-cyclical fiscal action (see Buti *et al.* 1998, 2001), and to ask whether fiscal policy rules could be designed to substitute for the loss of monetary policy as an instrument of domestic demand management (see Westaway, 2003)[1].

One difficulty in analyzing whether fiscal policy can play a valuable role is that fiscal policy is a more complex policy instrument than monetary policy. In the original Neoclassical-Keynesian Synthesis the channel of transmission of fiscal policy, through direct expenditures and disposable income, was well understood. Even once additional channels of transmission were introduced for fiscal policy, through portfolio and wealth effects[2], the analysis was qualitatively very similar. In contrast, the 'New Keynesian' approach[3], which combines the individual dynamic optimizing framework adopted by theorists from the 'new classical' tradition (such as real business cycle theory), with the assumption of sticky prices and/or wages, allows for a richer range of transmission effects. Modern macroeconomic models in the tradition of the New Keynesian approach have been developed so as to allow a number of both demand and supply-side effects for fiscal policy.

[1] For a recent survey of the issues surrounding monetary and fiscal interactions in EMU see Beetsma and Debrun (2004). They also cover issues surrounding the strategic interactions between monetary and fiscal authorities, which are not covered in detail here.

[2] See for instance Blinder and Solow (1973), and Tobin and Buiter (1976).

[3] The 'New Keynesian' approach is also generally known by other names, such as the New Neoclassical Synthesis (cf. Goodfriend and King, 1997), or the sticky-price DSGE (dynamic stochastic general equilibrium) approach.

The other difficulty lies in the fact that many 'New Keynesian' models are calibrated, or partially calibrated and estimated. In calibrated models[4], the impact of fiscal and monetary policy are studied through simulations, using parameters for the behavioral relationships that are drawn from other empirical studies, or are based on theoretical priors. Increasingly a number of New Keynesian models are estimated (cf. Smets and Wouters, 2002, Leith and Malley, 2002, Muscatelli *et al.*, 2003a,b, Del Negro *et al.* 2005). However, because the coefficients in the model equations are highly non-linear functions of the behavioral (structural) parameters, some restrictions are required to ensure identification or to ensure that the parameters are estimated with an acceptable degree of precision.

This paper provides an overview of recent attempts to use estimated New Keynesian models to study the extent to which fiscal policy can be used to stabilize the economy (see Muscatelli *et al.*, 2003a,b, 2004b). In these papers we have used estimated New Keynesian models to study the way in which fiscal policy rules, which mainly take the form of automatic stabilizers, interact with a monetary policy rule which characterizes the behavior of an independent central bank. We use a variety of different New Keynesian models, estimated on data for both the US and for the Euro area. These highlight the diverse transmission channels through which fiscal policy operates. Fiscal policy's role is enhanced by the presence of forward-looking behavior by consumers, and by the presence of wealth effects on consumption if Ricardian equivalence does not hold. Interestingly, there seems to be some 'value added' from fiscal policy, despite the fact that price and wage stickiness in these models is typically of limited duration. However, there are potential trade-offs between output and inflation stabilisation.

As an extension to our earlier work, we also examine the behavior of fiscal policies in a basic two-country version of our Euro-area model, in the presence of a monetary union. This focuses on the case of EMU without structural asymmetries, and highlights the extent to which an active fiscal policy might add value in the presence of asymmetric demand and supply shocks.

In our analysis we do not explicitly examine some of the strategic (game-theoretic) interdependencies between the fiscal and monetary authorities. These are an important field of study in the theoretical literature (see Beetsma and Bovenberg, 1998, Dixit and Lambertini, 2001, 2003 a,b; and for a survey

[4] See, for instance, Westaway (2003).

Beetsma and Debrun, 2004). By focusing on simple feedback rules we also do not conduct the type of welfare analysis of monetary-fiscal interactions pioneered by Benigno and Woodford (2003). We do nevertheless examine the impact of different policy rules on output and inflation variability, and our results can therefore be interpreted in terms of a conventional welfare analysis framework (see Woodford, 2003).

In the next section we provide a brief survey of the nature of monetary and fiscal policy interactions in New Keynesian models. In Section 3 we present a broad outline of our estimated structural single-country models. We evaluate the extent to which fiscal policy adds value in the single-country model context in Section 4. In Section 5, we present some preliminary results using a two-country version of the New Keynesian model. Section 6 concludes.

2 Fiscal Policy in New Keynesian Models: a Brief Overview

Early versions of New Keynesian macroeconomic models involved a limited role for fiscal policy, by assuming that taxation is lump-sum and that representative agents have an infinite planning horizon. By assuming Ricardian equivalence, the only impact through which fiscal policy interacts with monetary policy is through a resource-withdrawal effect[5]. When simple feedback rules for government expenditure are combined with an inertial monetary policy rule, it can be shown that the impact is not unambiguously welfare-improving in terms of reducing the volatility of output and inflation (see Muscatelli *et al.*, 2003a). The impact of fiscal policy is solely that of changing the profile of aggregate demand.

Whether consumption actually increases in such models depends crucially on the assumptions made about labour supply and price-stickiness, given the linkage between consumption and leisure (and hence the real wage) via the consumer's optimization problem[6]. On the other hand, empirical studies of

[5]The usual assumption is that the government does not violate its solvency constraint on the budget, i.e. that the fiscal policy regime is 'Ricardian' (see Woodford, 1994, Sims, 1994). Throughout this paper we shall consider policies that do not violate the solvency constraint, and which do not run into the problems associated with the 'fiscal theory of the price level' (see Buiter 2001, Canzoneri et al., 2001).

[6]For a detailed analysis of the transmission of fiscal policy in the standard New Keynesian model, see Linnemann and Schabert (2003).

the impact of fiscal policy on the business cycle using VAR-type models do not support this simplest version of the New Keynesian model. Studies such as Galí (1994), Blanchard and Perotti (2002). De Arcangelis and Lamartina (2003) provide a useful survey. Blanchard and Perotti (2002) and Muscatelli *et al.* (2004a) show that fiscal shocks have conventional Keynesian effects, in that an increase in government spending causes a persistent rise in output[7] and consumption. In a non-VAR context, Giavazzi *et al.* (2000) investigate both country and time-specific fiscal policy events and show that both Keynesian and neoclassical (Ricardian) effects are present. Galí *et al.* (2002) demonstrate that by adding non-optimising behavior to the conventional New Keynesian model on the part of a proportion of consumers, who are constrained to consume out of current income (so-called 'rule of thumb' consumers), one can, under particular parameterizations, provide an explanation for the positive response of consumption to a temporary government spending shock. In essence, if the increase in government spending generates an increase in the real wage (providing the substitution effect between consumption and leisure dominates the wealth effect), this generates an increase in aggregate consumption because 'rule-of-thumb' consumers spend out of current income. The dynamics of this relationship can be made richer by introducing inertia in consumer behavior through, say, habit formation.

A number of other channels can be introduced for fiscal policy. A separate role can be introduced for taxation, and taxes can be modelled as lump-sum or distortionary. They can also be designed to have a differential impact on optimizing and non-optimising consumers. By including payroll taxes one can also model a supply-side impact for taxation.

Turning to government debt, this provides another channel of interaction between fiscal and monetary policy through the government budget identity. Debt-financed fiscal deficits will have an impact on aggregate demand in versions of the New Keynesian model which depart from Ricardian equivalence because of the presence of finite horizons, as in the classic Blanchard-Yaari model (see Blanchard, 1985). Alternative effects of government debt on consumer behavior can also be considered, such as the impact that financial wealth (money and bonds) has on household transactions costs, which also can explain a departure from Ricardian equivalence (see Linnemann and Schabert, 2002, Schabert, 2004). Clearly one could also introduce more complex supply-side effects for fiscal policy by allowing public expenditures (invest-

[7] The implied fiscal multiplier is close to or greater than unity.

ment) to have a role in private production and for tax distortions to impact on private investment decisions.

As noted earlier, there is a trade-off in estimating New Keynesian models with respect to the richness and complexity of the model which can be considered and the number of structural parameters which can be estimated freely. In what follows we examine the interaction of fiscal and monetary policy rules in the context of estimated New Keynesian models for the USA and Euroland, which contain a number of the features discussed above: habit persistence in consumption; non-optimising (rule-of-thumb) consumers; finite horizons in consumers' optimizing decisions; sticky prices; government expenditures; taxation effects on both consumption and on firms' marginal costs (through payroll taxes). In the case of each model, the question we address is whether fiscal policy, through feedback rules on output adds value to the stabilization role played by monetary policy, which is assumed to follow a standard (inertial) forward-looking inflation targeting rule.

3 Structure of the Models

3.1 General Structure

We consider two basic versions of the New Keynesian model for estimation and policy simulation. The models are set out in detail in the Appendix. The basic model follows Galí *et al.* (2002) in assuming that some consumers (a proportion ϑ) are non-optimising (rule-of-thumb), and simply consume out of current disposable income. We modify the Galí *et al.* (2002) model by allowing for habit formation on the part of optimizing consumers (the remaining proportion $1 - \vartheta$), who optimize over an infinite horizon with a discount factor β. Despite the presence of non-optimising consumers, Ricardian equivalence holds in the model as there is no link between government liabilities and aggregate demand.

The production sector of the model follows the standard New Keynesian assumption of monopolistic competition in the production of the consumption good, which firms produce using a Cobb-Douglas technology with labour and a fixed capital stock. Total consumption is given by an aggregate of the imperfectly substitutable goods, where the consumption aggregator is given by a CES function. This coupled with the assumption of sticky prices in the form of Calvo's (1983) assumption of staggered price setting, combined with a degree of partial indexation which introduces an element of inflation persistence (see Galí *et al.*, 2001)[8]. Following the Calvo pricing mechanism, $(1-\xi)$ is the proportion of firms adjusting their prices every period, and the remainder supply output on demand, at a constant price. Of those who adjust prices, a share γ of these is assumed to index prices to inflation in the previous period, whereas the rest, $(1-\gamma)$, set their prices optimally to maximize expected discounted real profits, with a discount factor β. We do not model wage rigidity explicitly[9], but simply assume in our simulations that nominal wages adjust to past inflation over two quarters.

In this basic model (which we label version I), fiscal policy impacts on the economy through the New Keynesian 'IS-curve' by directly affecting the consumption of rule-of-thumb (ROT) consumers, and the consumption-smoothing behavior of optimizing consumers. Government spending is non-productive and adds to aggregate demand. It is financed through personal taxation, which is paid by consumers (of both types), and through a payroll tax on firms' employees. The payroll tax ensures that taxation impacts on pricing behavior by firms by introducing a tax wedge in the New Keynesian 'Phillips Curve'.

We then consider a modified version of this model (which we label version II), which introduces the debt-channel as an additional channel of transmission for fiscal policy. Whilst retaining the assumption that some consumers follow a ROT behavior, here we introduce the assumption that optimizing consumers have Blanchard (1985)-type finite horizons with a constant probability of death as in Leith and Wren-Lewis (2004). This removes Ricardian equivalence, and allows debt-financed fiscal policy to impact, through wealth effects, on the consumption of optimizing consumers. The introduction of a wealth effect also introduces a channel of interaction between monetary and fiscal policy, as interest-rate changes will impact on aggregate demand through the government budget constraint.

3.2 Measuring the Performance of Policy Rules

We simulate our estimated models by combining feedback fiscal rules based on the usual structure of automatic fiscal stabilizers with a forward-looking

[8] This was pioneered by Galí and Gertler (1999). Similar backward-looking elements can be introduced to the NKPC equation by introducing indexation of all non-re-optimised prices (Christiano, Eichenbaum and Evans, 2001, and Woodford, 2003).

[9] For an example of an estimated model of wage rigidity, see Leith and Malley (2002).

inflation targeting monetary (interest rate) rule, which is estimated/calibrated on the data, and which allows us to examine the efficiency of different fiscal rules when combined with a monetary rule. Both the fiscal and monetary policy rules are allowed to display a certain amount of inertia, in that as well as depending on the output gap (and expected inflation in the case of the monetary rule), they contain an autoregressive element.

In analyzing the interactions between fiscal and monetary policy rules we do not conduct a formal welfare analysis as in Benigno and Woodford (2003), or an analysis of the optimal degree of inflation, government debt and tax rates volatility as in Schmitt-Grohé and Uribe (2001). Nevertheless, our results provide a useful benchmark in understanding how fiscal policy rules, as characterized by automatic stabilizers, interact with monetary policy rules in the current institutional arrangements where the fiscal and monetary policy authorities act independently of each other. We present our results both as dynamic simulation runs and as variance frontiers illustrating the trade-off between output and inflation volatility of different degrees of responsiveness of interest rates to expected inflation. The results can therefore be interpreted without having to adopt a particular welfare criterion.

One possible criticism of our approach is that, by focusing on estimated/calibrated monetary policy rules, we do not examine how the monetary authorities might respond to different forms of fiscal intervention. In practice one might expect an independent central bank to change its optimal response to change in response to changes in the fiscal rule. We might therefore be underestimating the welfare-enhancing effect of some fiscal rules. There are three possible responses to this observation. First, estimated monetary policy rules typically involve a greater degree of inertia than optimal monetary rules derived from a dynamic optimization exercise[10], and hence looking at fully optimal rules may not be a good description of how monetary policy works in practice. Second, the information requirements for the monetary authorities to respond to perceived changes in fiscal rule are likely to be quite demanding. This issue, together with the related one of strategic interactions between fiscal and monetary authorities will be explored in future work[11]. Third, the

[10]In Muscatelli *et al.* (2003a) we compare the performance of an optimal monetary policy rule with an estimated/calibrated rule. There are various possible explanations for the estimated inertia in reaction functions. Objectives such as financial stability are not captured by simple New Keynesian models. Inertial rules may also be robust in some instances (see Giannoni and Woodford 2002a,b).

[11]This is an issue which pre-dates New Keynesian models (see McKibbin and Sachs,

aim of this work is not to conduct some historical counterfactual analysis to see if monetary or fiscal policy 'could have done better' during some particular historical period. Rather, it looks at whether how different fiscal policy rules perform in the presence of the type of monetary policy behavior that has characterized the recent era of inflation targeting.

Our work complements that of previous authors. Gordon and Leeper (2003) find, using a calibrated model for the US economy, that fiscal stabilization policies tends to destabilize the business cycle because of their impact on debt service obligations. Jones (2002) uses an estimated stochastic growth model (without price stickiness) for the US to show that fiscal policy had limited stabilization effects in the post-war period. Andrés and Doménech (2003) also examine the design of fiscal rules and their impact on macroeconomic stability, but focus mainly on the comparison of distortionary and lump-sum taxes on output volatility. Their model does not allow for non-optimising behavior or finite horizons on the part of consumers, but allows for a richer specification of distortionary taxation. They find that distortionary taxes may worsen the inflation-output volatility trade-off unless there are substantial real and nominal rigidities. Hence automatic stabilizers may not be welfare-enhancing because of their impact on the aggregate supply side of the economy, unless there are considerable frictions in the economy.

3.3 Policy Rules

3.3.1 Monetary Authority

In what follows, 'hatted' lower-case variables represent percentage deviations from the steady state, and 'barred' variables denote steady-state values. The forward-looking monetary policy rule for the nominal interest rate $\widehat{i_t}$ follows a form similar to the standard forward-looking Taylor rule specification which has become commonplace in the literature[12] (see Clarida *et al.*, 1998, 2000; Muscatelli *et al.* 2002; Giannoni and Woodford, 2002a,b),

1988).

[12] The main difference is that we use a contemporaneous value of the output gap (see Muscatelli *et al.* 2002) as opposed to expected future values, as in Clarida, Gali and Gertler (1998, 2000). For a detailed discussion of these issues, see Giannoni and Woodford (2002a,b). For an alternative approach to modeling interest rate responses, involving nonlinearities in reaction functions, see Cukierman and Muscatelli (2001).

$$\widehat{i}_t = \phi_1 \widehat{\pi}_{t+q} + \phi_2 \widehat{y}_{t+s} + \phi_3 \widehat{i}_{t-1} \tag{1}$$

where the rule also allows for interest-rate smoothing (inertia) if $\phi_3 \neq 0$, and where $\widehat{y}_{t+s}$ is the output gap (expected at time t+s), and $\widehat{\pi}_{t+q}$ is expected inflation (at time t+q).

3.3.2 Fiscal authority

We consider a simple backward-looking format for the government's fiscal policy rules (automatic stabilizers), following *inter alia* Van den Noord (2000), Westaway (2003) and Andrés and Doménech (2003). This captures the more realistic lagged response of fiscal policy to macroeconomic variables due to automatic stabilizers:

$$\widehat{g}_t = \delta_1 \widehat{g}_{t-1} - \delta_2 \widehat{y}_{t-1} - \delta_3 \widehat{b}_t \tag{2}$$

$$\widehat{\tau}_t = \varphi_1 \widehat{\tau}_{t-1} + \varphi_2 \widehat{y}_{t-1} + \varphi_3 \widehat{b}_t \tag{3}$$

where $\widehat{g}_t$ is government spending, $\widehat{\tau}_t$ is the vector of our two tax measures, personal taxes $\widehat{t}_t$ and payroll taxes, $\widehat{t^*}_t$. Our taxation rule therefore imposes the same adjustment pattern on both taxes, and does not look at how a mix of tax measures might improve the design of policy[13]. In the case of our single-country models we adopt fiscal policy rules that only feed back on the output gap and the lagged policy variable. Our chosen policy parameters and estimated structural parameters are such that when the single-country models are simulated the fiscal policy regime is Ricardian and there are no problems with determinacy.

For our baseline case, we set $\delta_1 = \varphi_1 = 0.6$, $\delta_2 = \varphi_2 = 0.5$, $\delta_3 = \varphi_3 = 0.05$. A coefficient of 0.5 on output is consistent with the empirical evidence in Van den Noord (2000) and adopted in studies on fiscal stabilization (e.g. Westaway, 2003), and are broadly consistent with the correlations for US fiscal data over the cycle (cf. Gordon and Leeper, 2003). We allow for an element of inertia as empirical estimates of fiscal policy rules on quarterly data suggest an important role for an autoregressive term. The term on debt,

[13] The importance of the taxation policy mix is considered in Muscatelli *et al.* (2003b, 2005). There we also consider a number of variants for the fiscal rules, and we also conduct some sensitivity analysis, to see to what extent the performance of these fiscal rules is affected by small changes in the estimated model parameters.

which follows Bohn (1998), has a coefficient of 0.05. This feedback on debt is sufficient to ensure that there is determinancy.

The government is assumed to finance its deficits using indexed bonds. The debt dynamics are given by a log-linearised version of the standard government budget constraint (where $\widehat{r_t}$ is the real interest rate, and $\widehat{g_t^{TR}}$ are government transfers which are kept constant during our simulations):

$$\widehat{b_t} = (1+\overline{r})\,\widehat{b_{t-1}} + \overline{r}\widehat{r}_t + \overline{\left(\frac{G^{TR}}{B}\right)}\widehat{g_t^{TR}} + \overline{\left(\frac{G}{B}\right)}\widehat{g}_t - \overline{\left(\frac{T^*}{B}\right)}\widehat{t_t^*} - \overline{\left(\frac{T}{B}\right)}\widehat{t_t} \quad (4)$$

Our models are simulated under forward-looking (model-consistent) expectations, where consumers take into account the policy rules and the government budget constraint.

3.4 Econometric Estimation and Calibration

In our empirical work (see Muscatelli *et al.* 2003b, 2004b) we estimate the IS and Phillips curves for version I of the model using US quarterly data, over the sample period 1970(1)-2001(2). For the Euro area, we estimate the IS curve and use the estimates for the Phillips curve reported in Galí *et al.* (2001)[14]. The Euro area study uses the artificial Euro data from Fagan *et al.* (2001), over the sample 1970(1)-1998(2). The equations are estimated using the generalized methods of moments (GMM) framework. The steady-state values in the equations are taken from the sample means[15]. As noted above, the highly nonlinear nature of the estimation equations and the need for sufficient restrictions to ensure identification imply that some of the model parameters have to be imposed. In particular, in the case of the USA in estimating the Phillips Curve we have to impose that the price elasticity of the differentiated goods, θ is equal to 4, implying a price-mark-up[16] of 30%,

[14] For another approach to the estimation of DSGE models, see Del Negro and Schorfeide (2004) and Del Negro et al. (2005). Van Aarle et al. (2003) examine the transmission of monetary and fiscal policy in EMU and two-country models.

[15] The detailed issues surrounding the estimations are not reported here for reasons of space. The interested reader should consult Muscatelli *et al.* (2003a,b, 2004b) for more details, including the steady-state values used.

[16] This follows Erceg *et al.* (2000). It is a lower value of the elasticity of substitution than that used by Galí *et al.* (2001) and Leith and Malley (2002), where $\theta > 10$ but in practice the estimates of the other parameters did not seem to be very sensitive to changes

that the labour elasticity of output, $1-\alpha$ is equal to 0.6 and that in Version I of the model, the habit formation parameter on aggregate consumption (λ) is unity[17], which implies that the stock of habits are equal to aggregate lagged consumer expenditure. In the case of the Euro area the estimates of the coefficient of relative risk aversion in the consumption function (ρ) were imprecise and we imposed a value of 4, following a grid search[18]. Similarly, in the case of the USA, we could not get precise estimates without imposing a value for the discount factor in the consumers' optimization problem (β), which following a grid search so as to minimize the criterion function was fixed at 0.99. Thus, in the case of Version I of the model, our structural model is essentially estimated, subject to the restrictions on the steady-state values and on the above parameters. Table 1 reports the estimated values of the key structural parameters in our models (see Muscatelli *et al.*, 2003b, 2004b).

In the case of version II, we use a calibrated model, retaining the parameter values estimated in Version I of the model, augmenting them with a calibrated value for the probability of death[19] (ϖ). Here we assume that $(1-\varpi) = 0.9943$ which implies an average life-span for the consumer of 30 years, as our models are based on quarterly data.

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in the value of θ. However, a higher mark-up does seem to be more sensible given that marginal costs exclude capital costs in this framework. In addition, a higher value of θ would imply an implausibly small direct effect of output on prices through the marginal cost term. For the Euro area estimates, Galí *et al.* (2001) use a labour income share of 0.75.

[17] In our earlier study, Muscatelli et al. (2003a), where we estimate λ freely in a simpler version of the IS curve we found that it was insignificantly different from unity.

[18] In current work we are exploring alternative estimation methodologies (see Del Negro and Schorfheide, 2004).

[19] In practice we would not expect the addition of an additional term to the IS equation with an imposed parameter to make a considerable difference to the estimated structural parameters.

Table 1: Structural Parameter Estimates- USA and Euro-Area

Parameter	USA Estimates	Euro-area Estimates[20]
ρ - coefficient of relative risk aversion in utility function	3.18 (1.27)	4.00 ($-$)
ϑ- proportion of RT consumers	0.366 (0.097)	0.508 (0.083)
$\frac{\overline{N^{RT}}}{\overline{N}}$ - proportion of total employment determined by RT consumers in steady state	0.586 (0.155)	0.720 (0.201)
$\frac{\overline{C^o}}{\overline{C}}$-proportion of total consumption determined by optimisers in steady state	0.839 (0.258)	0.698 (0.105)
β - consumers' discount factor	0.99 ($-$)	0.923 (0.071)
ξ - proportion of firms not adjusting prices every period	0.433 (0.103)	0.843 (0.066)
γ - proportion of firms adjusting prices who index to past inflation	0.492 (0.111)	0.307 (0.128)

Turning to the monetary policy rule, for the USA Muscatelli *et al.* (2003b) estimate the following values of the policy rule parameters: $\phi_1 = 0.209$, $\phi_2 = 0.148, \phi_3 = 0.885$, with all parameters highly significant at the 5% level. The long-run effect of expected inflation on nominal interest rates

[20] For β, γ, ξ we are simply reporting the estimated values in Galí *et al.* (2001) as corrected in Galí *et al.* (2003).

that is given by $\phi_4 = (\phi_1/(1-\phi_3))$, and is significantly greater than unity ($\phi_4 = 1.817$ with an asymptotic standard error equal to 0.095). For the case of the Euro-area, we use the estimated interest rate rule parameters reported in Sauer and Sturm (2003).

4 Simulation Results

We now use these estimated and calibrated models to illustrate the extent to which fiscal policy might provide a useful role in stabilization policy. We begin by looking at some of the properties of the different versions of the New Keynesian model in relation to the transmission of fiscal policy, and then examine the extent to which the richer version of the model provides us with useful insights for current policy questions.

In the case of Euroland, clearly the assumption of a single fiscal authority is false, and the characterization would be one where similar symmetric shocks are hitting all countries in the Euro area, and the fiscal rules assumed here represent an aggregate response. In Section 5 we will consider the more realistic case of a two-country model where each country has its own fiscal authority so that we can consider asymmetric shocks.

4.1 The transmission of fiscal policy under different models

Figures 1-4 show, for the case of the Version I model, estimated on US data, the response profiles of output and inflation following a temporary shock to the IS curve (Figures 1-2) and to the Phillips curve (Figures 3-4)[21]. For each shock we examine the behavior of the model when the monetary policy rule alone (1) is active, and when both monetary policy and the fiscal policy rules (2) and (3) are active. When monetary policy is acting alone, we set $\delta_1 = \varphi_1 = \delta_2 = \varphi_2 = 0$, but still allow fiscal policy to stabilize the debt dynamics which result from the monetary policy response, and maintain long-run fiscal balance.

[21] The shocks to the IS and Phillips Curves are temporary, imparting a shock of 1% in the first period to output and inflation respectively, and decaying with an autoregressive parameter of 0.5. The IS curve could be interpreted as a temporary consumption shock, whilst the Phillips curve shock could be interpreted as a temporary shock to marginal costs.

Figures 1-4 show that in Version I fiscal policy does reduce the volatility of output and inflation in response to demand shocks, and the volatility of output due to a supply shock. Government spending stabilizes output directly, via the resource-withdrawal effect in the IS curve which impacts on optimizing consumers. Taxation functions through two channels. Personal taxes reduce the disposable income of ROT consumers, and thereby impact on optimizing consumers. Payroll taxes reduce aggregate supply by increasing the cost of production of firms. However, payroll taxes also tend to increase prices (cf. Buti *et al.*, 2003).

What role do ROT consumers play in the transmission of fiscal policy? In order to see this, we plot Figures 5-8, which repeat the shocks in Figures 4, but where we have modified the baseline parameters of the Version I model to include a higher proportion of ROT consumers. To be precise, these figures show the impact of raising the proportion of employment made up by ROT consumers[22] $(\overline{N^{RT}}/\overline{N})$ to 0.7, and consequently lowering the proportion of consumption determined by optimizing consumers $(\overline{C^o}/\overline{C})$ to 0.571. Having more ROT consumers makes the economy more volatile to demand and supply shocks. It is important to note that there are two effects at play here. First, increasing the number of ROT consumers makes payroll taxes more effective. Second, it reduces the degree of consumption smoothing, and reduces the effectiveness of monetary policy by reducing the size of the coefficient on the interest rate in the IS curve. This second effect is found to dominate[23]. Fiscal policy does add assist monetary policy, whose potency has diminished, as payroll taxes impact directly on ROT consumers' disposable income and expenditure.

However, as might be expected in version I of the model, where fiscal policy plays a limited role, the impact on volatility is not large. This supports the findings of Andrés and Doménech (2003). Our models do not allow for major tax distortions and hence they have more limited supply effects. It is apparent why, quantitatively, if taxation were to have distortionary effects on supply, it might outweigh the benefits of aggregate demand stabilization.

Next, let us consider what the impact is of allowing Blanchard-type finite

[22] The value of 0.7 corresponds to the upper end of the 95% confidence band given the estimated parameter shown in Table 1.

[23] This can be verified by plotting variance frontiers for different proportions of ROT. See the results reported in Muscatelli *et al.* (2003b). The intuition behind this result is apparent from the Appendix, as ROT consumers do not smooth income a high proportion of ROT consumers reduces the impact of interest rates in consumption.

horizons in consumer behavior, as in version II of the model. Table 2 shows, for the case of the USA, the variance of output and inflation when we simulate Version II of the model following a demand and supply shock, in the case where the optimizing consumers have finite horizons, and the special case[24] where the consumers have infinite horizons as the probability of death goes to zero. The demand (IS) and supply (NKPC) shocks are identical to the experiments performed with Version I.

Table 2: Finite Horizons and Fiscal Policy - the USA case

	Blanchard Consumers		Infinite Horizons	
Demand Shock	Output Var	Inflation Var	Output Var	Inflation Var
M	1.05	0.05	1.35	0.12
M+fiscal	0.54	0.04	1.23	0.11
Supply Shock				
M	1.39	0.25	1.43	0.27
M+fiscal	1.22	0.26	1.38	0.26

Note that the impact of introducing finite horizons is that fiscal policy becomes more powerful, as the variance of output is reduced considerably by adding fiscal policy (M+fiscal) to monetary policy alone (M). In all cases, the impact on the variability of inflation is small. The reduction in output volatility works through two channels: in terms of the first-period response of output to shocks it is less than with infinite horizons, as the feedback response of fiscal policy to output and the impact of fiscal and monetary policy on debt dynamics is factored into consumers' expectations. However, the cyclical impact of the monetary-fiscal interactions is more marked, and provokes a cyclical rather than a monotonic adjustment, potentially increasing the variability of output and inflation. The cyclicality is due to the dynamic interaction between Blanchard-type consumers' response to the debt dynamics in the model, and the ROT consumers who introduce inertia in consumer spending. Therefore potentially there is a trade-off from finite horizons, and this result may be dependent on the model's parameters. It would therefore be interesting to do some sensitivity analysis, by comparing the performance of fiscal policy in the USA with that in our model estimated and calibrated on Eurozone data, and to check to what extent the results are dependent on the

[24] This special case of Version II is essentially Version I without habit formation in consumption.

strength of fiscal policy's cyclical response and monetary policy's response to inflation. We now examine this issue.

4.2 Does Fiscal Policy Help to Stabilize Output and Inflation? The USA versus Europe

In order to address this question, we extend the results of Table 2 by comparing the cases of the USA and Europe. To limit the number of cases considered, we focus solely on supply shocks. We also consider the impact of varying the responses of fiscal and monetary policy. Again, Table 3 shows the variances of output and inflation when the model is simulated with only monetary policy active (M), and monetary plus fiscal policy (M+fiscal). In addition, however, we also show what happens if fiscal policy responds more powerfully over the cycle ($\delta_2 = \varphi_2 = 0.9$), designated by M+fiscal2, than in the baseline case; and we show what happens if monetary policy responds more powerfully to inflation ($\phi_4 = 2.4$), designated as M2+fiscal, than in the baseline case.

Table 3: Adding Value from Fiscal Policy - the USA vs Europe

	Blanchard Consumers		Infinite Horizons	
Eurozone	Output Var	Inflation Var	Output Var	Inflation Var
M	1.21	0.30	1.25	0.31
M+fiscal	1.06	0.32	1.18	0.30
M+fiscal2	1.02	0.33	1.16	0.31
M2+fiscal	1.15	0.29	1.22	0.29
USA				
M	1.39	0.25	1.43	0.27
M+fiscal	1.22	0.26	1.38	0.26
M+fiscal2	1.17	0.27	1.35	0.28
M2+fiscal	1.35	0.23	1.44	0.24

Note from Table 3 that, in the case of Europe (a) fiscal policy reduces output variability more than in the USA; and (b) the existence of Blanchard-type finite horizons enhances fiscal policy more than in the USA. In comparison, however, Europe exhibits a larger trade-off in terms of higher inflation variability. Note, however, that the impact on inflation volatility is much smaller than that of output volatility, so that fiscal policy is likely to be welfare-enhancing unless a much greater weight is placed on inflation stability[25].

The explanation for the greater impact of fiscal policy in Europe probably lies in three factors: the higher steady-state share of taxation, which strengthens the force of fiscal policy; the slightly higher average steady-state level of debt which increases the impact of wealth effects on consumption; and the higher share of ROT consumers as evidenced by the estimated structural parameters reported in Table 1.

It does suggest a greater advantage to using fiscal policy in Europe. However, we should recall that we are considering the artificial case of a coordinated fiscal policy across the Eurozone. A more pertinent question is whether in the actual case of a centralized European Central Bank monetary policy and a decentralized (and uncoordinated) fiscal policy across different Eurozone countries this apparent advantage to using fiscal policy countercyclically still holds. We now address this point using a two-country version of our model.

5 Fiscal Policy and EMU: a Two-Country Version of the Euro Model

Given the positive results obtained for the use of fiscal policy in the Version II model calibrated on Eurozone data, the natural question is whether one could find a role for fiscal policy in a two-country version of the model where shocks and fiscal responses are not perfectly symmetric, and where fiscal policy is delegated to national authorities but there is a single ECB. Analyzing monetary-fiscal policy interactions in two-country model would require a full paper in itself, and here we can only begin to highlight some of the issues that one might address. In a follow-up paper (Muscatelli *et al.*, 2005) we explore the issue more fully, using a richer open economy model[26].

In order to make our results comparable with those in the previous sections, we take the simplest possible case: we assume that the two countries

[25] Which is possible if the welfare criterion is mainly concerned with price distortions (see Woodford, 2003).

[26] Galì and Monacelli (2004) consider optimal fiscal policy in a small open economy, rather than the two-country open-economy version considered here. Government spending in their model enters the utility function of consumers.

are entirely symmetric in terms of structure, so that each has the same structural parameters as those estimated on Euro-wide data. The detailed model is outlined in the Appendix.

The model can be parameterized using the same structural parameter and steady state values as the single Euro-area model. The only caveat is that the assumed price elasticity of demand θ is quite large, as it is set at 4, and this implies a rather large relative demand effect within EMU. However, for most of the shocks considered here the movement in relative prices between countries is quite small, so the relative demand effect will not dominate the results.

The other point to note is that equilibrium in asset markets implies that the sum of domestic and foreign bonds held by consumers in both country equals the joint supply of bonds provided by each fiscal authority. In simulating the model one could focus on equilibria where, given the absence of default risk and exchange risk, the debt of each fiscal authority grows or declines over time. However, recall that the fiscal rules for each country not only a includes a feedback term on the output gap and an autoregressive parameter, but also has a feedback on deviations of debt from steady state (with feedback parameters $\delta_3 = \varphi_3 = 0.05$). This means that following the shock the model returns to a more realistic steady state, which embodies the type of constraint envisaged in the Maastricht criteria and the Stability and Growth Pact. Each country will seek to restore its initial level of debt. Given that our model is in deviations from equilibrium, this is equivalent to the fiscal authorities targeting a given level of the debt-income ratio.

5.1 Fiscal and Monetary Interactions in a Two-Country Model

In considering asymmetric shocks, we focus on demand and supply shocks on one of the two EMU countries. The reason for not considering pure asymmetric shocks (shocks of equal and opposite sign on each EMU country) is that, given the identical structure of the two countries, and that the ECB is assumed to target EMU average outcomes, monetary policy will not react to such shocks, and there will not be any fiscal-monetary policy interactions. Instead we focus on temporary shocks to the IS curve and Phillips curve of one of the two EMU countries, using the same format for the demand and supply shocks as we have used before.

Again we tabulate our results for the variance of output and inflation in each country when the fiscal rules are active and are absent in Table 4. Table 4 shows the case where only ECB policy is active (M) and the case where ECB policy and both countries fiscal policies are active (M+fiscal). In order to clarify the discussion, we normalize the variances of output and inflation relative to the case where monetary policy is operating alone (i.e. we normalize the first row of variances of each shock to unity). This shows the net impact of adding fiscal policy to a central monetary policy. In our discussion we shall focus mainly on output, as the impact of fiscal policies through demand on inflation are quite small given the coefficients on outputs and payroll taxes in the estimated Phillips curve, and any benefits from fiscal policy will accrue largely through output stabilization. This was also apparent from the earlier single-country simulations following a supply shock.

Table 4: Fiscal Conflict in Europe

	Country 1		Country 2	
Demand Shock	Output Var	Inflation Var	Output Var	Inflation Var
M	1	1	1	1
M+fiscal	0.83	0.99	1.01	1.01
Supply Shock				
M	1	1	1	1
M+fiscal	0.90	0.99	1.05	1.01

Turning first to the demand shock, we see that there is a reduction in output volatility, albeit a small one, in country 1. In the case of country 2 the initial impact of the fiscal policy is to cause a greater deviation in output from equilibrium, although the speed of convergence is slightly improved. The overall impact is to increase the variance of output slightly as can be seen from Table 4, with most of the variation coming in the first 2-3 quarters. The reasons why in a two-country setting the value added from fiscal policy is less than might be expected is that we are not considering a pure asymmetric shock, when the two countries' fiscal policies would be acting in concert and monetary policy remains inactive[27]. In the single country shock considered here, the monetary authority reacts to the demand shock by raising interest

[27] This is related to a point made by Uhlig (2002) who notes that in EMU the negative externalities of different fiscal authorities reacting to a symmetric shock runs through the central bank's reaction function. In our case it occurs even though the shock only occurs in a single country.

rates, thus causing output to fall in country 2. Thus, the two fiscal policies will be acting against each other in the short run. In addition, the presence of a feedback term on debt implies that the increase in interest rates will increase debt finance and will partially constrain fiscal policy in both countries. As noted by Leith and Wren-Lewis (2004), varying the feedback term on debt in the fiscal rule can have a significant impact on the output dynamics in a model with Blanchard-type consumers.

Turning to the supply shock, again we observe a reduction in variability in output in country 1, but in country 2 output variability increases, as the cost of adjustment is pushed from country 1 to country 2. Given that the fiscal rules in the two countries are symmetric and operate with some inertia, country 2 suffers again from the fact that the ECB reacts to future expected inflation increases, and forward-looking consumers take this into account. This externality from fiscal policy is partly a result of the formulation of the fiscal rules, and in Muscatelli et al. (2005) we investigate the robustness of this conflict in greater detail. In general we find that some aspects of the fiscal conflict are robust to different specifications, including a more contemporaneous correlation between automatic stabilizers and output.

6 Conclusions

In this review we have provided a preliminary assessment of the extent to which fiscal policy provides a valuable tool for stabilization alongside monetary policy in the context of New Keynesian models.

What have we learned? There are three main themes that emerge. The first is that, once one allows for substantial deviations from the assumption that consumers are fully optimizing and have infinite horizons, there is considerable scope for fiscal policy to reduce output volatility, although in some contexts this might be at no improvement in terms of reducing inflation volatility, or may result in trading off lower output volatility against higher inflation volatility.

The second theme is that estimated New Keynesian models still involve limited channels for fiscal-monetary policy interactions. Our model allow for a richer range than some recent New Keynesian models, but in other respects are still limited: for instance in the range of taxation distortions on the supply side, which may be significant in reducing the efficiency of fiscal policy. Allowing an impact of public expenditure on private consumption and investment may change the results in either direction. The efficiency of fiscal policy will also be reduced by the extent to which the fiscal policy instruments are subject to stochastic deviations which are proportional to the strength of the fiscal stabilizers. Finally, as with most estimated New Keynesian models, our models are limited in the range of parameters that can be freely estimated. The development of new estimation techniques in this area may improve the robustness of our estimates.

The third main theme is that in two-country models it becomes apparent that automatic stabilizers may, in certain circumstances, offset each other in ways that may limit the effectiveness of fiscal policy. In general the focus has been on the ability of fiscal stabilizers to cope with the case of a pure asymmetric shock, where externalities still exist, but where providing fiscal policy reactions are sufficiently aggressive, output can be stabilized. What we focus on here is the interactions between fiscal and monetary policy where there is an asymmetric shock which impacts differentially on the two countries and therefore triggers as response from the ECB. We demonstrate that this might hamper the efficacy of fiscal policy. In these cases, the precise design of the feedback rules and the automatic stabilizers becomes important and this should be the subject of further research (see Muscatelli et al., 2005). In particular, looking at optimally designed simple rules should improve the performance of fiscal policy against the benchmarks analyzed here.

To sum up, New Keynesian models have evolved to the point where a role can be found for fiscal policy, and empirically estimated models suggest that such policies could be welfare enhancing. But there is no unambiguous endorsement of some of the more optimistic Keynesian pronouncements of the 1960s and early 1970s, which saw fiscal policy as a necessary tool of stabilization policy even for relatively small deviations from the full employment/natural rate equilibrium. In this sense there is no return to the

Keynesian economics of the early post-war era.

7 Figures

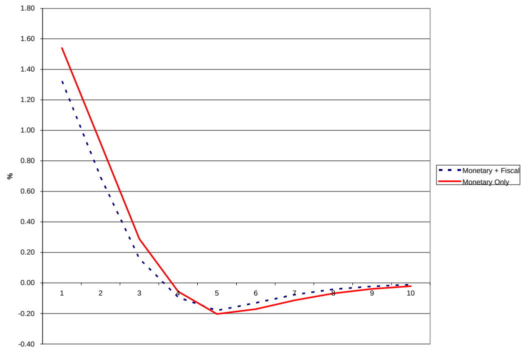

Figure 1 - Output response to Demand Shock

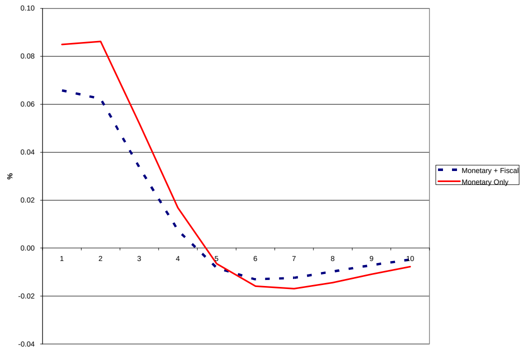

Figure 2 - Inflation response to Demand Shock

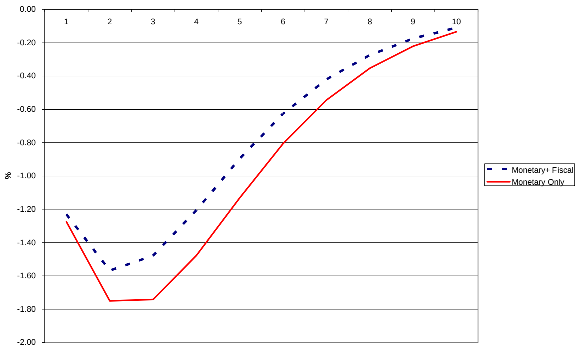

Figure 3: Output Response to Supply Shock

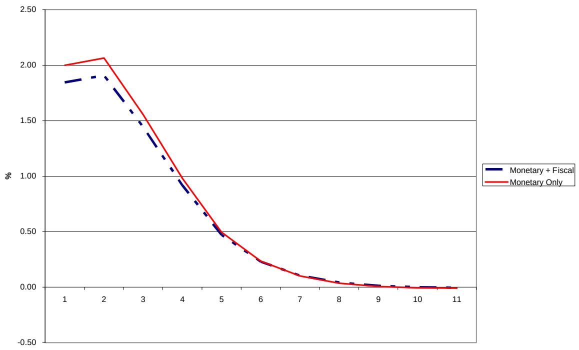

Figure 4: Inflation Response to Supply Shock

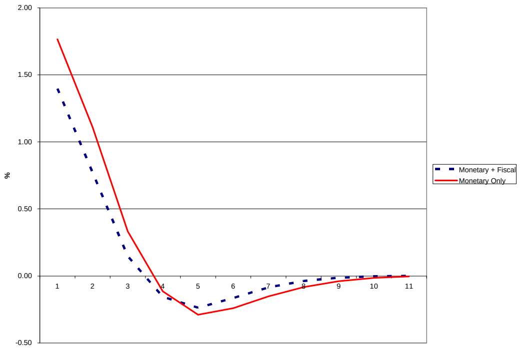

Figure 5: Output Response to Demand Shock - High ROT

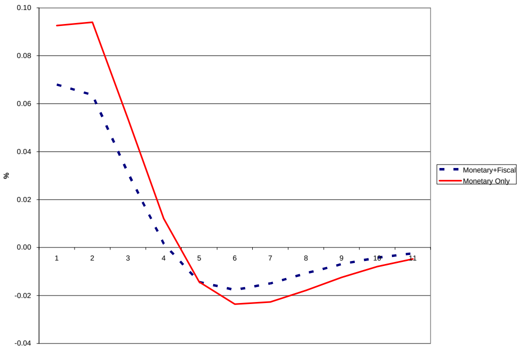

Figure 6: Inflation Response to Demand Shock - High ROT

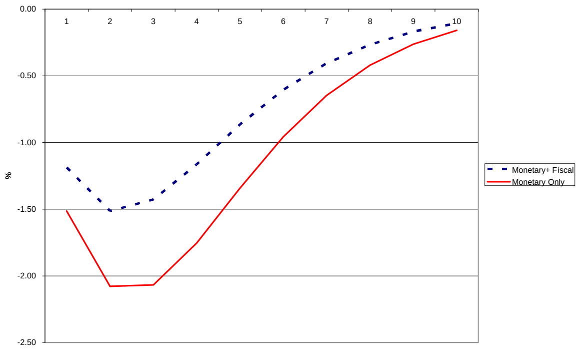

Figure 7: Output Response to Supply Shock - High ROT

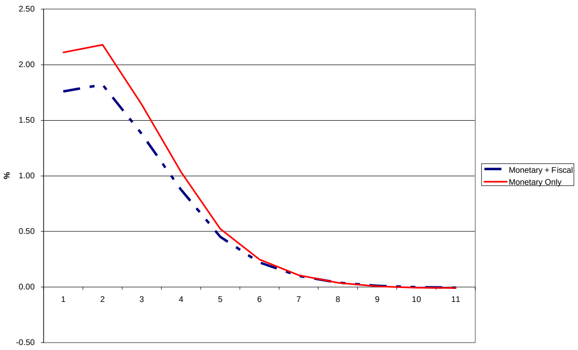

Figure 8: Inflation Response to Supply Shock - High ROT

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9 Appendix: The Models

9.1 One-Country model

9.1.1 Version I

Consumers As noted above, in this version of the model we follow Galí *et al.* (2002) by assuming two types of consumers, although we also assume that the optimizing consumers' utility is affected by habit. A proportion ϑ of consumers follow a rule of thumb, and consume out of current disposable income. This admittedly ad hoc assumption may be justified by assuming myopia or limited participation to capital markets. We also assume that rule-of-thumb consumers supply a fixed amount of labour. Thus the consumption function of the representative rule-of-thumb consumer, j, depends on current disposable income:

$$P_t C_t^{RTj} = \bar{N}^{RT} W_t + P_t \left(G_t^{TRj} - T_t^j \right) \tag{5}$$

where P_t is the consumption price level, $\bar{N}^{RT}$ defines a constant amount of labour supply[28], W_t is the nominal wage, $G_t^{TRj} - T_t^j$ defines net taxes (transfers, G_t^{TRj}, minus taxes, T_t^j) lump-sum by assumption.

Consumers in the second group, i, benefit from full access to capital markets and are therefore free to optimize. The proportion of optimizing consumers in the economy is given as $(1-\vartheta)$. Each optimizing consumer is assumed to maximize an intertemporal utility function given by:

$$E_t \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\rho} (C_t^{oi}/H_t^i)^{1-\rho} - \frac{\varepsilon^l}{1+\varphi} (N_t^{oi})^{1+\varphi} \right) \tag{6}$$

where C_t^o represents consumption of a basket of goods (to be defined below), H_t is an index of external habits, ρ is the coefficient of relative risk aversion, N_t^o is the level of employment, and ε^l is a shock to labour supply. As in Smets and Wouters (2002), money does not appear in the

[28] Galì et al. (2003) show that supplying a constant amount of labour is optimal when consumption and leisure are non-separable in the utility function and net taxes, levied on rule-of-thumb consumers are always nil. This result would never obtain in our model, where taxes and transfers are explicitly modeled. For sake of simplicity we assume a constant labour supply. Since consumption cannot be negative, this implies that we impose a lower bound on $\left(G_t^{TR} - T_t\right)$ for any given level of the real wage.

utility function(6), nor is part of financial wealth[29].We assume that habits depend on past aggregate consumption, C^T:

$$H_t^i = \left(C_{t-1}^T\right)^\lambda \tag{7}$$

Optimizing consumers maximize (6) subject to their intertemporal budget constraint, which is expressed as:

$$\frac{B_t^{oi}}{(1+r_t)} \leq B_{t-1}^{oi} + D_t^i + \frac{W_t}{P_t} N_t^{oi} - C_t^{oi} + \left(G_t^{TRi} - T_t^i\right) \tag{8}$$

where consumers hold their financial wealth in the form of inflation-indexed bonds, B, which yield a real return of r_t. The optimizing consumer's disposable income consists of real labour income $\frac{W_t}{P_t} N_t^{oi}$ plus the real dividends from the profits of the imperfectly competitive firms, D_t^i, plus real public transfers G_t^{TRi} minus real personal taxes T_t^i.

Firms Firms' production technology is assumed to be a simple Cobb-Douglas function of labour and capital for each consumption good variety z. Capital is assumed fixed and normalized to unity:

$$Y_t(z) = A(N_t(z))^{1-\alpha} \tag{9}$$

We introduce fiscal distortions by assuming that taxes on labour take the form of a uniform payroll tax[30]. Therefore firms' demand for labour is defined as:

$$(1-\alpha)\, A(N_t(z))^{-\alpha} = \frac{W}{P} + t^* \tag{10}$$

where t^* is the tax rate per unit of employed labour, i.e. $t^* = \frac{T^*}{N}$, where $T^*$are the total revenues from the payroll tax.

Turning next to the model of firms' pricing behavior, we consider a standard model of monopolistic competition with sticky prices, as set out in Galí *et al.* (2001), and Leith and Malley (2002)[31]. Total consumption is given by a

[29] As in Woodford (2003), the economy is assumed to be 'cashless' in the limit at the steady-state equilibrium.

[30] This implies that the optimizing consumer's choice between leisure and consumption is not affected.

[31] See also Erceg *et al.* (2000), and Sbordone (2002).

standard CES function of imperfectly substitutable varieties of consumption goods z:

$$C_t^i = \left[\int_0^1 \left(C_t^i(z) \right)^{\frac{\theta}{\theta-1}} dz \right]^{\frac{\theta}{\theta-1}} \tag{11}$$

Given this, consumption of each variety of the consumption good is given by:

$$C_t^i(z) = \left[\frac{P_t(z)}{P} \right]^{-\theta} C_t^i \tag{12}$$

where $P_t(z)$ is the price of good z, and P_t is the consumption price index given by the aggregator:

$$P_t = \left[\int_0^1 \left(P_t(z) \right)^{1-\theta} dz \right]^{\frac{1}{1-\theta}} \tag{13}$$

Sticky prices in the model are modeled as described in the main text.

9.1.2 Version II

Consumers In this second version of the model all individuals do not expect to live forever and face a constant probability of death in each period, ϖ. However, as before there are two types of consumers. A proportion ϑ of consumers follow a rule of thumb, as in (5).

The optimizing consumers, making up a proportion $(1 - \vartheta)$, now behave differently because of the presence of a finite horizon. Each optimizing consumer i in cohort s, is assumed to maximize an intertemporal utility function given by:

$$E_t \sum_{t=0}^{\infty} \beta^t (1 - \varpi)^t \left\{ \frac{1}{1-\rho} C_{s,t}^{oi} - \frac{\varepsilon^l}{1+\varphi} \left(N_{s,t}^{oi} \right)^{(1+\varphi)} \right\} \tag{14}$$

where the notation is the same as above.

The optimizing consumers intertemporal budget constraint, is now expressed as:

$$\frac{B_{s,t}^{oi}}{(1+r_t)} \leq (1-\varpi)^{-1} B_{s,t-1}^{oi} + D_{s,t}^{oi} + \frac{W_t}{P_t} N_{s,t}^{oi} - C_{s,t}^{oi} + \left(G_t^{TRi} - T_t^i\right) \qquad (15)$$

where again the notation is as before. Again, we assume that government debt is indexed. For an comparison of cases where government debt are indexed and non-indexed in a model with Blanchard-type consumers, see Leith and Wren-Lewis (2004).

In this version of the model we assume the same behavior on the part of firms as in Version I.

9.1.3 Estimation Models

By log-linearizing the model around steady state we are then able to derive the New Keynesian 'IS-curve' and 'Phillips curve' (for proofs, see Muscatelli et al., 2003a,b, Leith and Malley, 2002, Galí *et al.*, 2001).

The IS curves under Versions I and II are given by:

Version I:

$$\widehat{y}_t = \begin{array}{c} a_1 a_2 \left[a_3 E_t \{\Delta \widehat{n}_{t+1}\} + a_4 \Delta \widehat{t}^*_{t+1}\right] - a_1 a_5 E_t \left\{\Delta \left(\widehat{G^{TR}_{t+1} - T_{t+1}}\right)\right\} + \\ + a_1 a_6 \frac{\overline{G}}{\overline{Y}} \widehat{g}_t + a_1 a_7 \left[\widehat{y}_{t-1} - \frac{\overline{G}}{\overline{Y}} \left(\widehat{g}_{t-1}\right)\right] - a_1 \left(\frac{\overline{C^o}}{\overline{C}}\right) \left(\frac{\overline{C}}{\overline{Y}} \frac{1}{\rho}\right) \widehat{r}_t + a_1 \widehat{y}_{t+1} - a_1 \frac{\overline{G}}{\overline{Y}} \widehat{g}_{t+1} \end{array} \qquad (16)$$

where: $a_1 = \left[1 - \left(\frac{\overline{C^o}}{\overline{C}}\right)\left(\frac{1-\rho}{\rho}\right)\lambda\right]^{-1}$; $a_2 = \frac{\overline{N^{RT}}}{\overline{N}} \frac{\overline{N\left(\frac{W}{P}\right)}}{\overline{Y}}$;

$a_3 = \left[\alpha - \frac{\overline{T^*}}{\overline{N}\left(\frac{\overline{W}}{\overline{P}} + \frac{\overline{T^*}}{\overline{N}}\right)}\right] \frac{\left(\frac{\overline{W}}{\overline{P}} + \frac{\overline{T^*}}{\overline{N}}\right)}{\left(\frac{\overline{W}}{\overline{P}}\right)}$; $a_4 = \frac{\overline{T^*}}{\overline{N\left(\frac{W}{P}\right)}}$;$a_5 = \vartheta\left(\frac{\overline{G^{TR} - T}}{\overline{Y}}\right)$;

$a_6 = \left[1 + \left(\frac{\overline{C^o}}{\overline{C}}\right)\left(\frac{\rho-1}{\rho}\right)\lambda\right]$; $a_7 = \left(\frac{\overline{C^o}}{\overline{C}}\right)\left(\frac{\rho-1}{\rho}\right)\lambda$;

$\frac{\overline{C^o}}{\overline{C}} = 1 - \left(1 - \frac{\overline{G}}{\overline{Y}}\right)^{-1} \left[\frac{\overline{N^{RT}}}{\overline{N}} \frac{\overline{N\left(\frac{W}{P}\right)}}{\overline{Y}} + \frac{\vartheta\left(\overline{G^{TR} - T}\right)}{\overline{Y}}\right]$

where $\widehat{g}_t$ is government spending excluding government transfers $\widehat{G^{TR}}$.

Version II:

$$\widehat{y}_t = \begin{array}{c} a_1 \left[a_2 E_t \{\Delta \widehat{n}_{t+1}\} + a_3 \Delta \widehat{t}^*_{t+1}\right] - a_4 E_t \left\{\Delta \left(\widehat{G^{TR}_{t+1} - T_{t+1}}\right)\right\} + \\ + \left(\frac{\overline{C^o}}{\overline{C}}\right) \left[a_6 \widehat{b}_t - \left(\frac{\overline{C}}{\overline{Y}} \frac{1}{\rho}\right) \widehat{r}_t\right] + \widehat{y}_{t+1} - \frac{\overline{G}}{\overline{Y}} \Delta \widehat{g}_{t+1} \end{array} \qquad (17)$$

where: $a_1 = \frac{\overline{N^{RT}}}{\overline{N}} \frac{\overline{N\left(\frac{W}{P}\right)}}{\overline{Y}}$;

$a_2 = \left[\alpha - \frac{\overline{T^*}}{\overline{N}\left(\frac{\overline{W}}{\overline{P}}+\frac{\overline{T^*}}{\overline{N}}\right)}\right] \frac{\left(\frac{\overline{W}}{\overline{P}}+\frac{\overline{T^*}}{\overline{N}}\right)}{\left(\frac{\overline{W}}{\overline{P}}\right)}$; $a_3 = \frac{\overline{T^*}}{N\left(\frac{\overline{W}}{\overline{P}}\right)}$;$a_4 = \vartheta\left(\frac{\overline{G^{TR}-T}}{\overline{Y}}\right)$; $a_6 = \frac{\overline{B}}{\overline{Y}} \frac{\varpi[1-\beta(1-\varpi)]}{(1-\varpi)}$;

$\frac{\overline{C^o}}{\overline{C}} = 1 - \left(1 - \frac{\overline{G}}{\overline{Y}}\right)^{-1} \left[\frac{\overline{N^{RT}}}{\overline{N}} \frac{\overline{N\left(\frac{W}{P}\right)}}{\overline{Y}} + \frac{\vartheta\left(\overline{G^{TR}-T}\right)}{\overline{Y}}\right]$

The Phillips Curve is given by:

$$\widehat{\pi}_t = \frac{\gamma\widehat{\pi}_{t-1} + \beta\xi E_t\widehat{\pi}_{t+1}}{\xi + \gamma(1 - \xi(1 - \beta))} + \frac{(1-\gamma)(1-\xi)(1-\gamma\xi)}{[\xi + \gamma(1 - \xi(1-\beta))][1 + (\alpha/(1-\alpha))\theta]}\widehat{s}_t \quad (18)$$

where $\widehat{s}_t$ is the percentage change from steady state of the labour cost share, which is given[32] by $\widehat{s}_t = \frac{\overline{N\left(\frac{W}{P}\right)}}{\overline{N\left(\frac{W}{P}\right)+T^*}} \left(\widehat{w-p}\right) + \frac{\overline{T^*}}{\overline{N\left(\frac{W}{P}\right)+T^*}} \left(\widehat{t^*} - \widehat{n}\right) + \widehat{n}_t - \widehat{y}_t$

The IS curve and Phillips curve constitute our structural model, which is then simulated jointly with the policy rules, the government budget constraint, and with the assumptions made about nominal wage adjustment.

9.2 A Two-country New Keynesian Model

We now extend the model to account for open economy features, assuming that two countries (Domestic, d, and Foreign, f) form a monetary union. Total consumption is still defined as in (11), but only a proportion n^* of them is produced in the Home economy. Domestic consumers can now hold their wealth in domestic (B^d) or foreign (B^f) bonds, denominated in the same currency, and earning the same nominal return, i_t. The Home price index is therefore defined as:

$$P_D = \left[\int_0^{n^*} \left(P_t^d(z)\right)^{1-\theta} dz + \int_{n^*}^{1} \left(\overline{e}P_t^f(z)\right)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \quad (19)$$

[32] Galí *et al.* (2001) specify (18) in terms of average real marginal cost (mc). Note that, in levels:

$$s_t = \frac{(1-\alpha)}{mc_t}$$

where $P_t^f(z)$ defines the foreign currency price of good (z) and $\overline{e}$ is the fixed nominal exchange rate, normalized at 1[33]. Home consumer's demand for product z is defined as:

$$C_t^{i,j,d}(z) = \left[\frac{P_t^d(z)}{P_{D,t}}\right]^{-\theta} C_t^{i,j,d} \tag{20}$$

Correspondingly, for the foreign consumer

$$C_t^{i,j,f}(z) = \left[\frac{P_t^f(z)}{P_{F,t}}\right]^{-\theta} C_t^{i,j,f} \tag{21}$$

As in Leith and Wren Lewis (2004) we assume that PPP holds for the aggregate price level, and therefore world demand for product z is given by:

$$y(z)_t = \left[\frac{P_t(z)}{P_t}\right]^{-\theta} \left(C_t^d + G_t^d + C_t^f + G_t^f\right)$$

The log-linearised two-country model is then given by:

$$\widehat{y}_t^d = \begin{array}{c} \frac{a_1}{2}\left\{a_2\left[E_t\left\{\Delta\widehat{n}_{t+1}^d\right\} + E_t\left\{\Delta\widehat{n}_{t+1}^f\right\}\right] + a_3\left[\Delta\widehat{t}_{t+1}^{d,*} + \left(\Delta\widehat{t}_{t+1}^{f,*}\right)\right]\right\} \\ -\frac{a_4}{2}\left[E_t\left\{\Delta\left(\widehat{G_{t+1}^{d,TR} - T_{t+1}^d}\right)\right\} + E_t\left\{\Delta\left(\widehat{G_{t+1}^{f,TR} - T_{t+1}^f}\right)\right\}\right] + \\ +\left(\frac{\overline{C^o}}{\overline{C}}\right)\left\{\frac{a_6}{2}\left[\widehat{b}_t^d + \widehat{b}_t^f\right] - \left(\frac{\overline{C}}{\overline{Y}}\frac{1}{\rho}\right)\widehat{r}_t\right\} + \widehat{y}_{t+1}^d \\ -\frac{\overline{G}}{2\overline{Y}}\Delta\widehat{g^d}_{t+1} - \theta\left\{\left[\widehat{p}_t^d - \widehat{p}_t^f\right] - \left[E_t\left\{\widehat{p}_{t+1}^d\right\} - E_t\left\{\widehat{p}_{t+1}^f\right\}\right]\right\} \end{array} \tag{22}$$

$$\widehat{y}_t^f = \begin{array}{c} \frac{a_1}{2}\left\{a_2\left[E_t\left\{\Delta\widehat{n^d}_{t+1}\right\} + E_t\left\{\Delta\widehat{n}_{t+1}^f\right\}\right] + a_3\left[\Delta\widehat{t}_{t+1}^{d,*} + \left(\Delta\widehat{t}_{t+1}^{f,*}\right)\right]\right\} \\ -\frac{a_4}{2}\left[E_t\left\{\Delta\left(\widehat{G_{t+1}^{d,TR} - T_{t+1}^d}\right)\right\} + E_t\left\{\Delta\left(\widehat{G_{t+1}^{f,TR} - T_{t+1}^f}\right)\right\}\right] + \\ +\left(\frac{\overline{C^o}}{\overline{C}}\right)\left\{\frac{a_6}{2}\left[\widehat{b}_t^d + \widehat{b}_t^f\right] - \left(\frac{\overline{C}}{\overline{Y}}\frac{1}{\rho}\right)\widehat{r}_t\right\} + \widehat{y^f}_{t+1} \\ -\frac{\overline{G}}{2\overline{Y}}\Delta\widehat{g^f}_{t+1} + \theta\left\{\left[\widehat{p}_t^d - \widehat{p}_t^f\right] - \left[E_t\left\{\widehat{p}_{t+1}^d\right\} - E_t\left\{\widehat{p}_{t+1}^f\right\}\right]\right\} \end{array} \tag{23}$$

$$\widehat{\pi^d}_t = \frac{\gamma\widehat{\pi}_{t-1}^d + \beta\xi E_t\widehat{\pi}_{t+1}^d}{\xi + \gamma(1-\xi(1-\beta))} + \frac{(1-\gamma)(1-\xi)(1-\gamma\xi)}{[\xi + \gamma(1-\xi(1-\beta))][1+(\alpha/(1-\alpha))\theta]}\widehat{s}_t^d \tag{24}$$

[33]Under this assumption $P_d = P_f$.

$$\widehat{\pi}_t^f = \frac{\gamma\widehat{\pi}_{t-1}^f + \beta\xi E_t\widehat{\pi}_{t+1}^f}{\xi + \gamma(1-\xi(1-\beta))} + \frac{(1-\gamma)(1-\xi)(1-\gamma\xi)}{[\xi + \gamma(1-\xi(1-\beta))][1+(\alpha/(1-\alpha))\theta]}\widehat{s}_t^f \quad (25)$$

$$\widehat{s}_t^d = \overline{\frac{N\left(\frac{W}{\overline{P}}\right)}{\overline{\overline{N\left(\frac{W}{P}\right)}+\overline{T^*}}}}\left(\widehat{w}_t{}^d - \widehat{p}^d\right) + \frac{\overline{T^*}}{\overline{N\left(\frac{W}{P}\right)}+\overline{T^*}}\left(\widehat{t^*}^d - \widehat{n}^d\right) + \widehat{n}_t^d - \widehat{y}_t^d \quad (26)$$

$$\widehat{s}_t^f = \overline{\frac{N\left(\frac{W}{\overline{P}}\right)}{\overline{\overline{N\left(\frac{W}{P}\right)}+\overline{T^*}}}}\left(\widehat{w}_t{}^f - \widehat{p}^f\right) + \frac{\overline{T^*}}{\overline{N\left(\frac{W}{P}\right)}+\overline{T^*}}\left(\widehat{t^*}^f - \widehat{n}^f\right) + \widehat{n}_t^f - \widehat{y}_t^f \quad (27)$$

$$\widehat{b_t}^d = (1+\overline{r})\,\widehat{b_{t-1}}^d + \overline{r}\widehat{r}_t + \overline{\left(\frac{G^{TR}}{B}\right)}\widehat{g_t^{d,TR}} + \overline{\left(\frac{G}{B}\right)}\widehat{g}_t{}^d - \overline{\left(\frac{T^*}{B}\right)}\widehat{t_t^*}^d - \overline{\left(\frac{T}{B}\right)}\widehat{t_t}^d \quad (28)$$

$$\widehat{b_t}^f = (1+\overline{r})\,\widehat{b_{t-1}}^f + \overline{r}\widehat{r}_t + \overline{\left(\frac{G^{TR}}{B}\right)}\widehat{g_t^{f,TR}} + \overline{\left(\frac{G}{B}\right)}\widehat{g}_t{}^f - \overline{\left(\frac{T^*}{B}\right)}\widehat{t_t^*}^f - \overline{\left(\frac{T}{B}\right)}\widehat{t_t}^f \quad (29)$$