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Strategic Monetary and Fiscal Policy Interactions: An Empirical Investigation *

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Abstract

This paper identifies leadership regime in monetary-fiscal policy interactions in the three countries, UK, US and Sweden. We specify a small-scale, structural general equilibrium model of an open economy and estimate it using Bayesian methods. We assume that the authorities can act strategically in non-cooperative policy game and compare three different leadership regimes. We find that the model of fiscal leadership gives the best fit for the UK and Sweden, while in the US the Nash or non-strategic regime dominates.

Key Words: Monetary and Fiscal Policy, Leadership, Macroeconomic Stabilisation, Bayesian Estimation

JEL Reference Number: E52, E61, E63

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1 Introduction

There is a renewed interest in the role of fiscal policy for a short-run macroeconomic stabilisation, especially with the onset of European Monetary Union. Many policy-oriented studies, for example HM Treasury (2003), Westaway (2003) and, consequently, Woods (2005) discuss the importance and possibility of fiscal stabilisation in the UK, and the need for institutional changes.

In order to assess the (potential) importance of fiscal stabilisation and to provide a guidance for a design of more flexible fiscal policy, most of the research is done using calibrated models. A growing body of literature now provides a theoretical framework to analyse joint stabilisation problems; see Benigno and Woodford (2004), Dixit and Lambertini (2003) and Beetsma and Jensen (2004a,b) amongst many others. Most of the theoretical literature studies the question in an optimising framework, typically in a *cooperative* setup with well defined social objectives. The assumption of complete cooperation, however, is not always realistic as the authorities are not likely to cooperate on all targets; for example, fiscal policy might be concerned with debt stabilisation, unlike monetary policy. The monetary authority might be more inflation-conservative than the fiscal authority and the society.

The existing research that uses non-cooperative models suggests that making fiscal policy flexible can be very costly. Fiscal targets, if they are different from monetary targets, can lead to a 'fight' between monetary and fiscal authorities, and the result of this fight very much depends on the leadership structure of the game between the two authorities. For example, the Nash game results in a particularly bad outcome if the central bank is made inflation-conservative (Dixit and Lambertini (2003)) of if there is an excessive weight on output stabilisation in fiscal objectives (Kirsanova et al. (2005)). In the latter case, however, the regime of fiscal leadership delivers good results. Generally speaking, the fight can be avoided or mitigated by an appropriate choice of targets for the authorities, but welfare implications can still be very different for different leadership regimes.

What policy implications should we draw from these and similar theoretical results? What would be a good design for a flexible fiscal policy? If we make it flexible, shall we still introduce the debt or deficit target for fiscal authorities or can we make it more concerned with output stabilisation than the society? It is difficult to answer these and similar questions without knowing the way the authorities *actually* interact with each other. For example, if the UK and the US operate under different leadership regimes and both countries want more of fiscal flexibility then a fiscal policy design for the UK may not be good for the US and vice versa. The theoretical analysis gives us a menu of policy options, but an empirical analysis should make some of these options more preferable or just rule out some of them as not feasible.

There is little doubt that the authorities *can* act strategically: an existing empirical literature on monetary-fiscal interactions suggests that fiscal policy does more than simply allows automatic stabilisers to operate, see e.g. Taylor (2000), Auerbach (2002) and Favero and Monacelli (2005) on fiscal policy in the US. However, the empirical literature does not seem to be linked well to theoretical models: most of empirical models of monetary-fiscal interactions use a rule-based approach without any clear link to policy objectives. We are unaware of any empirical research that would investigate the degree of cooperation of the two authorities and would identifythe structure of the game.

The main aim of this paper is to provide an empirical account of monetary and fiscal interactions in European countries, taking into account potential strategic interplay.[1] In particular, we investigate the conduct of monetary and fiscal policy in the UK and Sweden. Both these countries retained an independent monetary policy over the last decade, and had relatively stable inflation targets in the post-ERM period. A stability of policy objectives is important if we are to analyse potential interactions between the two authorities. The post-ERM period is relatively short for empirical analysis, however. In order to control for possible misspecifications on this ground, and also to study a potentially different regime, we also investigate joint stabilisation in the US, for which we have longer data series, and for which macroeconomic policy is more extensively studied in the literature. We aim to identify the leadership regime in the three countries.

In order to study monetary and fiscal interactions we use a simple theoretical model of an open economy based on the New Open Economy Macroeconomics. We solve the model assuming that policymakers act non-cooperatively, potentially have different policy objectives and they act under discretion. The optimal policy reaction functions can be presented in the form of feedback rules, and different assumptions about the leadership regime leads to different empirical *specifications* of policy reaction rules. Estimation of these policy reaction functions and a consequent analysis of the information structure and policy objectives is the main focus of this paper.

Rather than estimating policy reactions in an univariate setting we estimate the entire structural model using Bayesian methods. In this we follow Lubik and Schorfheide (2006), who demonstrate how the Bayesian analysis can be used in a similar problem. They demonstrate that even with a minimalist version of an economic model, the Bayesian estimation technique allows us to detect key differences in policy reactions.[2] Essentially, a simple model serves as a data generating process to provide identification restrictions for the estimation of policy rules.

Our choice of model is based on this understanding. Lubik and Schorfheide (2006) provide the methodological framework which we follow closely. We ignore the possibility of estimating a detailed model, but focus on estimation of policy reaction functions.[3] Similar to Lubik and Schorfheide (2006), our model is a stripped down version of Gali and Monacelli (2005, 2004) model.[4] We estimate a strictly

[1] We do not study whether there is a regime of monetary of fiscal dominance in the sense of Sargent and Wallace (1981). Neither of the authorities is able to precommit to future paths of either money growth or fiscal deficits. The joint dynamics of inflation and output is a result of monetary-fiscal *policy mix*.

[2] Lubik and Schorfheide (2006) study exchange rate targeting by monetary policy. Among the countries of interest, the UK had a long period of fixed exchange rate regime, while Australia did not. This difference in policy objectives was unambiguously picked up by the approach: UK was found to be an 'exchange rate targeter', while Australia was not.

[3] Although a more detailed specification of the model would be of independent interest in getting estimates of structural parameters, such a model (as for example Smets and Wouters (2003)), would make achieving our goal of learning about policymakers' priorities very difficult.

[4] We added a government solvency constraint into the system. We shall argue that this is a necessary element of any

theoretical model as this allows us to formulate hypotheses to test the leadership regime. Simulations of such a simple theoretical model also provide us a lot of guidance in setting priors.

We do not expect to demonstrate big differences in the conduct of macroeconomic policies across our countries. The UK and Sweden are two similar European countries, and both adopted an inflation targeting regime after the collapse of the ERM. We also have a prior about the form of leadership regime. Many would agree that regime of fiscal leadership can be an adequate description of the situation in any developed country which retains its independent monetary policy, see Hughes Hallett (2005). Indeed, fiscal decisions are taken at much lower frequency than monetary policy decisions, they are extensively discussed before they are actually implemented. In the UK a representative of HM Treasury informs the MPC members about fiscal policy and participates in their meetings.[5] Sweden has very similar institutional arrangements, see Heikensten and Vredin (2002) and Leeper (2003). In the US, however, the process of monetary policymaking is less transparent and the Fed might pay less attention to fiscal stance when making decisions: the Nash equilibrium or a non-strategic play are conceivable options. Monetary leadership regime, perhaps, should be disregarded as implausible for all three countries because of institutional restrictions. Our analysis, however, does not allow us to distinguish between the Nash regime and non-strategic behaviour of the fiscal authorities.

Our findings suggest that in the UK and Sweden the regime of fiscal leadership fits the data best: the likelihood of that the data were generated under a Nash regime (or under monetary leadership) versus fiscal leadership regime is less than 0.005. In the US, however, we find that the Nash (or non-strategic fiscal) regime dominates the fiscal leadership regime: the odds in favor of the fiscal leadership regime versus the Nash (or non-strategic fiscal) regime are 0.08.

The paper is organised as follows. Section 2 describes the model. We first describe the theoretical specification of the model and the microfounded welfare metric, and then discuss modifications that are needed for an empirical analysis. In Section 3 we discuss our econometric methodology. Section 4 discusses the empirical results and tests the leadership hypotheses. We start the analysis assuming the regime of fiscal leadership for all three countries. This implies that the main object of our study becomes the monetary policy reaction function. Essentially, we test the hypothesis that the monetary policymaker, when makes decisions, takes into account the fiscal stance. We also check if we are able to reject alternative specifications of the model, those which describe either Nash or monetary leadership regimes. Section 5 concludes.

model that aims to explain fiscal policy reactions.

[5] Generally, the *Inflation Report* clearly links contemporary fiscal developments in the economy to inflation peformance in the future, *provided that interest rate stays unchanged.* See Bank of England (2003) for example.

2 A Simple Model

2.1 Evolution of Economy

Our model is a version of Gali and Monacelli (2005, 2004), to which we refer for details on the derivation of the reduced form equations. The model leads to a two-equation system that describes evolution of out of the steady state economy, a system of an open economy IS curve and a Phillips curve. We also add a government solvency constraint, as in Kirsanova et al. (2007). Specifically, the evolution of the economy is determined by the following equations.

The household is infinitely lived and maximises utility

$$W = \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} + \chi \frac{G_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \tag{1}$$

subject to intertemporal budget constraint. C is private consumption, G is government spending and N is labour supplied. After the linearisation of first order conditions and substituting consumption out using the national income identity and the risk sharing condition, Gali and Monacelli (2005, 2004) obtain an open economy IS curve:

$$\tilde{y}_t = \mathcal{E}_t \tilde{y}_{t+1} - \frac{1}{\sigma_\alpha} \left(\tilde{r}_t - \mathcal{E}_t \tilde{\pi}_{Ht+1} \right) - \mathcal{E}_t \tilde{g}_{t+1} + \tilde{g}_t - \frac{(1+\varphi)(1-\rho_a)}{\sigma_\alpha + \varphi} \tilde{a}_t - \frac{\alpha\varphi(\omega - 1)}{\sigma_\alpha + \varphi} \left(1 - \rho_{y^*}\right) \tilde{y}_t^* . \tag{2}$$

Endogenous variables are aggregate output $\tilde{y}_t = \ln(Y_t)$, government spending $\tilde{g}_t = -\ln(1 - G_t/Y_t)$, nominal interest rate $\tilde{r}_t = \ln(R_t)$ and *domestic* inflation $\tilde{\pi}_{Ht} = \ln\left(P_{Ht}/P_{Ht-1}\right)$. All structural parameters are defined in Appendix. Import component of CPI inflation was substituted out using the risk sharing condition.[6] $\tilde{y}_t^*$ is exogenous world output and $a_t = \log A_t$ is a technology shock that follows an AR(1) process.

Optimal price setting of domestic firms results in the following open economy Phillips curve:

$$\tilde{\pi}_{Ht} = \beta \mathcal{E}_t \tilde{\pi}_{Ht+1} + \lambda \left((\sigma_\alpha + \varphi) \left(\tilde{y}_t - \tilde{y}_t^n \right) - \sigma_\alpha \tilde{g}_t \right) + \varepsilon_t^\pi \tag{3}$$

where $\tilde{y}_t^n = \frac{(1+\varphi)}{(\sigma_\alpha+\varphi)} \tilde{a}_t - \frac{(\sigma-\sigma_\alpha)}{(\sigma_\alpha+\varphi)} \tilde{y}_t^*$ is potential output in the absence of nominal rigidities and distortionary cost push shocks. The slope coefficient λ is a function of household discount rate and of the length of fixed price contracts. Different from Gali and Monacelli (2005) model, we introduce a cost push shock ε_t^π, which can appear in the system because of variable mark up, see e.g. Beetsma and Jensen (2004a). (An also includes all other disturbances to marginal costs that are not captured by our model.) We add the government solvency constraint that can be written as:

$$\tilde{b}_t = \tilde{r}_t + \frac{1}{\beta} \left(\tilde{b}_t - \tilde{\pi}_{H,t} + \frac{C}{B} \tilde{g}_t + \frac{1 - C - \tau}{B} \tilde{y}_t \right) \tag{4}$$

where $\tilde{b}_t = \ln(\mathcal{B}_t / P_{H,t-1})$, $\mathcal{B}_t$ is nominal debt stock, B the steady state debt to GDP ratio, C is steady state consumption to GDP ratio and τ is a *constant* income tax rate. We assume that debt is observed

[6] Some structural parameters of the dynamic system become non-identifieable in an empirical procedure, however this has no implications for the identification of policy parameters. We discuss this issue further in the text.

at the beginning of the period, see Kirsanova et al. (2007) for further discussion of such specification. We also assume that there are no solvency problems in the efficient equilibrium; for example, there is always a lump-sum tax that allows to balance the budget. This yields $\tilde{g}_t^n = 0$ if χ is constant, see Gali and Monacelli (2005) for derivation.[7]

The Gali and Monacelli (2005, 2004) model assumes using spending as fiscal instrument. Empirical evidence in Favero and Monacelli (2005), Taylor (2000) and Auerbach (2002), for example, suggests that both government spending and taxes do move.

2.2 Strategic interactions between monetary policy and fiscal policy

2.2.1 Policy Objectives

A maximisation of aggregated household utility (1) implies the following optimisation problem for the policymakers. Each policymaker minimises the discounted sum of all future losses:

$$W = \sum_{t=0}^{\infty} \beta^t W_t^S \tag{5}$$

where, under certain restrictions on parameters, the intra-period term can be written as:

$$W_t^S = \frac{\epsilon}{\lambda} \tilde{\pi}_{Ht}^2 + (1+\varphi)\left(\tilde{y}_t - \tilde{y}_t^n\right)^2 + \frac{1}{\chi} \tilde{g}_t^2, \tag{6}$$

where terms independent of policy, terms of higher order and the common multiplier are ignored. (The presence of the government solvency constraint does not affect the derivation of the quadratic approximation to the social welfare as we assume that a lump sum tax is available to ensure government solvency in the efficient equilibrium.)

2.2.2 Optimal Discretionary Policy

We assume that both monetary and fiscal authorities act *non-cooperatively* in order to stabilise the economy against shocks. Both authorities are assumed to act under *discretion*. Monetary authorities choose the interest rate to minimise the welfare loss with intra-period metrics *like* (6) subject to system (2)-(4) and fiscal authorities choose spending to minimise welfare loss with intra-period metrics *like* (6) subject to the same system. If both authorities are benevolent, then *each of them* use *the* intra-period social loss (6) as their objective function. If the authorities are not benevolent, then they can have a welfare loss which is different from (6). In what follows we assume that they can vary weights on microfounded objectives, or they can pursue additional targets, like an interest rate smoothing target for the monetary authorities or debt target for the fiscal authorities, see one example below;

[7] As well as Gali and Monacelli (2005, 2004) do, we assume a constant employment subsidy, that offsets monopolistic and tax distortions in the steady state. This subsidy is financed by lump-sum taxes. As the subsidy and lump-sum taxes do not depend on time, they do not enter linearised budget constraint.

but there can be many extensions each of which would use the social welfare (6) as a 'component'.[8] Both authorities have the same discount factor which is the household discount rate.

We consider three leadership regimes: monetary or fiscal leadership and a Nash game. Our model belongs to the class of nonsingular linear stochastic rational expectations model of the type described by Blanchard and Kahn (1980) augmented by a vector of control instruments, see Appendix A. Specifically, the evolution of the economy is explained by the following system:

$$\begin{bmatrix} \mathsf{y}_{t+1} \\ \mathsf{x}_{t+1} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} \mathsf{y}_t \\ \mathsf{x}_t \end{bmatrix} + \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} \mathsf{u}_t^L \\ \mathsf{u}_t^F \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}, \tag{7}$$

where y_t is a vector of predetermined variables with initial conditions y_0 given, $\mathsf{y}_t = [\varepsilon_t^\pi, b_t]'$, x_t is a vector of non-predetermined (or jump) variables, $\mathsf{x}_t = [\pi_{Ht}, x_t]'$ where $x_t \equiv y_t - g_t$. u_t^F and u_t^L are the two vectors of policy instruments of two policymakers, named F and L. u_t^F and u_t^L are either interest rate or spending in our model.

The two policymakers have the following loss functions:

$$J_t^i = \frac{1}{2}\mathcal{E}_t \sum_{s=t}^{\infty} \beta^{s-t}(g_s' \mathcal{Q}^i g_s), \tag{8}$$

where $i = \{L, F\}$ and g_s is a vector of goal variables of the policymaker, which is a linear function of state variables and instruments, $g_s = \mathcal{C}\left[\mathsf{y}_s', \mathsf{x}_s', \mathsf{u}_s^{L\prime}, \mathsf{u}_s^{F\prime}\right]'$.

In the linear quadratic framework optimal discretionary policy reaction function is necessarily presented in the form of linear rules with feedback coefficients on predetermined state variables, see e.g. Oudiz and Sachs (1985). It can also be shown (see Blake (2007)) that a solution to a linear-quadratic optimization problem with two players subject to time consistency constraint can be written as a pair of linear rules

$$\mathsf{u}_t^F = -F^F \mathsf{y}_t - L\mathsf{u}_t^L, \tag{9}$$

$$\mathsf{u}_t^L = -F^L \mathsf{y}_t, \tag{10}$$

where $L = -\partial \mathsf{u}_t^F / \partial \mathsf{u}_t^L$: in a leadership equilibrium the follower treats the leader's policy instrument parametrically and the leader can manipulate the follower. If the authorities play a Nash game then $L \equiv 0$. Depending on the policy regime, therefore, the policy reaction can include additional terms in contemporary instruments. Note that if g_s includes lags of state variables or instruments, like output growth or there is interest rate smoothing, then system (7) also should be rewritten in the form that includes past output or past interest rate among y_t.

[8] Of course, we cannot claim that the actual authorities use microfounded welfare as the 'benchmark scenario', i.e. the relative weights on inflation and output and government spending could be equally biased for the both authorities. This can be because the authorities cannot 'compute' social welfare, or because they do not use labour subsidy and the social weights in (6) are different.

An example: Instrument Smoothing. It is instructive to demonstrate a simple example. Suppose the fiscal authority is required to change policy instrument in a smooth way. The flow policy objectives, correspondingly W_t^M and W_t^F, are the following. (Here and everywhere below we write our model and policy reactions in the form of gap variables, i.e. for any variable U_t, $u_t = \tilde{u}_t - \tilde{u}_t^n$, see Appendix A for the final specification of the model in gaps.)

$$\begin{aligned} W_t^M &= \frac{\epsilon}{\lambda}\pi_{Ht}^2 + (1+\varphi)\, y_t^2 + \frac{1}{\chi} g_t^2, &(11)\\ W_t^F &= \frac{\epsilon}{\lambda}\pi_{Ht}^2 + (1+\varphi)\, y_t^2 + \frac{1}{\chi} g_t^2 + \Phi_g\,(g_t - g_{t-1})\,, &(12)\end{aligned}$$

so fiscal policy has to be 'slow'. The vector of predetermined state variables is $\mathsf{y}_t = [\varepsilon_t^\pi, b_t, g_{t-1}]'$. Suppose there is a regime of fiscal leadership. Then policy reactions have the form of (9)-(10):

$$\begin{aligned} r_t &= \theta_\pi \varepsilon_t^\pi + \theta_b b_t + \theta_g g_{t-1} + \xi_g g_t, &(13)\\ g_t &= \kappa_\pi \varepsilon_t^\pi + \kappa_b b_t + \kappa_g g_{t-1}. &(14)\end{aligned}$$

By definition $\xi_g \neq 0$, but we can also show that, additionally, it should be required $\theta_g \equiv 0$. Indeed, it is obvious that system (13)-(14) is equivalent to a system that would contain equation (14) and a linear combination of equations (13) and (14). In other words, unless we impose one additional condition on system coefficients, the system is not identifiable. It can be shown formally, using the first order conditions for discretionary optimisation problem, that $\theta_g \equiv 0$. Intuitively, in an internally consistent system all information in g_{t-1} is 'encoded' in g_t and becomes redundant if the monetary authority feeds back on g_t; keeping $\theta_g \neq 0$ leads to using the same information twice.

More general specification. In more general case the specification of policy reaction functions can be written in one of the three following ways.

1. If the authorities play a *Nash game*, they make decisions 'simultaneously', without taking into account each other's reactions. (Remember that $\partial r_t/\partial g_t = \partial g_t/\partial r_t = 0$.) Hence, the contemporary fiscal variable does not enter the monetary reaction function, and the contemporary interest rate does not affect the fiscal policy decisions as discussed above. Specifically, the policy reactions can be written as:

$$\begin{aligned} r_t &= \theta_\pi \varepsilon_t^\pi + \theta_b b_t + [\theta_r r_{t-1} + \theta_g g_{t-1} + \theta_y y_{t-1}]\,, &(15)\\ g_t &= \kappa_\pi \varepsilon_t^\pi + \kappa_b b_t + [\kappa_r r_{t-1} + \kappa_g g_{t-1} + \kappa_r y_{t-1}]\,, &(16)\end{aligned}$$

where θ and κ denote feedback coefficients on predetermined state variables. Unless there is either monetary or fiscal instrument smoothing, or a growth rate of output target, the terms in square brackets are all zero and the only state variables are the distortionary shock and debt.

2. If the *fiscal authorities lead*, they know the reaction function of the monetary authorities and take it into account when making decisions. In other words, the monetary authorities are being manipulated by the fiscal authorities. Formally, $\partial r_t/\partial g_t \neq 0$, $\partial g_t/\partial r_t = 0$. The contemporary interest rate does not enter the fiscal policy reaction function, but the contemporary fiscal variable enters the monetary reaction function, and

$$r_t = \theta_\pi \varepsilon_t^\pi + \theta_b b_t + \xi_g g_t + [\theta_r r_{t-1} + \theta_y y_{t-1}], \tag{17}$$
$$g_t = \kappa_\pi \varepsilon_t^\pi + \kappa_b b_t + [\kappa_r r_{t-1} + \kappa_g g_{t-1} + \kappa_y y_{t-1}]. \tag{18}$$

We call coefficient ξ_g a leadership coefficient.

3. If *the monetary authorities lead*, they know the reaction function of the fiscal authorities and take it into account when making decisions. Here, the fiscal authorities are being manipulated by the monetary authorities. Formally, $\partial r_t/\partial g_t = 0$, $\partial g_t/\partial r_t \neq 0$. The contemporary fiscal variable enters the monetary reaction function, but the contemporary interest rate does not enter the fiscal policy reaction function, and

$$r_t = \theta_\pi \varepsilon_t^\pi + \theta_b b_t + [\theta_r r_{t-1} + \theta_g g_{t-1} + \theta_r y_{t-1}], \tag{19}$$
$$g_t = \kappa_\pi \varepsilon_t^\pi + \kappa_b b_t + \xi_r r_t + [\kappa_g g_{t-1} + \kappa_r y_{t-1}]. \tag{20}$$

Coefficient ξ_r is a leadership coefficient.

Evolution of the system under control. Having obtained policy reaction functions in the form of (9)-(10) we can substitute them into system (7). The resulting system can be written as $\left[\mathsf{y}_{t+1}', \mathsf{x}_{t+1}'\right]' = \Omega\left[\mathsf{y}_t', \mathsf{x}_t'\right]'$ and we can apply the Blanchard-Kahn decomposition (Blanchard and Kahn (1980)). As a result, evolution of state variables in the economy under optimal control can be written in the linear form $\mathsf{y}_{t+1} = M\mathsf{y}_t$, $\mathsf{x}_t = N\mathsf{y}_t$. This system for our model takes the form:

$$\pi_{Ht} = \lambda_\pi \varepsilon_t^\pi + \lambda_b b_t + [\lambda_r r_{t-1} + \lambda_g g_{t-1} + \lambda_y y_{t-1}], \tag{21}$$
$$x_t \equiv y_t - g_t = \zeta_\eta \varepsilon_t^\pi + \zeta_b b_t + \left[\zeta_r r_{t-1} + \zeta_g g_{t-1} + \zeta_r y_{t-1}\right], \tag{22}$$
$$b_{t+1} = \mu_\eta \varepsilon_t^\pi + \mu_b b_t + \left[\mu_r r_{t-1} + \mu_g g_{t-1} + \mu_r y_{t-1}\right]. \tag{23}$$

Note that in relationships (21)-(23), as well as in policy rules, all variables in square brackets are only present if they enter objectives of one or both policymakers.

2.3 Empirical Specification

2.3.1 The model

Empirical specification of the system consists of equations (2)–(4) and two policy reaction functions, which we specify next. The model essentially serves as a data generating process to estimate policy rules for all countries. Because of our specific research question which concerns leadership regimes, we will not estimate a separate equation for the terms of trade, as did Lubik and Schorfheide (2006). Although this reduces the number of identifiable structural coefficients of the model, the model remains internally consistent and allows direct comparison of alternative policy regimes. Parameters that become non-identifiable play no role in our analysis.

Note that although we aim to estimate *optimal* policy rules, i.e. resulting from the optimisation with well defined policy objectives, we shall estimate policy feedback coefficients as 'structural' parameters – instead of weights on policy objectives – and then try to restore the weights on policy objectives using these estimates. Treating policy objective weights as structural parameters is problematic, as it is practically not feasible to obtain an analytic solution to a discretionary problem if there are predetermined state variables. Unless there is an extremely simple model (for example, as discussed in Clarida et al. (1999)) a solution to the Bellman equation is a fixed point and should be found numerically. We have several predetermined variables (debt, past values of policy instruments) and two optimising policymakers that complicates the solution even further. Therefore, it will be practically more convenient if we estimate the policy feedback coefficients first, and then try to solve the inverse problem: find weights on policy objectives that can generate the estimates policy reactions.

Our theoretical model assumes that all contemporary shocks are observable by policymakers. Moreover, neither contemporary inflation nor output are among the variables in feedback rules, as they are non-predetermined at time t. Equilibrium relationship (21) allows us to substitute the cost push shock out of the policy reactions to give a *representation* of policy rules that includes inflation.[9] This transformation leads to the following specification of the policy rules[10]

$$
\begin{aligned}
r_t &= \rho_r r_{t-1} + (1-\rho_r)(r_\pi \pi_{Ht} + r_y y_{t-1}) + r_b b_t + r_{glag} g_{t-1} + \{r_g g_t\} + \varepsilon_t^r, && (24)\\
g_t &= \rho_g g_{t-1} + \left(1-\rho_g\right)(g_\pi \pi_{Ht} + g_y y_{t-1}) + g_b b_t + g_{rlag} r_{t-1} + \{g_r r_t\} + \varepsilon_t^g, && (25)
\end{aligned}
$$

where

$$
\begin{aligned}
\rho_r &= \theta_r - \frac{\theta_\pi}{\lambda_\pi}\lambda_r, \quad (1-\rho_r) r_\pi = \frac{\theta_\pi}{\lambda_\pi}, \quad (1-\rho_r) r_y = \theta_y - \frac{\theta_\pi}{\lambda_\pi}\lambda_y && (26)\\
r_b &= \theta_b - \frac{\theta_\pi}{\lambda_\pi}\lambda_b, \quad r_{glag} = \theta_g - \frac{\theta_\pi}{\lambda_\pi}\lambda_g, \quad r_g = \xi_g. && (27)
\end{aligned}
$$

$$
\begin{aligned}
\rho_g &= \kappa_g - \frac{\kappa_\pi}{\lambda_\pi}\lambda_g, \quad \left(1-\rho_g\right) g_\pi = \frac{\kappa_\pi}{\lambda_\pi}, \quad \left(1-\rho_g\right) g_y = \kappa_r - \frac{\kappa_\pi}{\lambda_\pi}\lambda_r && (28)\\
g_b &= \kappa_b - \frac{\kappa_\pi}{\lambda_\pi}\lambda_b, \quad g_{rlag} = \kappa_r - \frac{\kappa_\pi}{\lambda_\pi}\lambda_r, \quad g_r = \xi_r. && (29)
\end{aligned}
$$

[9] Note that this substitution is legitimate, because if $\mathcal{E}_t(\varepsilon_t|r_{t-1}) = \mathcal{E}_t(\varepsilon_t|g_{t-1}) = \mathcal{E}_t(\varepsilon_t|y_{t-1}) = \mathcal{E}_t(\varepsilon_t|b_t) = \mathcal{E}_t(\varepsilon_t|\varepsilon_t^\pi) = 0$, for $\varepsilon_t \in \{\varepsilon_t^r, \varepsilon_t^g\}$, then from (21) it follows that $\mathcal{E}_t(\varepsilon_t|\pi_{Ht}) = 0$. Together with the assumption of that all structural shocks are uncorrelated, this allows us to have this substitution. If we went further and used (22) to substitute debt out of the policy rules and to derive 'conventional' policy rules with inflation and output as key determinants of the instruments, then such substitution would not be legitimate. We would obtain that $\mathcal{E}_t(\varepsilon_t|y_t - g_t) = 0$ but not $\mathcal{E}_t(\varepsilon_t|y_t) = \mathcal{E}_t(\varepsilon_t|g_t) = 0$ as needed to keep the existing structural form of policy rules for each of the three strategic regimes.

[10] Although we shall use word 'rule', no precommitment is assumed neither here or anywhere below.

and we added an i.i.d. terms $\varepsilon_t^r, \varepsilon_t^g$ that describe non-systemic policy.

Rules (24) can be interpreted in the usual way: the central bank adjusts its instrument in response to movements in inflation and there is also a possibility of stabilisation of the growth rate of output. The term in curly brackets is only present if we assume that there is a regime of fiscal leadership. The parameter ρ_r captures the degree of interest rate smoothing. If the fiscal rule is persistent, then g_{t-1} becomes a state variable so, generally speaking, $r_{glag} \neq 0$.In the empirical specification we also allow for an error term ε_t^r which describes non-systemic component of monetary policy and is i.i.d..[11]

Specification (25) suggests that fiscal policy can support monetary policy in short-run stabilisation of the economy. If there is an interest rate smoothing, r_{t-1} becomes a state variable and $g_{rlag} \neq 0$.The term in curly brackets is only present if there is a regime of monetary leadership.

As we discussed above, specifications (24) and (25) are close to those conventionally used in the literature. Although there are some unconventional terms, like debt in the monetary policy reaction function or inflation in the fiscal policy reaction function, their presence is justified because we estimate these equations as part of internally consistent system, that describes the evolution of the economy under policy control. We assume that this system is correct: there are no omitted variables, and all mechanisms of interactions are embedded in the reduced form system (2)–(4), and (24)-(25). The policymaker's decisions are adequately explained by relationships (24)-(25), provided that system (2)–(4) is also observable by the policymaker. This internal consistency also allows us to keep domestic inflation in the policy rule, rather than to use CPI inflation as is typically the case in empirical models that are not internally consistent.

Finally, equations (2)–(4), a system for natural rates and equations (24)-(25) constitute a complete, internally consistent structural model. These equations define five endogenous variables of our model, $\pi_{Ht}, y_t, b_{t-1}, r_t, g_t$. The stochastic behaviour of the system is driven by three exogenous shock variables $(a_t, y_t^*, \varepsilon_t^\pi)$, and two policy shocks $(\varepsilon_t^r, \varepsilon_t^g)$. Shocks (a_t, y_t^*) are assumed to follow an independent first-order autoregressive stochastic process and shocks $(\varepsilon_t^\pi, \varepsilon_t^r, \varepsilon_t^g)$ are assumed to be i.i.d.-independent processes. Note that equation (4) is an accounting relationship. We shall use it to determine the (non-explosive) path of debt, so we shall treat debt as an unobservable variable.[12]

2.3.2 Strategic Policy Regimes

In this paper we aim to check whether the common belief, that a policy regime in a single country like UK is a regime of fiscal leadership, can be confirmed empirically. We shall compare three specifications of the policy reactions, with particular restrictions on coefficients, that are implied by different assumptions about the leadership regime. The three hypotheses are non-nested and can be formulated

[11] There is an alternative view on the general form of policy reactions: an assumption of AR(1) error term and no instrument smoothing, see Rudebusch (2002). In this paper we investigate an instrument smoothing case.

[12] An alternative approach can be to use actual data for the government debt. In this case, however, we would need to introduce an error component into this equation in order to capture the heterogeneity of components of debt with different maturity. This error term would collect all the measurement errors too. We shall discuss this later in the text.

as follows.

If the authorities play a *Nash game*, they make decisions 'simultaneously', without taking into account each other's reactions. Hence, the contemporary fiscal variable does not enter the monetary reaction function, and the contemporary interest rate does not affect the fiscal policy decisions. However, if the authorities smooth policy instruments then past interest rate and past spending become predetermined state variables.[13] They do affect decisions of the authorities, as they contain information about the state of the economy, and this information is available to both authorities. In policy reactions in form (24) and (25) we, therefore, impose

$$H_0^N : r_g = \xi_g = 0, \quad g_r = \xi_r = 0, \quad r_{glag} \neq 0, \quad g_{rlag} \neq 0. \tag{30}$$

If there is a regime of *fiscal leadership*, then the monetary authorities do take into account the contemporary actions of fiscal authorities and the restrictions are:

$$H_0^{FL} : r_g = \xi_g \neq 0, \quad g_r = \xi_r = 0, \quad \theta_g = 0, \quad g_{rlag} \neq 0. \tag{31}$$

Note that we impose $\theta_g = 0$ as explained above. Although this restriction still allows $r_{glag} \neq 0$, this restriction will help us to choose priors and identify the leadership regime, as discussed in the next Section.

Similarly, the restrictions in the case of *monetary leadership* are:

$$H_0^{ML} : r_g = \xi_g = 0, \quad g_r = \xi_r \neq 0, \quad r_{glag} \neq 0, \quad \kappa_r = 0. \tag{32}$$

2.3.3 Choice of Optimal Policy

The assumption of discretionary interactions might not be not an innocuous assumption. As discretionary policy is time-consistent, this implies that policy reactions can be written as linear relationships. But discretionary policy is not the only policy which leads to linear rules. Suppose that the true policy is formulated in terms of simple (optimal) rules. None of the authorities is able to exploit the other's reaction function in this case, so such policy is non-strategic. Can we design a test to distinguish *empirically* between strategic Nash game and non-strategic rules-based policy? The answer seems to be negative. Although we can choose in favour of Stackelberg leadership if there is a statistically significant leadership coefficient – as there is no theoretical reason to have this term if the authorities operate with optimal rules – it is problematic to be able to choose Nash equilibrium over non-strategic policy. Suppose that the policy rules that are associated with discretionary policy are 'implementable', i.e. they do not leave the economy indeterminate. In this case the same dynamics of the model can be a result of the policy of simple rules, i.e. the two policies are observationally

[13] In what follows we shall always assume that an instrument smoothing takes place. We shall see that this assumption has strong empirical support (provided that non-systematic components of policy reactions are i.i.d.), so it is convenient to account for such behaviour from the very beginning and not to redo all derivations later.

equivalent. There is a reason, of course, to discriminate against *monetary* policy rules on the basis of that no central banks can precommit to them, being responsible for financial stability not only for macroeconomic stabilisation. We cannot use this argument to discriminate against fiscal rules though. It should always be kept in mind when interpreting the results.

By assuming discretionary policy we also assume away another frequently discussed possibility, policy under commitment. Central banks often claim that they can precommit to the target: they are aware of the Barro and Gordon (1983) problem and they are not willing to use discretion (see e.g. Vickers (1998)). However, these claims are about 'level bias', not 'stabilisation bias'. Discussing the dynamic reaction function of the Bank of England, Vickers (1998) comments that as complete contracts are not feasible discretionary decisions are inevitable. However, partial commitment is possible. Again, by restricting ourselves to discretionary outcomes, we ignore such possibility. The empirical implication of this is that we might have omitted variables in our policy rules. These variables are Lagrange multipliers, or, equivalently, they are integrals of past values of jump variables, inflation and consumption.[14] Their absence affects all policy regimes in a similar way and should not preclude the identification of the leadership regime. Their absence, however, might be crucial if we want to restore policy objectives from the estimated policy reactions. The latter question, however, is beyond the scope of this paper.

3 Estimation Strategy and Empirical Implementation

3.1 Econometric Methodology

There are various ways of estimating parameters of a linearised DSGE model. One possible way of estimation is to use structural VARs. The estimation is based on minimisation of the distance between theoretical impulse response functions of the model and empirical impulse responses estimated from a structural VAR. Its disadvantage is that it requires a correctly identified and precisely estimated VAR impulse response to a shock. Another approach is to use a single-equation GMM estimation. It has a disadvantage that it leaves parts of the model unspecified, and relies on the good choice of instruments. Additionally, the government solvency constraint is an important identifying restriction in our model, but it would be difficult to account for it had we used the GMM. We, therefore, choose to use a system-based Bayesian approach. The estimation is based on the likelihood function generated by the DSGE model, and we use a prior distribution that incorporates additional information in the estimation. This method allows us to work with a small scale and potentially misspecified DSGE models. As we concentrate on the estimation of policy rules, the rest of the model – which can be extremely simple – serves as a data generating process to provide identification restrictions for the

[14] See brief description of non-cooperative solution under commitment in Kirsanova et al. (2005).

estimation of policy rules.[15] This approach, therefore, is robust to the problem of endogeneity, see An and Schorfheide (2006) for further discussion.

The estimation procedure is clearly explained in An and Schorfheide (2006) and consists of several steps. From the reduced form solution of the model we obtain a state space representation of the model where unobserved state variables are mapped in the observed data (this can lead to an identification problem since the mapping from the vector of structural parameters into the state space representation is highly nonlinear). A Kalman filter is applied to calculate the likelihood function of the observed data. The joint posterior distribution is obtained first by numerical optimization of the posterior mode and the Hessian matrix evaluated at the mode. Then, Bayesian DSGE use the Metropolis-Hastings algorithm to generate a sample from the posterior distribution, using the Hessian matrix. We use DYNARE toolbox for MATLAB (Juillard (2005)).

There are several problems with this approach that are most commonly discussed in the literature (see Canova and Sala (2006) among others). One problem is a possible lack of identification of structural parameters, when several specifications of the model can lead to the same reduced form. A practical way to detect it is to look at posterior distributions. If some parameter is not identifiable, this results in a situation where the posterior distribution is (nearly) identical to the prior distribution. However, the apparent similarity between the prior and the posterior can also be a consequence of the fact that the estimation objective function has little curvature along this parameter, so the data essentially 'agree' with any prior in a wide area. The latter property is a property of the data rather than of the model, so different results for different countries can help to distinguish between the potential causes of the problem.

The change between a prior and a posterior can also tell us about potential model misspecification, since DSGE models impose cross-coefficient restrictions on the time series that imply poor out-of-sample fit compared to a more densely parameterised models such as a VAR. A structural model only provides an approximation to the law of the motion of the time series. A shift from prior to posterior distribution can reveal tension between different sources of information (see An and Schorfheide (2006) for more details).

In our model, the fact that the model contains five structural shocks and there are only four observable variables might raise an identification issue. Identification is achieved by assuming that each of the structural shocks are uncorrelated and that three of the five shocks follow a white noise process.

In order to test the hypothesis that the policy authorities operate in the regime of fiscal leadership, we estimate three versions of the model, imposing restriction H_0^{FL}, H_0^{N} and H_0^{ML} (see (30)-(32)). We then perform Bayesian posterior odds tests that utilise the entire information contained in the model

[15] The need for instruments arises because of the joint endogeneity of the variables in both policy reaction functions. The full-information likelihood-based approach optimally adjusts the estimation of the policy rule coefficients for the endogeneity of the right hand side variables.

and the data.

3.2 Data Description

In our empirical analysis we use observations on real GDP, GDP deflator, nominal interest rate and government spending to GDP ratio for all countries. All data are seasonally adjusted and at quarterly frequencies. For the two European countries we use data for the post-ERM period 1992:3 to 2006:2. We therefore exclude the period when the Bank of England and the Sveriges Riksbank had an explicit exchange rate target. For the US we use data from the beginning of the period when Greenspan became a chairmen of the Fed, 1987:3–2006:2. This choice is supposed to ensure stability of monetary policy objectives.[16] All of the UK data series are obtained from the Office of National Statistics Database, the Swedish data series are taken from the Riksbank database and the Statistics Sweden database. The US data were produced by the Bureau of Economic Analysis and the Fed and are taken either from NIPA or the Flow of Funds tables; the Appendix gives all details. Home inflation rates are defined as log differences and multiplied by 100 to obtain quarterly percentage rates. In order to match maturities, we use interest rate on 3 months Treasury bills for all countries, which closely follows the rate that is targeted by the corresponding central bank. As a proxy for government expenditures we take 'current government spending on goods and services' in the UK and the US, but use 'total government spending' for Sweden as more disaggregated series on the quarterly basis are not available for the whole period. We therefore do not include interest payments and compensation of government employees in the UK and the US, but include them in the case of Sweden. The data series on real GDP are detrended with Hodrick-Prescott filter. All data series are demeaned prior to estimation.

3.3 Choice of Prior

We choose priors for structural parameters to be estimated based on several considerations. Prior distributions are assumed to be independent. We implement size restrictions on the parameters, such as non-negativity, by either truncating the distribution or redefining the parameters to be estimated.

We keep a number of parameters fixed. Most of them can be directly related to the steady state variables and could be estimated from the means of observable variables. However as our set is demeaned, we cannot pin them down in estimations. The discount factor, β, is calibrated to be 0.99, which implies an annual steady state interest rate of about 4%. In the UK the tax rate is set to 0.36, as the data suggest, the debt to annual GDP ratio is set to 0.5. As the model is in reduced form, we can estimate σ_α as a structural parameter instead of η, α, σ. As the model is in reduced form, σ_α becomes the only structural parameter. As σ_α is a function of η, α, σ, instead of estimating σ_α we can calibrate α and η and estimate σ, as we do. This has an advantage of that we are able to compare our

[16] We therefore exclude the Volker period (1980-87) that had periods of very high interest rates. We discuss below the results of estimation if this period is taken into account.

estimates of σ with those available in the literature. Using data on import share we calibrate $\alpha = 0.3$ for the UK and Sweden and $\alpha = 0.1$ for the US.[17] We calibrate $\eta = 1$ following Lubik and Schorfheide (2006).

Note that more diffuse priors do not necessarily deliver higher marginal data density. While the in-sample fit improves slightly, wider priors relax some of the parameter restrictions and this leads to a larger penalty for model complexity. The second effect can outweigh the first one and this leads to an overall fall in the marginal data density.

We use fairly loose priors for parameters of policy rules. We start with priors for the monetary policy parameters r_π and r_y that are centered around the values that are commonly associated with Taylor rule. We also allow for interest rate smoothing parameter which is consistently found in the literature. Table 1 summarises results of some empirical research which we take into account when setting priors for monetary rules.[18] We use estimates in Muscatelli et al. (2004a) in order to set priors for fiscal policy coefficients on output.[19] The priors for most[20] other coefficients in the policy rules – for coefficients that are not common in the literature, and in particular r_g, r_{glag}, g_{rlag} and g_r which are crucial to identify leadership regime – are set based on trials with a very weak prior.[21]

We also use simulations in order to set the prior for the fiscal feedback on debt. If the fiscal feedback on debt is too small then fiscal policy does not control domestic debt and the model is unstable.[22] Instead of limiting the domain of support for the prior, we choose to set the mean of the prior a little bit higher than where we expect to find the mode. This would prevent us from having active constraints in the estimation and poor convergence of the MH algorithm. If the data conflict with the prior we will notice this conflict.

We also set priors for structural parameters θ, σ and φ. As our model is extremely simple, potential misspecification of it will be first of all reflected in data tensions for these parameters. We started with setting the mean of the Calvo parameter θ to 0.70 which assumes the average length of fixed price contracts is slightly less than one year, but the standard error allowed for variation between

[17] It can be argued that a model of *small* open economy is not suitable for the US. However, one should remember that the model is only used as a data generating process to provide identifying restrictions for policy rules. Modelling *large* open economy implies that the system of identifying restrictions for policy rules in the US should include equations for the rest of the world that determine foreign interest rate and foreign consumption. Instead of doing this, we essentially model the US economy as a nearly *closed* economy, by imposing very small α. We believe this can still adequately provide all identifying restrictions and ensure unified framework for all three countries.

[18] The literature on monetary policy rules is large; we only cite several papers, those which use comparable data periods and comparable methodology. In particular, we compare our results with those obtained in models with i.i.d. error terms in policy reactions.

[19] The literature on empirical fiscal rules is limited, and specifications differ widely. It is also common to use taxes or deficit as policy instrument.

[20] As mentioned above, we set $r_{g\_lag} = 0$ for the regime of fiscal leadership, and $g_{r\_lag} = 0$, for the regime of monetary leadership.

[21] If we find a tension in the data, we move priors of these parameters in the idenified direction to accomodate the tension, unless there is a theoretical reason not to do so. We stop when the mode is within a 95% confidence interval of the prior mean.

[22] Given that monetary policy acts in an 'active way' (Leeper (1991)), which is always the case in our countries.

three quarters and two years. For σ and φ we use the findings of Smets and Wouters (2003) to choose initial priors. We inevitably shift them slightly in order to remove tensions with the data.

The first three columns of Tables 2 and 3 give an overview of our assumptions regarding the prior distribution of parameters. All the variances of the shocks are assumed to be distributed as an inverted Gamma distribution with a degree of freedom equal to 2. This distribution guarantees a positive variance within a rather wide domain. The means are taken from similar studies, predominantly from Smets and Wouters (2003). Again, similar to their work, we use rather strict standard errors for autocorrelated shocks in order to distinguish them from non-persistent shocks.

3.4 The use of simulations

Finally, in order to illustrate the usefullness of simulations in setting priors we demonstrate the following example. Suppose the monetary authority is inflation conservative and smooth interest rate, i.e. its objectives can be written as:

$$W_s^M = \rho_c \frac{\epsilon}{\lambda} \pi_t^2 + (1+\varphi) y_t^2 + \frac{1}{\chi} g_t^2 + \rho_i (r_s - r_{s-1})^2 .$$

Suppose the fiscal authority smooth the policy instrument and have a deficit target, i.e. its objectives can be written as:

$$W_s^F = \frac{\epsilon}{\lambda} \pi_t^2 + (1+\varphi) y_t^2 + \frac{1}{\chi} g_t^2 + \rho_g (g_s - g_{s-1})^2 + \rho_d d_s^2,$$

where $d_s = \frac{C}{B} g_s + \frac{1-C-\tau}{B} y_s$ is linearised primary deficit.

Then, the optimal policy reaction functions *in the case of fiscal leadership* under the base line calibration (Appendix A) and $\rho_i = 100$, $\rho_g = 20$, $\rho_c = 3$, $\rho_d = 50$ can be written as

$$r_t = 0.88\pi_{Ht} + 0.00b_t + 0.59r_{t-1} - 0.01g_{t-1} + 0.10g_t, \quad (33)$$

$$g_t = -0.04\pi_{Ht} - 0.01b_t + 0.02r_{t-1} + 0.25g_{t-1}. \quad (34)$$

We can change the policy objectives or/and leadership regimes to see how our policy coefficients change. We can also observe the order of magnitude and the sign of policy coefficients.

4 Empirical Results

We begin by fitting our small-scale open economy DSGE model to the regime of fiscal leadership and discuss the resulting parameter estimates and dynamics of the model. We then reestimate the model assuming alternative policy regimes, and using longer data samples where possible.

4.1 Estimation of Fiscal Leadership Regime

4.1.1 Post-ERM period: policy reactions and structural parameters

Policy reaction functions. We present the Bayesian estimates of policy parameters in assuming the regime of fiscal leadership in Table 2. This table contains results of estimation for UK, Sweden and the US, all based on comparable data samples for the post-ERM period in Europe. (We also visualise results for the UK and Sweden in Figure 1.)

In addition to the prior distribution, this table reports two sets of results regarding the parameter estimates. The first set contains the estimated posterior mode of the parameters, which is obtained by directly maximising the log of posterior distribution with respect to the parameters, and an approximate standard error based on the corresponding Hessian. The second set reports the 5th, mean and 95th percentile of the posterior distribution of the parameters obtained through the Metropolis-Hastings sampling algorithm. The latter is based on 100,000 draws.[23]

We discuss the results for the three countries together, as they are similar in several respects.

The reaction function of the monetary authorities is in line with the one proposed by the literature on Taylor rules. We find evidence of strong interest rate smoothing: the coefficient on the lagged interest rate is statistically significant and close to 0.9, which is consistent with findings in the literature. The long-run reaction function suggests that monetary authority raises the interest rate if there is an inflation shock.[24] The most active monetary rule was estimated for the two European countries, and the least active was found for the US. The estimates of r_π are generally consistent with the evidence from the literature, summarised in Table 1. Although neither of the models listed there has an identical specification with our model, the results concerning the form (and the strength of responses) of monetary reaction functions are in close agreement. We also find a rather small feedback coefficient on the output gap, which is also consistent with some other findings, in particular those obtained by Bayesian methods for Eurozone by Smets and Wouters (2003), or by GMM for the US in Clarida et al. (1998).

Apart from conventional feedback coefficients on inflation and output, we have a feedback on *contemporary* government spending. In order to estimate this leadership coefficient we did many trials with very weak prior and came to the specification where the prior mean is between the posterior mean and zero. The latter observation helps to be clear with the sign of the posterior. We found that the leadership coefficient is positive for the two European countries. The posterior is also much more concentrated than the prior for the two European countries. In the US, however, several trials with weak prior did not result in a concentrated posterior distribution. The data also agree more with a negative leadership coefficient. We will discuss implications of these results in the next section.

The hypothesis of fiscal leadership requires us to impose $\theta_g = 0$ which, for the specification with contemporary inflation in policy rules, and under the assumption of that θ_π and λ_π are of order one, implies that r_{glag} should be of order λ_g (which is the cumulative effect of fiscal spending on inflation) and negative, see equations (26)-(27). The results of the estimation demonstrate that the data do

[23] A sample of 100,000 draws was sufficient to ensure convergence of the MH sampling algorithm. The acceptation rate was 55% on average for all three countries.

[24] Strictly speaking, r_π, r_y are not long run feedback coefficients, but they are very close to them as feedbacks on fiscal variables are small in size. In what follows, we refer to these coefficients (and to the corresponding coefficients in fiscal rules) as to long-run coefficients.

not disagree with this hypothesis. For each country, although posterior means are not statistically different from zero, they have negative means.

The estimates of the fiscal policy reaction function are also similar for all three countries. We observe a substantial fiscal smoothing, as reported in other studies, see Muscatelli et al. (2004a) for the US data.[25] We also identify negative long-run fiscal feedback on inflation. We did not find statistically significant fiscal feedback from output for the UK and Sweden. For the US this feedback was found to be negative but the data were not very informative: if we change the prior then the posterior would follow very closely. A close resemblance between the prior and posterior suggests that the likelihood objective function is very flat in this parameter.[26] We therefore report means that deliver higher marginal density.

We did not find a significant fiscal feedback on past interest rate, g_{rlag}. We included g_{rlag} on the grounds that, in the world where monetary policy smooths interest rate, past interest rate becomes a state variables, and a full information fiscal policy has to feed back on it. This coefficient is identifiable, but the likelihood function is flat in it.

We obtained that there is a small feedback coefficient on debt.[27] Its absolute value is not much above the instability boundary, below which the government debt would become unstable.[28] As we described above, we had to reduce the variance of the prior for g_b and raise its mean (in absolute value) in order to avoid problems with estimation of posterior mode, as there is a tight lower limit on the values of this parameter.

Our findings suggest that a contractionary monetary policy coexists with contractionary fiscal policy. Theoretically, in a model with forward-looking optimising agents this is not an entirely obvious result. If there is no need to stabilise debt then a contractionary monetary policy would be *optimally* supported by an expansionary fiscal policy. In response to a cost push shock, for example, and under conventional social welfare objectives, the monetary authorities would optimally raise the interest rate. A resulting recession would be optimally offset by a hike in fiscal spending.[29] In the presence of domestic debt, however, such policy can lead to the instability of debt. In a model with a debt accumulation process contractionary fiscal policy becomes optimal from the social perspective, and

[25] Note that although our description of monetary objectives are unlikely to have structural breaks in monetary regime, there is a possibility of change in fiscal regimes for all three countries. Unaccounted structural breaks can generate some additional persistence, see Perron (1989). As our main objective is to estimate monetary policy rule in assuming either the fiscal leadesrship regime or the Nash game, we chose to ensure stability of monetary objectives, and estimate fiscal reactions 'on average'. We leave further analysis of these issues for future research.

[26] The policy coefficients are identifiable.

[27] Although we present results for the model where debt is treated as unobservable variable, we also obtained very similar results for the model with observable debt. There, the fiscal feedback on debt was more statistically significant, although its size was similar to the coefficient presented in this paper. That model also had to have an error term in the debt equation, in order to account for portfolio composition with different debt components of different maturities, and we estimated a substantial variance of this error term.

[28] Leith and Wren-Lewis (2000) discuss that the instability boundary is just above the steady state value of the real interest rate. This boundary is even lower if fiscal policy feeds back on other variables besides debt.

[29] Blake and Kirsanova (2006) discuss in detail that this is a consequence of forward-looking structure of the model, where fiscal policy can affect output directly, but monetary policy is only able to influence change in consumption.

we find empirical evidence for such behaviour.

Structural parameters and shocks. The estimates of structural parameters and shocks are given in Table 3. Overall, the estimates of the structural parameters fall within plausible ranges. In all cases, estimated reaction of consumption to changes in long-run interest rate is within plausible ranges. The estimate of φ is around 2.0 implying a rather intermediate estimate of the elasticity of labour supply. There is only a small difference between the estimates of $1/\sigma$ and φ for different countries. (Note that the value of behavioural parameter σ depends on calibration of partly institutional parameter η (Obstfeld and Rogoff (2000)), which we set to unity for all countries.) Our estimate of θ suggests that prices are kept constant for between three quarters in Europe and for slightly longer than one year in the US, which does not contradict most of the evidence.

We find substantial persistency of both AR(1) shocks, productivity and the world demand shock. The estimates of standard deviations for all structural shocks are very close to those obtained in Smets and Wouters (2003) and in Lubik and Schorfheide (2006) for an equally stylised model.

Policy objectives. We do not attempt to identify policy objectives formally, but we note that the structural form of empirical rules is close to the one that can be obtained by simulations if we assume instrument smoothing, some monetary conservatism and a deficit target for fiscal authorities. Compare the results for the UK, for example, with simulation results presented in (34)-(33): we have the same signs of all coefficients, although the size of coefficients differ. Further analysis is needed to restore policy objectives: for example a coexistence of strong instrument smoothing and active long-run monetary policy could not only be a result of the presence of different targets in policy objectives than those we consider, it can also be a result of precommitment of the authorities, either to the whole stabilisation programme or to some rule-type responses to particular events, as it is well known that commitment generates higher degree of smoothing. If this is the case, our empirical reaction functions do not satisfy a Bellman equation, unlike the simulated reaction. We leave this issue beyond the scope of this paper.

4.1.2 Variance Decomposition and Impulse Responses

The top part of Table 7 presents variance decomposition that quantifies the importance of individual shocks in the UK model. UK output is largely driven by technology shocks and to a lesser degree by fiscal policy shocks. The contribution of monetary policy innovations is less than 10% which is in line with evidence from VAR studies. Interestingly, cost push shocks contribute very little to inflation volatility. This is not surprising as they are i.i.d. shocks to an entirely forward-looking Phillips curve, which generates zero persistence on its own. The movements of fiscal instrument, on the other hand, are largely determined by fiscal shocks, and to a smaller degree by the world output. Fiscal innovations describe non-systemic fiscal policy, that is not picked up by our model. Fiscal volatility affects volatility of all endogenous variables both directly and indirectly. For example, interest rate changes when there is a fiscal shock. It is either because fiscal shocks affect output, or because monetary policy directly reacts to fiscal disturbances as it is a follower in the policy game.

The model dynamics can be further studied by computing impulse response functions. We report them in Figure 3 for the UK only, as they are similar for other countries. Each subplot shows mean responses of *observable* variables together with 5th and 95th percentiles. We plot impulse responses to each shock in a separate row of subplots. There is some endogenous propagation of shocks, partly because both policy reactions exhibit substantial smoothing. In part, this smoothing is responsible for the observed cyclical behaviour with long cycles that last for about 40 quarters. This does not lead to a very big loss of efficiency as the amplitude of these cycles is relatively small. They are most noticeable in the response to the fiscal policy shock as we discuss below.

Both productivity shocks and world output shocks do not affect the output gap. As both monetary and fiscal policy instruments react to 'gap' variables, the actual interest rate and the spending move one-to-one with shocks to the efficient equilibrium. Following a positive productivity shock, potential output rises. The 'natural rate' interest rate falls and so does the actual interest rate. The effect from lower interest rate outweighs the effect of higher output on debt and fiscal spending should be increased. Although the output gap is unaffected, there is still an effect of higher government spending on marginal cost. The marginal cost falls and so does inflation. The actual interest rate falls to offset this decline in marginal cost and to reduce the interest rate gap.

Higher foreign output leads to fall in home potential output and fall in marginal cost (under our estimates of σ and subsequent calibration of σ_α). The 'natural rate' interest rate will fall and so monetary policy will lower the actual interest rate. The debt will fall and fiscal spending will be raised. The fall in marginal cost will drive inflation down. Monetary policy react by keeping interest rate low.

Cost push shocks are distortionary, they affect gap variables directly and do not affect natural rates. A cost push shock raises inflation. Output falls following an interest rate increase. Fiscal policy does not react much as an increase in spending to stabilise output is offset by a decrease in spending in order to keep debt under control.

Contractionary monetary policy lowers inflation and output. Higher interest rate and the consequent debt accumulation lead to a cut in government spending. Lower government spending also helps to stabilise inflation.

Fiscal shocks cause cyclical adjustment. First, expansionary fiscal policy drives output and home inflation up. There is a relatively small impact on inflation as the effect of higher output gap on marginal costs is offset by the effect of higher spending. As fiscal policy destabilises debt, interest rate has to be lowered (only by little) in order to keep debt under control. An additional increase in output causes inflation to rise again and the interest rate has to be raised eventually in order to keep inflation under control, while fiscal policy takes over the debt stabilisation policy. This eventual fiscal contraction brings output and inflation back to the equilibrium. Output then continues to fall because fiscal spending remain in the negative area for too long. Generally speaking, this cyclical behaviour is a consequence of highly persistent fiscal responses and also persistent but different nature of the debt accumulation process: slow proportional control cannot stabilise integrated process well.[30] Estimated fiscal policy is not flexible and, although it does react to contemporary variables, responses are smoothed over time for too long and lead to cycles.

We also present variance decomposition for Sweden assuming the fiscal leadership regime, and for the US assuming Nash regime. Although we discuss identification of policy regimes in the next section, we note here that all presented tables are very similar. The only substantial difference is that cost-push shocks play bigger role in explaining the US inflation (that perhaps reflects the absence of strict inflation targeting in the US), and that the non-systemic fiscal policy in the US accounts for much smaller variation in government spending than it does in the UK or Sweden. We do not plot impulse responses for the other two countries as they are qualitatively similar, but we note that the US fiscal policy does not induce as much cyclicality as does fiscal policy in the two European countries.

4.2 Comparison of Different Regimes

We have reestimated the model assuming either Nash or Monetary Leadership regimes. The policy parameter estimates are presented in Tables 4-6 and posterior odds are given in Table 8. We find important differences in policy rules for all three countries. As structural parameters are all very similar for the three regimes for every country we do not present them to save the space.

Table 4 reports results for the UK. For convenience, we also included the results on fiscal leadership, that were discussed above. In order to estimate the model under assumption of Nash equilibrium, we removed contemporary government spending from the list of important variables for the monetary authorities. We also relaxed all assumptions on possible values of r_{glag}. We report identical priors for r_{glag} for the Nash and fiscal leadership regimes, but this is rather an identical outcome of several trials with weak and possibly different priors. Overall, although all estimated coefficients are close to those obtained under the regime of fiscal leadership[31], the predictive power of the model falls, see Table 8. This is a consequence of restricting $r_g = 0$: lagged fiscal spending is not able to explain the behaviour of the monetary authorities as well as contemporary fiscal spending does. Overall, the marginal data density for the Nash model is lower than it is for the model of fiscal leadership, and this translates into a posterior odds ratio of 3/1000. In other words, the likelihood that the data were generated under Nash regime versus fiscal leadership regime is 0.003.

If we estimate the model assuming that there is a regime of monetary leadership, the predictive

[30] Formally, such process of control can be explained by a differencial system of the second order, which is likely to have a pair of complex eigenvalues.

[31] Compare coeffeicients with the reduced form reactions under the fiscal leadership.

power is lower than for the model of the fiscal leadership. The effect of contemporary fiscal policy on monetary decisions is assumed away, and the fiscal policy is supposed to take into account the contemporary level of interest rate. The posterior leadership coefficient is more diffuse than the prior; the presence of this coefficient does not increase the predictive power. Although we were able to increase the predictive power by obtaining more statistically significant effect of past spending on interest rate, this increase is not enough to generate superiority of this regime over the regime of fiscal leadership. The monetary leadership model as a description of policy interactions in the UK is inferior to the model of fiscal leadership with posterior odds ratio of 5/1000.

Before we move further we note that, of course, we could improve the log marginal data densities for each regime by making priors close to previously estimated posteriors and iterating on this process. However, this adjustment leads to a relatively similar gain in predictive power for each regime and does not change the ranking of regimes. Although we have conducted this experiment to check robustness of results, we do not report results to save the space. We rather report results with similar priors where possible, in order to control for similar model complexities. We also demonstrate that data are informative, i.e. that posterior and prior distributions are different. These observations remain valid for all other regimes and countries we discuss further in the text.

We obtain very similar results for Sweden. Although for both Nash and monetary leadership regimes we obtain statistically significant and more concentrated estimates of r_{glag}, the marginal data density falls substantially. Past fiscal policy contains much less important information to explain monetary policy decisions. We also find that fiscal policy does not take monetary decisions into account.

The results for the US are very different. First, the Nash regime dominates the regime of fiscal leadership. As soon as we remove the contemporary spending term from the monetary policy reaction function, this reduces the number of potentially important variables but it also reduces the complexity of the model. Apparently, the second effect dominates and the log marginal data density rises, see Table 8. Table 6 reports the results. It is also more difficult to distinguish between the Nash regime and the regime of monetary leadership, see Table 8. Table 6 also suggests that, although the leadership coefficient in the fiscal reaction function g_r was not found to be statistically significant, its inclusion did not increase the complexity of the model, and the log marginal data density did not fall enough to firmly discriminate against the monetary leadership regime. However, the results in Table 8 were obtained in assuming that prior odds are identical for all three regimes. Any prior discrimination of the monetary leadership regime, for example on the ground that it is inconsistent with institutional structure in any of the three countries, will lead to posterior odds in favour either Nash or fiscal leadership regimes.

There is slight tension with the data in the estimate of r_{glag}. We have imposed a positive prior mean and restricted the distribution domain, but the data agree more with negative r_{glag}, which is difficult to reconcile with the theory[32] in the Nash regime. Even with restriction $r_{glag} \geq 0$ the resulting posterior odds signal in favour of the Nash regime, the support of this regime would become stronger, had we allowed $r_{glag} < 0$.

To summarise, this analysis shows that the regime of fiscal leadership is the most adequate description of the policy regime in the UK and Sweden, and the Nash regime describes best the evidence from the US in the class of strategic regimes. Note, however, that we could not rule out the possibility that fiscal authorities in the US behave non-strategically, using rules-based policy. In what follows, we continue in assuming possibility of strategic interactions in all three countries. If the US authorities use non-strategic fiscal rules, this does not prevent these rules to be consistent with some fiscal targets.

4.3 Robustness

In order to check robustness of obtained results, we conducted several exercises. Most of them are described above: we were increasing standard deviations of the priors and also changing their means. Although the posteriors were pulled in the direction of the prior means, such experiments generally led to a fall in log marginal data density because of the increased complexity of the model. If we consequently moved mean priors in the direction of the previously estimated posterior mean, then the log data density would increase. This increase however would not be big enough in order to change ranking between the regimes, and this exercise would constrain us in the ability to demonstrate how informative data were.

As an additional experiment, we reestimated the model for the US using the data from the end of 1987 when Alan Greenspan became the chairmen of the Fed. We present the results for policy parameters under the Nash regime in Figure 2.[33] The first two rows of subplots report the results for the post-1992 period, and the bottom two rows report the results for the whole data sample. It is apparent that the results are in very close agreement indeed. Further, had we included the Volker period (1980-1987) we would obtain very similar estimates of the policy coefficients (although ρ_r would increase even further), but there would be bigger data tension in estimates of the model structural parameters. In particular, the Calvo parameter would become implausibly high. As some studies suggest that there was a structural break in preferences of the Fed after the tough measures to combat high inflation were not needed any more, we omit this period from estimation.[34]

Generally, these results are in close agreement with those obtained in Favero and Monacelli (2005) and Muscatelli et al. (2004b), although we estimate parameters without assuming any regime changes. The results suggest that the monetary policy in the US (a) operates with high interest rate smoothing, (b) reacts actively to inflation. The fiscal policy in the US (a) operates with substantial smoothing of

[32] This means we were not able to obtain this sign in any simulations of the theoretical model under the assumtions discussed in this paper.

[33] All tables are available from the authors upon request.

[34] Further detais on estimation using the whole Volker-Greenspan period are available from the authors upon request.

fiscal instrument, (b) is countercyclical.

Table 8 reports that the regime of fiscal leadership is still dominated by the Nash regime. It again suggests that it is very difficult to distinguish between the Nash regime and the regime of monetary leadership. Again, given the very different frequency of the policy decisions, we might want to compute posterior odds assuming the prior odds in favour either Nash or fiscal leadership regimes. In this case we would be able to discriminate against the monetary leadership regime.

These results suggest that the results obtained using a small sample provide a good approximation of results for a longer data period, provided that the monetary policy objectives stay unchanged.

5 Conclusion

This paper identifies leadership regime in monetary-fiscal policy interactions in the three countries, UK, US and Sweden. We specify a small-scale, structural general equilibrium model of an open economy and estimate it using Bayesian methods. Unlike most of the empirical research we explicitly take into account the solvency constraint, faced by fiscal authorities, that plays an important role as an identification restriction. For the UK and Sweden we find strong empirical support for the hypothesis that the monetary and fiscal authorities act in a non-cooperative manner under the regime of fiscal leadership. We do not find evidence that the Fed in the US explicitly takes into account the fiscal stance when making decisions: instead the monetary and fiscal authorities in the US are likely to operate under the Nash regime, or they act non-strategically.

Additionally, we find that relative to the results for the two European countries fiscal policy in the US can be more adequately described by a feedback rule: we find that the non-systemic component in the fiscal policy reaction function plays substantially smaller role in the US than in the two European countries. Moreover, fiscal policy in the US does not induce as much cyclical adjustment as it does in the UK and Sweden.

These results aim to help to improve policy design, in particular they can help to design more flexible fiscal policy which will *not* counteract monetary policy because of different policy targets. It is important to know the leadership structure to avoid the ‘fight’ between the authorities, as the strength of such fight and its welfare consequences depend on the ability of authorities to lead in the policy game. We provide an empirical account of leadership interactions in the three economies that have retained independent monetary policy.

We also see this analysis as a first step that needs to be done if one is to analyse monetary-fiscal interactions in a multi-country setting, in particular in EMU. As the design of flexible fiscal policy is a question of particular importance in this case, further work could be to apply this approach to investigate leadership regime within monetary union. Unlike fiscal authorities in the US, fiscal authorities in European countries are bigger and more independent players. Not all fiscal authorities should necessarily be in the same leadership position with respect to the European Central Bank. We can use the approach suggested in this paper to construct testable hypotheses to identify the leadership regime in EMU. Knowing their ability to manipulate each other would help to improve institutional design.

Our results have to be qualified with respect to the structural model employed as it may be misspecified. We have simplified the model up to an absolute minimum that might have led to an exclusion of important transmission mechanisms. In particular, our conclusions about the policy regime are based on the assumption that all our countries use fiscal spending as a policy instrument to the same extent. We have ruled out the possibility of policy commitment while it might provide better empirical fit to the data. We also did not attempt to recover policy objectives, although the presence of some particular variables in empirical policy reactions suggests the existence of some particular targets like instrument smoothing. We leave these and similar issues for a future research.

Table 1: Parameter estimates for policy reaction functions available in the literature.

Monetary Reaction Function							
			UK[1]	UK[2]	Sweden[3]	Eurozone[4]	US[5]
1	smoothing	ρ_r	0.29	0.69	0.9	0.95	0.92
2	inflation	r_π	1.27	1.86	1.7	1.69	1.8
3	output	r_y	0.47	0.31	0.2	0.09	0.1
4	output growth	r_{dy}	–	–	0.13	0.15	–

Note:
[1]– Nelson (2003), IV, 1992-1997,
[2]– Martin and Milas (2006), ARCH, 1992-2003, quarterly data
[3]– Adolfson et al. (2005), Bayesian analysis, 1980-2004, quarterly data;
[4]– Smets and Wouters (2003), Bayesian analysis,
[5]– Clarida et al. (1998), GMM, 1972-1994, monthly data.

Table 2: Parameter Estimates: Policy Reaction Functions under Fiscal Leadership Regime, post-ERM period.

			Prior Distribution type	Prior Distribution mean	Prior Distribution s.d.	Estimated Maximum Posterior mode	Estimated Maximum Posterior s.d.	Posterior Distribution MH 5%	Posterior Distribution MH mean	Posterior Distribution MH 95%
	UNITED KINGDOM: Monetary Reaction Function									
1	smoothing	ρ_r	beta	0.8	0.05	0.9043	0.0226	0.8532	0.8905	0.933
2	inflation	r_π	norm	2	0.5	2.3882	0.3919	1.8146	2.4636	3.1143
3	output	r_y	norm	0.1	0.05	0.0910	0.0498	0.0078	0.0880	0.1700
4	past spending	r_{glag}	norm	0	0.05	-0.0139	0.0480	-0.0921	-0.009	0.0703
5	debt	r_b	norm	0	0.005	0.0011	0.0050	-0.0068	0.0010	0.0090
6	leadership	r_g	norm	0.02	0.015	0.0235	0.0069	0.0116	0.0236	0.0356
	UNITED KINGDOM: Fiscal Reaction Function									
7	smoothing	ρ_g	beta	0.85	0.05	0.9188	0.0223	0.8831	0.9116	0.9453
8	inflation	g_π	norm	-0.25	0.1	-0.2542	0.1000	-0.4125	-0.2550	-0.0926
9	output	g_y	norm	0	0.1	0.0068	0.0997	-0.1577	0.0027	0.1610
10	past interest rate	g_{rlag}	norm	0	0.01	0.0011	0.0100	-0.0143	0.0016	0.0192
11	debt	g_b	norm	-0.05	0.001	-0.0499	0.0010	-0.0515	-0.0499	-0.0482
	SWEDEN: Monetary Reaction Function									
1	smoothing	ρ_r	beta	0.8	0.05	0.9127	0.0199	0.8711	0.9038	0.94
2	inflation	r_π	norm	2	0.5	2.207	0.3074	1.7814	2.2452	2.7824
3	output	r_y	norm	0.1	0.05	0.0910	0.0499	0.0086	0.0907	0.1748
4	past spending	r_{glag}	norm	0	0.05	-0.0150	0.0491	-0.0908	-0.0102	0.0749
5	debt	r_b	norm	0	0.005	0.0023	0.0050	-0.0061	0.0024	0.0107
6	leadership	r_g	norm	0.05	0.025	0.0529	0.0107	0.0384	0.0567	0.0756
	SWEDEN: Fiscal Reaction Function									
7	smoothing	ρ_g	beta	0.85	0.05	0.8779	0.0394	0.8055	0.8656	0.9324
8	inflation	g_π	norm	-0.25	0.1	-0.2531	0.0999	-0.4154	-0.2583	-0.0918
9	output	g_y	norm	-0.1	0.05	-0.1007	0.05	-0.1889	-0.1014	-0.0248
10	past interest rate	g_{rlag}	norm	0	0.025	0.0117	0.0245	-0.0326	0.0096	0.0482
11	debt	g_b	norm	-0.04	0.005	-0.0433	0.0049	-0.0525	-0.0441	-0.0359
	UNITED STATES: Monetary Reaction Function									
1	smoothing	ρ_r	beta	0.8	0.05	0.8905	0.0265	0.8292	0.8712	0.9187
2	inflation	r_π	norm	2	0.25	1.8218	0.2563	1.4528	1.8665	2.2487
3	output	r_y	norm	0.1	0.05	0.0861	0.0501	0.0006	0.0842	0.1615
4	past spending	r_{glag}	beta	0	0.05	-0.012	0.0499	-0.1043	-0.0174	0.061
5	debt	r_b	norm	0	0.005	-0.0001	0.005	-0.0083	0.0000	0.0084
6	leadership	r_g	norm	0	0.1	-0.0042	0.0077	-0.0186	-0.0062	0.0097
	UNITED STATES: Fiscal Reaction Function									
7	smoothing	ρ_g	beta	0.9	0.05	0.9376	0.0357	0.8749	0.9204	0.9720
8	inflation	g_π	norm	-0.25	0.1	-0.2541	0.1	-0.4169	-0.2525	-0.0892
9	output	g_y	norm	0	0.1	0.0101	0.0994	-0.1458	0.0140	0.1630
10	past interest rate	g_{r_lag}	norm	0.05	0.05	0.0362	0.0504	-0.0477	0.0392	0.1199
11	debt	g_b	norm	-0.03	0.01	-0.0110	0.0088	-0.0262	-0.0150	-0.0022

Table 3: Selected Parameter Estimates: Fiscal Leadership Regime, post-ERM period

		Prior Distribution			Estimated Maximum Posterior		Posterior Distribution MH		
		type	mean	s.d.	mode	s.d.	5%	mean	95%
UNITED KINGDOM									
productivity	σ_a	invg	0.25	2	0.3671	0.0581	0.2827	0.3644	0.4612
world demand	σ_{y^*}	invg	0.25	2	0.9537	0.5755	0.3763	1.4574	2.0647
mark up	σ_η	invg	0.05	2	0.0229	0.0092	0.0129	0.0393	0.0613
monetary policy	σ_r	invg	0.1	2	0.0802	0.0151	0.0595	0.0903	0.1194
fiscal policy	σ_g	invg	0.25	2	0.3376	0.0317	0.2927	0.3478	0.4038
productivity	ρ_a	beta	0.97	0.02	0.9315	0.0384	0.8654	0.9199	0.9779
world demand	ρ_{y^*}	beta	0.5	0.25	0.7876	0.0611	0.6822	0.7775	0.8715
Calvo parameter	θ	beta	0.7	0.05	0.6594	0.0405	0.5784	0.6466	0.7121
labour utility	φ	norm	2	0.5	2.4337	0.4102	1.7874	2.4775	3.1082
consumption utility	σ	norm	2	1	2.2707	0.7073	1.4248	2.1396	3.0907
SWEDEN									
productivity	σ_a	invg	0.25	2	0.4358	0.0674	0.3505	0.4509	0.5568
world demand	σ_{y^*}	invg	0.25	2	0.8508	0.3673	0.4109	0.9806	1.4889
mark up	σ_η	invg	0.05	2	0.0232	0.0097	0.0111	0.0385	0.0736
monetary policy	σ_r	invg	0.1	2	0.0800	0.0130	0.0640	0.0897	0.1139
fiscal policy	σ_g	invg	0.25	2	0.7586	0.0760	0.6406	0.7727	0.892
productivity	ρ_a	beta	0.97	0.02	0.9622	0.0206	0.9263	0.957	0.9895
world demand	ρ_{y^*}	beta	0.75	0.125	0.9139	0.0181	0.8749	0.9068	0.9389
Calvo parameter	θ	beta	0.65	0.05	0.547	0.0398	0.4832	0.5473	0.6173
labour utility	φ	norm	2	0.5	2.8725	0.4134	2.1957	2.8634	3.5154
consumption utility	σ	norm	3	1.5	3.6613	1.0295	2.2706	3.6799	5.0855
UNITED STATES									
productivity	σ_a	invg	0.25	2	0.475	0.0742	0.3517	0.4738	0.5788
world demand	σ_{y^*}	invg	0.25	2	0.8232	0.2497	0.4775	1.2401	2.9396
mark up	σ_η	invg	0.05	2	0.0184	0.0051	0.0123	0.0217	0.0314
monetary policy	σ_r	invg	0.1	2	0.0462	0.0097	0.0336	0.05	0.0652
fiscal policy	σ_g	invg	0.25	2	0.1493	0.0146	0.13	0.1553	0.1822
productivity	ρ_a	beta	0.97	0.015	0.9599	0.0151	0.9305	0.9568	0.9826
world demand	ρ_{y^*}	beta	0.7	0.15	0.8967	0.0205	0.8605	0.8912	0.9269
Calvo parameter	θ	beta	0.65	0.05	0.7988	0.0330	0.7374	0.788	0.8432
labour utility	φ	norm	2	0.5	2.2745	0.3817	1.6984	2.2839	2.9625
consumption utility	σ	norm	3	1.5	5.3883	1.0989	2.2877	4.8215	6.4503

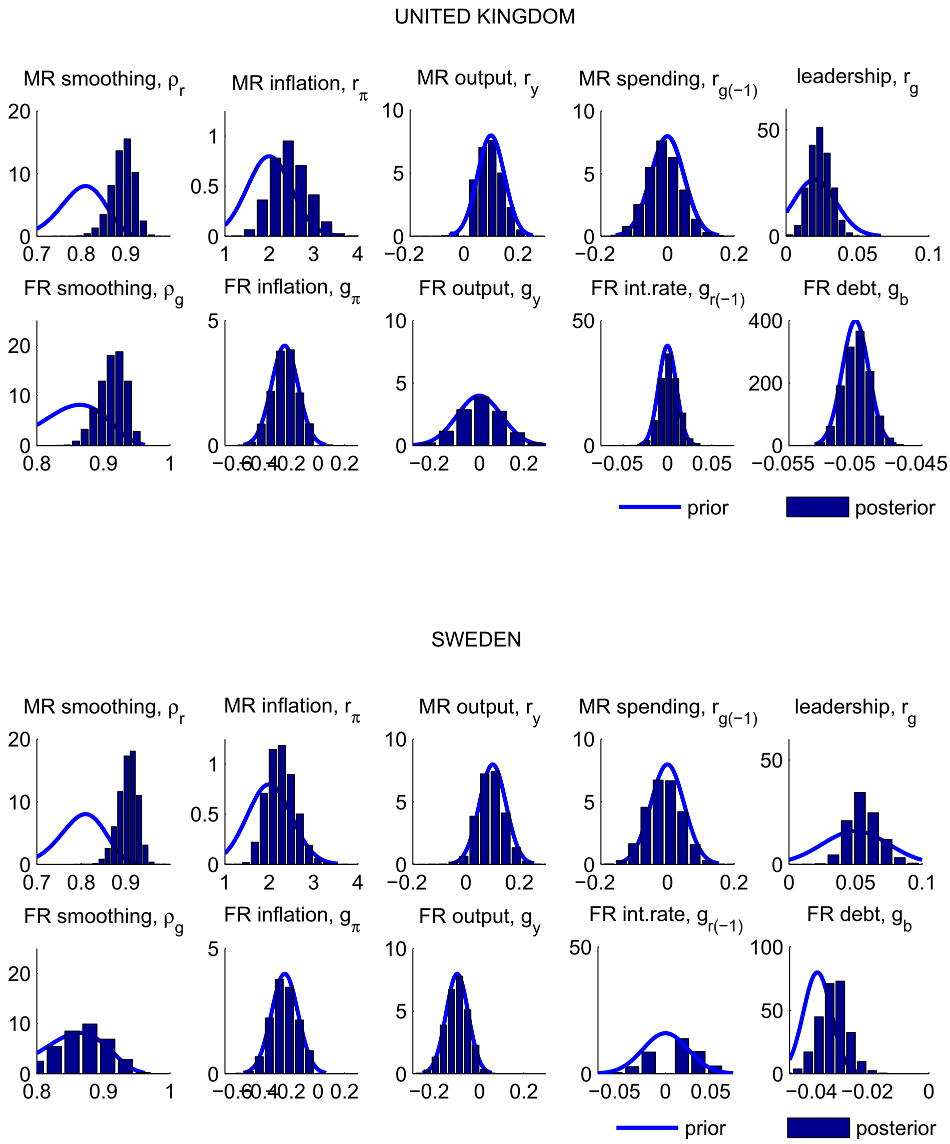

Figure 1: Prior and posterior distributions of policy parameters for the UK and Sweden for the post-ERM period.

Table 4: Parameter Estimates: Policy Reaction Functions in the United Kingdom for different leadership regimes

		Prior Distribution			Estimated Maximum Posterior		Posterior Distribution MH		
		type	mean	s.d.	mode	s.d.	5%	mean	95%
FISCAL LEADERSHIP: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.9043	0.0226	0.8532	0.8905	0.933
inflation	r_π	norm	2	0.5	2.3882	0.3919	1.8146	2.4636	3.1143
output	r_y	norm	0.1	0.05	0.0910	0.0498	0.0078	0.0880	0.1700
past spending	r_{glag}	norm	0	0.05	-0.0139	0.0480	-0.0921	-0.009	0.0703
debt	r_b	norm	0	0.005	0.0011	0.0050	-0.0068	0.0010	0.0090
leadership	r_g	norm	0.02	0.015	0.0235	0.0069	0.0116	0.0236	0.0356
FISCAL LEADERSHIP: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.85	0.05	0.9188	0.0223	0.8831	0.9116	0.9453
inflation	g_π	norm	-0.25	0.1	-0.2542	0.100	-0.4125	-0.255	-0.0926
output	g_y	norm	0	0.1	0.0068	0.0997	-0.1577	0.0027	0.1610
past interest rate	g_{rlag}	norm	0	0.01	0.0011	0.010	-0.0143	0.0016	0.0192
debt	g_b	norm	-0.05	0.001	-0.0499	0.0010	-0.0415	-0.0499	-0.0482
NASH: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.8672	0.0303	0.8090	0.8609	0.9119
inflation	r_π	norm	2	0.5	2.6040	0.4072	1.8914	2.5484	3.1994
output	r_y	norm	0.1	0.05	0.1561	0.0483	0.0728	0.1562	0.2336
past spending	r_{glag}	norm	0	0.01	0.0068	0.0098	-0.0101	0.0065	0.0231
debt	r_b	norm	0	0.005	0.0000	0.0050	-0.0083	0.0001	0.0073
NASH: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.85	0.05	0.9360	0.0220	0.8907	0.9212	0.9521
inflation	g_π	norm	-0.25	0.1	-0.2551	0.1001	-0.4258	-0.2577	-0.1145
output	g_y	norm	0	0.1	0.0108	0.0999	-0.154	0.0069	0.1744
past interest rate	g_{rlag}	norm	0.01	0.01	0.0114	0.0100	-0.0063	0.0104	0.0265
debt	g_b	norm	-0.05	0.001	-0.0498	0.0010	-0.0413	-0.0498	-0.0482
MONETARY LEADERSHIP: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.8749	0.0298	0.8160	0.8688	0.9195
inflation	r_π	norm	2	0.5	2.4647	0.4463	1.7019	2.4255	3.1857
output	r_y	norm	0.1	0.05	0.1495	0.0477	0.0684	0.1459	0.2182
past spending	r_{glag}	norm	0.02	0.015	0.0333	0.0143	0.0098	0.0328	0.0562
debt	r_b	norm	0	0.005	0.0000	0.0050	-0.0076	0.0000	0.0085
MONETARY LEADERSHIP: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.85	0.05	0.9303	0.0237	0.8887	0.9195	0.9521
inflation	g_π	norm	-0.25	0.1	-0.2568	0.1001	-0.4304	-0.2546	-0.0886
output	g_y	norm	0	0.1	0.0093	0.0999	-0.1616	0.0116	0.1719
past interest rate	g_{rlag}	norm	0	0.01	0.0013	0.0100	-0.0138	0.0016	0.0187
debt	g_b	norm	-0.05	0.001	-0.0498	0.0010	-0.0416	-0.0499	-0.0481
leadership	g_r	norm	-0.05	0.025	-0.0399	0.0251	-0.0861	-0.0431	-0.0057

Table 5: Parameter Estimates: Policy Reaction Functions in Sweden for different leadership regimes

		Prior Distribution			Estimated Maximum Posterior		Posterior Distribution MH		
		type	mean	s.d.	mode	s.d.	5%	mean	95%
FISCAL LEADESRSHIP: Monetary Reaction Function									
smoothing	ρ_r	beta	0.8	0.05	0.9127	0.0199	0.8711	0.9038	0.9400
inflation	r_π	norm	2	0.5	2.2070	0.3074	1.7814	2.2452	2.7824
output	r_y	norm	0.1	0.05	0.0910	0.0499	0.0086	0.0907	0.1748
past spending	r_{glag}	norm	0	0.05	-0.0150	0.0491	-0.0908	-0.0102	0.0749
debt	r_b	norm	0	0.005	0.0023	0.0050	-0.0061	0.0024	0.0107
leadership	r_g	norm	0.05	0.025	0.0529	0.0107	0.0384	0.0567	0.0756
FISCAL LEADESRSHIP: Fiscal Reaction Function									
smoothing	ρ_g	beta	0.85	0.05	0.8779	0.0394	0.8055	0.8656	0.9324
inflation	g_π	norm	-0.25	0.1	-0.2531	0.0999	-0.4154	-0.2583	-0.0918
output	g_y	norm	-0.1	0.05	-0.1007	0.0500	-0.1889	-0.1014	-0.0248
output growth	g_{dy}	norm	-0.2	0.1	-0.2027	0.1000	-0.3838	-0.215	-0.0556
past interest rate	g_{rlag}	norm	0	0.025	0.0117	0.0245	-0.0326	0.0096	0.0482
debt	g_b	norm	-0.04	0.005	-0.0333	0.0049	-0.0425	-0.0341	-0.0259
NASH: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.9119	0.0195	0.8765	0.9070	0.9382
inflation	r_π	norm	2	0.5	2.3314	0.3052	1.8687	2.3861	2.9245
output	r_y	norm	0.1	0.05	0.096	0.0500	0.0137	0.0992	0.1873
past spending	r_{glag}	norm	0.5	0.25	0.5395	0.1247	0.3624	0.5655	0.7785
debt	r_b	norm	0	0.005	0.0000	0.0050	-0.0078	0.0003	0.0084
NASH: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.85	0.05	0.9144	0.0306	0.8447	0.8959	0.9522
inflation	g_π	norm	-0.25	0.1	-0.2504	0.100	-0.4182	-0.2576	-0.0771
output	g_y	norm	-0.1	0.05	-0.0988	0.050	-0.1856	-0.101	-0.0207
past interest rate	g_{rlag}	norm	0	0.025	0.0147	0.0245	-0.0216	0.0145	0.0549
debt	g_b	norm	-0.04	0.005	-0.0392	0.0049	-0.0377	-0.0305	-0.0224
MONETARY LEADERSHIP: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.9111	0.0196	0.8715	0.9033	0.9411
inflation	r_π	norm	2	0.5	2.3842	0.3076	1.8748	2.4234	2.9106
output	r_y	norm	0.1	0.05	0.0960	0.0500	0.0102	0.0957	0.1692
past spending	r_{glag}	norm	0.5	0.25	0.5441	0.1248	0.3654	0.5649	0.7846
debt	r_b	norm	0	0.005	0.0000	0.005	-0.008	-0.0002	0.0081
MONETARY LEADERSHIP: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.85	0.05	0.9142	0.0310	0.8367	0.8925	0.9512
inflation	g_π	norm	-0.25	0.1	-0.2500	0.1000	-0.4133	-0.2545	-0.0783
output	g_y	norm	-0.1	0.05	-0.0988	0.0500	-0.1800	-0.1029	-0.0176
past interest rate	g_{rlag}	norm	0	0.025	0.0160	0.0245	-0.0244	0.0146	0.0536
debt	g_b	norm	-0.04	0.005	-0.0286	0.0050	-0.0380	-0.0299	-0.0221
leadership	g_r	norm	-0.05	0.025	-0.0332	0.0245	-0.0724	-0.0335	0.0055

Table 6: Parameter Estimates: Policy Reaction Functions in United States for different leadership regimes

		Prior Distribution			Estimated Maximum Posterior		Posterior Distribution MH		
		type	mean	s.d.	mode	s.d.	5%	mean	95%
FISCAL LEADESRSHIP: Monetary Reaction Function									
smoothing	ρ_r	beta	0.8	0.05	0.8905	0.0265	0.8292	0.8712	0.9187
inflation	r_π	norm	2	0.25	1.8218	0.2563	1.4528	1.8665	2.2487
output	r_y	norm	0.1	0.05	0.0861	0.0501	0.0006	0.0842	0.1615
past spending	r_{glag}	beta	0	0.05	-0.012	0.0499	-0.1043	-0.0174	0.0610
debt	r_b	norm	0	0.005	-0.0001	0.0050	-0.0083	0.0000	0.0084
leadership	r_g	norm	0	0.1	-0.0042	0.0077	-0.0186	-0.0062	0.0097
FISCAL LEADESRSHIP: Fiscal Reaction Function									
smoothing	ρ_g	beta	0.9	0.05	0.9376	0.0357	0.8749	0.9204	0.9720
inflation	g_π	norm	-0.25	0.1	-0.2541	0.1000	-0.4169	-0.2525	-0.0892
output	g_y	norm	0	0.1	0.0101	0.0994	-0.1458	0.0140	0.1630
past interest rate	g_{r_lag}	norm	0.05	0.05	0.0362	0.0504	-0.0477	0.0392	0.1199
debt	g_b	norm	-0.03	0.01	-0.0110	0.0088	-0.0262	-0.0150	-0.0022
NASH: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.8979	0.0249	0.8468	0.8878	0.9295
inflation	r_π	norm	2	0.25	1.7760	0.2563	1.4206	1.7923	2.2356
output	r_y	norm	0.1	0.05	0.0522	0.0438	-0.0166	0.0467	0.1216
past spending	r_{glag}	norm	0.025	0.0125	0.0206	0.0122	0.0018	0.0206	0.0404
debt	r_b	norm	0	0.005	0.0000	0.0050	-0.0079	0.0003	0.0089
NASH: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.9	0.05	0.9285	0.0330	0.8722	0.9164	0.9638
inflation	g_π	norm	-0.25	0.1	-0.2555	0.1000	-0.4187	-0.2542	-0.1009
output	g_y	norm	0	0.1	0.0086	0.0989	-0.1355	0.0178	0.1890
past interest rate	g_{rlag}	norm	-0.1	0.05	-0.1199	0.0498	-0.1998	-0.1189	-0.0301
debt	g_b	norm	-0.03	0.01	-0.0119	0.0088	-0.0259	-0.0150	-0.0032
MONETARY LEADERSHIP: *Monetary Reaction Function*									
smoothing	ρ_r	beta	0.8	0.05	0.8996	0.0246	0.8466	0.8883	0.9323
inflation	r_π	norm	2	0.25	1.7809	0.2555	1.3839	1.8021	2.2029
output	r_y	norm	0.1	0.05	0.052	0.0443	-0.0261	0.0440	0.1122
past spending	r_{glag}	norm	0.025	0.0125	0.0206	0.0122	-0.0006	0.0196	0.0400
debt	r_b	norm	0	0.005	0.0000	0.0050	-0.0088	-0.0001	0.0085
MONETARY LEADERSHIP: *Fiscal Reaction Function*									
smoothing	ρ_g	beta	0.9	0.05	0.9284	0.0329	0.8676	0.9157	0.9629
inflation	g_π	norm	-0.25	0.1	-0.2551	0.1000	-0.4085	-0.2550	-0.0978
output	g_y	norm	0	0.1	0.0093	0.0990	-0.1553	0.0140	0.1835
past interest rate	g_{rlag}	norm	0	0.05	-0.0202	0.0499	-0.098	-0.0185	0.0649
debt	g_b	norm	-0.03	0.01	-0.0122	0.0087	-0.0269	-0.0156	-0.0031
leadership	g_r	norm	0	0.1	-0.0649	0.0985	-0.2156	-0.0667	0.0996

Table 7: Variance Decomposition

			productivity a	world output y^*	mark up ε^π	monetary policy ε^r	fiscal policy ε^g
UK	inflation	π_H	0.059 [0.028,0.092]	0.129 [0.056,0.205]	0.006 [0.000,0.011]	0.549 [0.364,0.788]	0.258 [0.088,0.434]
UK	output	y	0.591 [0.318,0.876]	0.138 [0.020,0.267]	0.000 [0.000,0.000]	0.039 [0.009,0.063]	0.233 [0.058,0.404]
UK	interest rate	r	0.124 [0.045,0.212]	0.396 [0.209,0.586]	0.000 [0.000,0.000]	0.072 [0.036,0.0.113]	0.407 [0.148,0.593]
UK	spending	g	0.058 [0.022,0.095]	0.141 [0.059,0.203]	0.000 [0.000,0.000]	0.092 [0.052,0.145]	0.709 [0.611,0.813]
SW	inflation	π_H	0.049 [0.016,0.084]	0.175 [0.054,0.296]	0.001 [0.000,0.003]	0.126 [0.019,0.223]	0.648 [0.435,0.875]
SW	output	y	0.538 [0.282,0.776]	0.248 [0.045,0.416]	0.000 [0.000,0.000]	0.006 [0.002,0.011]	0.208 [0.011,0.360]
SW	interest rate	r	0.063 [0.011,0.104]	0.290 [0.075,0.462]	0.000 [0.000,0.000]	0.020 [0.006,0.029]	0.627 [0.391,0.880]
SW	spending	g	0.018 [0.004,0.029]	0.089 [0.027,0.112]	0.000 [0.000,0.000]	0.018 [0.006,0.028]	0.895 [0.841,0.962]
US	inflation	π_H	0.106 [0.015,0.191]	0.142 [0.058,0.225]	0.029 [0.010,0.052]	0.529 [0.375,0.743]	0.194 [0.068,0.297]
US	output	y	0.670 [0.463,0.903]	0.283 [0.078,0.469]	0.000 [0.000,0.000]	0.008 [0.004,0.013]	0.0384 [0.008,0.067]
US	interest rate	r	0.238 [0.169,0.328]	0.683 [0.602,0.773]	0.000 [0.000,0.000]	0.035 [0.008,0.059]	0.043 [0.010,0.072]
US	spending	g	0.235 [0.164,0.323]	0.335 [0.256,0.466]	0.000 [0.000,0.000]	0.053 [0.016,0.079]	0.377 [0.220,0.515]

Notes: The table reports posterior means and 90 percent probability intervals (in brackets) based on the benchmark prior for the post-1992 period

Table 8: Posterior Odds

Leadership Regime	Log Marginal Data Densities	Odds	Log Marginal Data Densities	Odds
	UK		Sweden	
Fiscal Leadership	-32.91	1.0000	-106.19	1.0000
Nash	-38.78	0.0028	-111.71	0.0040
Monetary Leadership	-38.14	0.0053	-112.73	0.0015
	US post-1992		US post-1987	
Fiscal Leadership	60.08	1.0000	72.22	1.0000
Nash	62.64	12.981	74.23	7.4875
Monetary Leadership	62.05	7.1687	74.11	6.6445

Note: The Table reports posterior odds of the hypothesis FL versus N or versus ML, assuming that the prior odds are one.

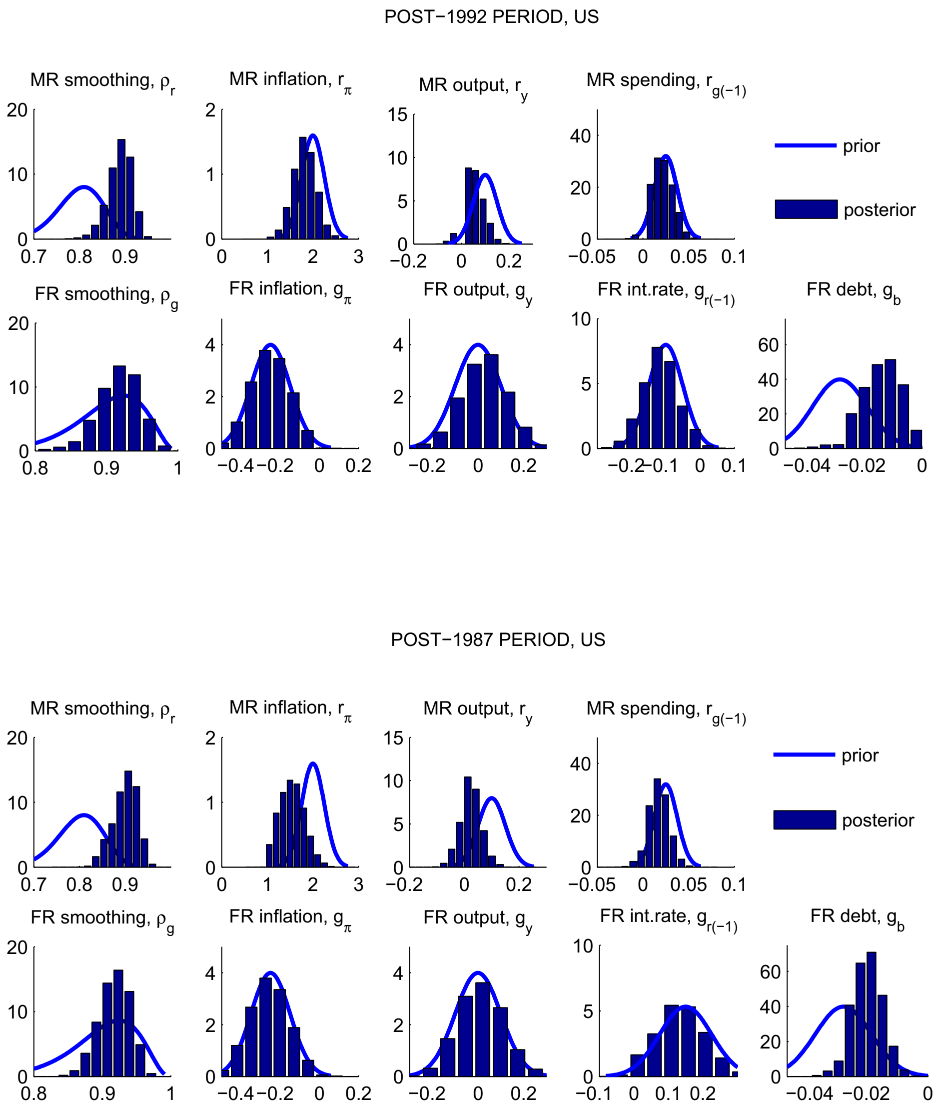

Figure 2: Prior and posterior distributions of policy parameters in the US for two different periods.

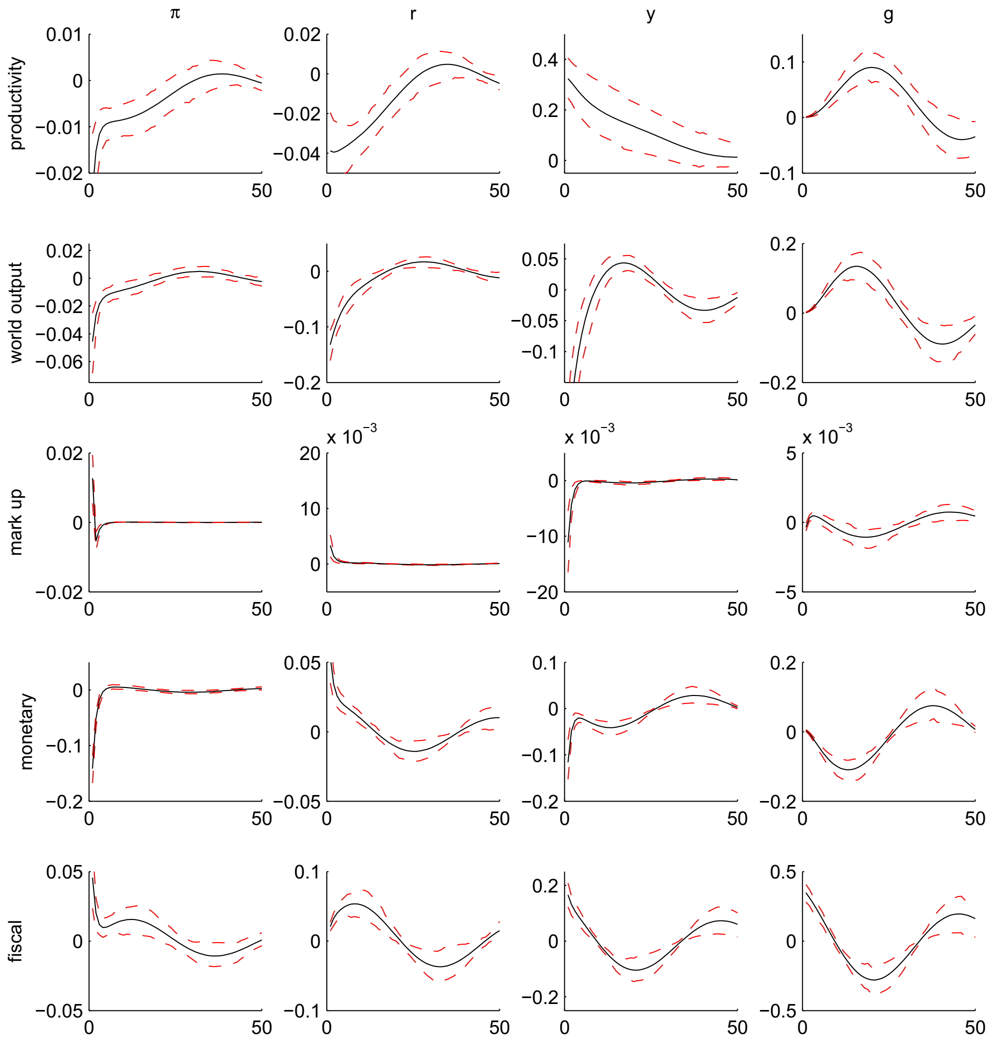

Figure 3: Impulse responses to shocks in the UK.

A Parameters and Calibration of Simple Model

Parameters in the model (2)–(4) and (6) are defined as:

$$
\begin{aligned}
\gamma &= \eta, \quad \omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1), \quad \chi = \zeta/(1-\zeta) \\
\lambda &= (1-\beta\theta)(1-\theta)/\theta, \quad \sigma_\alpha = \sigma/((1-\alpha)+\alpha\omega)
\end{aligned}
$$

where η is elasticity of substitution between foreign and domestic goods, $1/\sigma$ is intertemporal elasticity of substitution, α is openness of the economy, φ is labour elasticity, ε is elasticity of substitution between domestic goods, β is household discount rate, θ is probability of that price remains unchanged, and $\zeta = G/Y$ in the steady state. Simulated version of the Gali and Monacelli (2005, 2004) model is calibrated as follows:

β	σ	φ	η	θ	ε	α
0.99	1.0	3.0	1	0.80	6.0	0.30

These coefficients are close to those obtained empirically, and they allow to use theoretical welfare metrics (6).

The model in gaps form can be written as

$$
\begin{aligned}
x_t &= \mathcal{E}_t x_{t+1} - \frac{1}{\sigma_\alpha}(r_t - \mathcal{E}_t \pi_{Ht+1}), && (35) \\
\pi_{Ht} &= \beta \mathcal{E}_t \pi_{Ht+1} + \lambda((\sigma_\alpha + \varphi) x_t + \varphi g_t) + \varepsilon_t^\pi && (36) \\
b_{t+1} &= r_t + \frac{1}{\beta}\left(b_t - \pi_{Ht} + \frac{1-\tau}{B} g_t + \frac{1-C-\tau}{B} x_t\right) && (37) \\
x_t &= y_t - g_t && (38)
\end{aligned}
$$

with social welfare

$$
W_t^S = \frac{\epsilon}{\lambda}\pi_{Ht}^2 + (1+\varphi)(x_t + g_t)^2 + \frac{1}{\chi} g_t^2. \qquad (39)
$$

B Data

The next tables give data sources for the time series we used in estimation.

United Kingdom		
Variable	Description	ONS code
G	Current Expenditures on goods and services, CPNSA	GZSN
Y	Gross domestic product, CPSA	YBHA
R	Treasury bills 3 month yield, CPNSA	AJRP
P	GDP (Expenditure) ad market price defliator, CPSA	YBGB
B	Public sector finances: Net Debt, CPNSA	RUTN

Sweden		
Variable	Description	Sourse website
G	General government final consumption expenditures, CPNSA	www.ssd.scb.se
Y	GDP, CPNSA	www.ssd.scb.se
R	Swedish Treasury Bill maturity 3 months	www.riksbank.com
YR	Real GDP, SA	www.ssd.scb.se
B	Total Central Government debt, balance, CPNSA	www.ssd.scb.se

United States		
Variable	Description	Source
G	Government Current Consumption expendituures, SA	NIPA Table 3.1 (16)
Y	Gross Domestic Product, SA	NIPA Table 1.1.5 (1)
R	Market Yield on U.S Treasury securities at 3-month constant maturity, quoted on investment basis	www.federalreserve.gov
P	Gross Domestic Product Defliator, SA	NIPA Table 1.1.4 (1)
B	Treasury Liabilities	FOF Table L.4 (3)

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