FISCAL AND MONETARY POLICY INTERACTIONS: EMPIRICAL EVIDENCE AND OPTIMAL POLICY USING A STRUCTURAL NEW KEYNESIAN MODEL

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Abstract

This paper examines the interaction of monetary and fiscal policies using an estimated New Keynesian dynamic general equilibrium model for the US. In contrast to earlier work using VAR models, we show that the strategic complementarity or substitutability of fiscal and monetary policy depends crucially on the types of shocks hitting the economy, and on the assumptions made about the underlying structural model. We also demonstrate that countercyclical fiscal policy can be welfare-reducing if fiscal and monetary policy rules are inertial and not co-ordinated.

JEL Classification: E58, E62, E63.

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1 Introduction

Despite the existence of a vast literature on the robustness and optimality of monetary policy rules, relatively little attention has been given to the issue of monetary-fiscal interactions. A number of papers have examined the interdependence between fiscal and monetary policies using New Keynesian dynamic general equilibrium models[1], or game-theoretic models[2], but none of these models have been tested empirically. In this paper we jointly estimate a small econometric model and monetary and fiscal policy rules for the USA over the sample period 1970-2001. Our structural model is based on a conventional New Keynesian dynamic general equilibrium (DGE) model.

We use our estimated model to undertake a number of dynamic simulations, examining the responses of the endogenous variables (including the policy instruments) to both exogenous shocks in the structural model equations or unanticipated deviations from the policy rules. In addition, we conduct a number of historical (counterfactual) dynamic simulations, superimposing additional exogenous shocks to existing structural shocks and deviations from the monetary and fiscal rules, to examine how policy-makers might have reacted to different scenarios.

Overall, we find that the systematic responses of fiscal and monetary policy instruments to each other do tend to depend critically on the nature of the shocks hitting the economy. Whilst the New Keynesian structure of the model suggests a degree of substitutability between the two policy instruments in response to unexpected shocks in the policy rules, our historical simulations show that since the 1990s the two policy instruments have moved together in a more complementary way. To a large extent this is attributable to the nature of the underlying structural and policy shocks, which has changed in the 1990s relative to the 1980s. In particular demand shocks have become more predominant and the variance of deviations from policy rules has been reduced.

Finally, we conduct some normative analysis with our estimated models, to evaluate whether the introduction of endogenous fiscal policy rules markedly changes the optimal monetary policy rule. We thus compare our estimated monetary policy rule with others that can be derived from an optimal control exercise. Interestingly we find that countercyclical fiscal policy can be welfare-reducing in the presence of optimizing monetary policy-makers.

The rest of this paper is organized as follows. In the next section we will briefly survey the existing literature. In Section 3, we outline the structure of our estimated model and the empirical methodology. In Section 4, we report our estimates and discuss our dynamic simulations, while in Section 5 we focus on optimal policy. Section 6 concludes.

2 The Existing Literature

Dixit and Lambertini (2000, 2001) explore the interdependence between the fiscal authority and the central bank in a model where the latter has only partial control over inflation, which is also directly affected by the fiscal policy stance. They show that in equilibrium the two policy rules are complements when fiscal expansions have non-Keynesian (contractionary) effects on output and inflation. Buti, Roeger and in't Veld (2001) suggest that the specific form of interdependence between fiscal and monetary policies, i.e. the alternative between strategic substitutability and complementarity, should not necessarily be interpreted in terms of conflict or cooperation, and might be shock-dependent. In their model supply shocks unambiguously induce conflicting policies, whereas the opposite holds true for demand shocks.

Empirical contributions in this area are mainly based on panel data techniques and VAR analyses. Cross-sectional or panel data examine the relationship between fiscal and monetary policies over the cycle. Work by Mélitz (1997, 2000) and Wyplosz (1999) broadly supports the view that the two policies are strategic substitutes. Von Hagen, Hughes-Hallett and Strauch (2001) find that the interdependence between the two policymakers is asymmetric: looser fiscal stances match monetary contractions, whereas monetary policies broadly accommodate fiscal expansions. Muscatelli, Tirelli and Trecroci (2001) examine the interaction between fiscal and monetary policy instruments using conventional VAR and Bayesian VAR models for several G7 economies, and show that the fiscal shocks identified in the VAR have a significant impact[3]. They find that the result of strategic substitutability does not hold uniformly for all countries. Moreover, they report strong evidence that the linkage between fiscal and monetary policy has shifted post-1980, when fiscal and monetary policies became much more complementary. The main problem with the existing literature, and one of the key motivations for the present paper, is the following: without a structural model it is difficult to interpret the empirical correlations between the two policy variables. In the work of Mélitz (1997, 2000) and Wyplosz (1999) one cannot tell whether the correlation between the policy instruments over the cycle derives from systematic policy responses or from responses to structural or policy shocks. In the VARs estimated by Muscatelli, Tirelli and Trecroci (2001) the focus is on the reaction of policy instruments to other policy shocks, but it is notoriously difficult to interpret implicit policy reaction functions in VARs especially if the 'true' underlying structural model is forward-looking.

3 Empirical Methodology

As noted earlier, we estimate monetary and fiscal policy rules jointly with a small structural model. We use a small forward-looking New-Keynesian DGE model, comprising a dynamic IS model for output and a 'New Keynesian Phillips Curve' specification for inflation. We first outline the structural model and then consider the monetary and fiscal rules to be estimated.

3.1 A New-Keynesian Structural Model

Each consumer i is assumed to maximize an intertemporal utility function given by:

$$E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{1}{1-\rho} (C^i_{t+s} - H^i_{t+s})^{1-\rho} - \frac{\varepsilon^l}{1-\rho} (1 - N^i_{t+s})^{1-\rho} \right) \tag{1}$$

where C_t represents consumption of a basket of goods (to be defined below), H_t is an index of external habits, ρ is the coefficient of relative risk aversion, N_t is the level of employment. Normalising the consumer's time endowment to unity, $1 - N_{t+s}$ represents leisure, and ε^l is a shock to labour supply. Following Smets and Wouters (2002) we assume that habits depend on past aggregate consumption:

$$H^i_{t+s} = \lambda C_{t+s-1} \tag{2}$$

Consumers maximise (1) subject to their intertemporal budget constraint, which is expressed in real terms as:

$$(1/r_t) a^i_{t+1} = a^i_t - C^i_t + w^i_t N^i_t + D_t - T_t \tag{3}$$

where consumers hold their financial wealth (a^i_t) in the form of one-period state-contingent securities, which yield a return of r_t. Consumer disposable income consists of labour income $w_t^i N_t^i$ plus the dividends from the profits of the imperfectly competitive firms D_t, minus lump-sum taxes T_t.

This consumer problem has been explored extensively in the current literature using a variety of similar specifications (see for example Erceg, Henderson and Levin, 2000; Christiano, Eichenbaum and Evans, 2001; Leith and Malley, 2002; Smets and Wouters, 2002). Assuming that all consumers' preferences and their initial holdings of financial wealth are identical, the problem can be solved as a dynamic optimization problem and we can aggregate across consumers. Then, using the equilibrium condition for goods markets, given that we ignore investment and the external sector[4],

$$Y_t = C_t + G_t \tag{4}$$

we can derive the new-Keynesian IS curve by log-linearising the consumption Euler equation and (4) around the steady state. This yields (ignoring labour supply shocks) [5]:

$$\begin{aligned} \widehat{y}_t \;=\; & \frac{\lambda}{(1+\lambda)}\widehat{y}_{t-1} + \frac{1}{(1+\lambda)}E_t\widehat{y}_{t+1} \\ & -\frac{(1-\lambda)}{(1+\lambda)\rho}\left(\frac{\overline{C}}{\overline{\overline{Y}}}\right)\widehat{r}_t + \left(\frac{\overline{G}}{\overline{\overline{Y}}}\right)\widehat{g}_t - \frac{\lambda}{(1+\lambda)}\left(\frac{\overline{G}}{\overline{\overline{Y}}}\right)\widehat{g}_{t-1} \\ & -\frac{1}{(1+\lambda)}\left(\frac{\overline{G}}{\overline{\overline{Y}}}\right)E_t\widehat{g}_{t+1}, \end{aligned} \tag{5}$$

where 'hatted' lower-case variables represent percentage deviations from the steady state. 'Barred' variables denote steady-state values.

Turning next to the model of firms' pricing behaviour, we consider a standard model of monopolistic competition with sticky prices, as set out in Galí, Gertler and López-Salido (2001), and Leith and Malley (2002)[6]. Firms' production technology is assumed to be a simple Cobb-Douglas function of labour and capital for each consumption good variety z. Capital is assumed fixed and normalized to unity:

$$Y_t(z) = A(N_t(z))^{1-\alpha} \tag{6}$$

Total consumption is given by a standard CES function of imperfectly substitutable varieties of consumption goods z:

$$C_t^i = \left[\int_0^1 \left(C_t^i(z) \right)^{\frac{\theta}{\theta-1}} dz \right]^{\frac{\theta}{\theta-1}} \tag{7}$$

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

$$C_t^i(z) = \left[\frac{P_t(z)}{P} \right]^{-\theta} C_t^i \tag{8}$$

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

$$P = \left[\int_0^1 (P_t(z))^{1-\theta} dz \right]^{\frac{1}{1-\theta}} \tag{9}$$

Sticky prices are incorporated into this model, by assuming a Calvo pricing mechanism, with some proportion $(1-\xi)$ of firms adjusting their prices every period, and of these, a proportion (γ) indexing prices to inflation in the previous period[7], and the rest $(1-\gamma)$ setting their prices optimally to maximise expected discounted real profits[8], given technology, with a discount factor equal to that of consumers, β.

The firms' optimization, together with the assumptions about Calvo pricing and indexation, lead to an expression for price-setting which can be log-linearized to yield:

$$\begin{aligned} \widehat{\pi}_t \quad = \quad & \frac{\gamma}{\xi + \gamma(1-\xi(1-\beta))} \widehat{\pi}_{t-1} + \frac{\beta\xi}{\xi + \gamma(1-\xi(1-\beta))} E_t \widehat{\pi}_{t+1} \\ & + \frac{(1-\gamma)(1-\xi)(1-\gamma\xi)}{[\xi + \gamma(1-\xi(1-\beta))][1 + (\alpha/(1-\alpha))\theta]} \widehat{s}_t \end{aligned} \tag{10}$$

where $\widehat{s}_t$ is the percentage change from steady state of the labour income share, which is given[9] by $\widehat{s}_t = \widehat{w}_t + \widehat{n}_t - \widehat{y}_t$ as in Leith and Malley (2002)

Equations (5) and (10) constitute our structural model to be jointly estimated with the policy rules. It is important to note that in estimating (10), we treat real wages and employment as exogenous. Other recent contributions (Leith and Malley, 2002, Smets and Wouters, 2002) estimate wage equations, and adding a wage equation would have enabled us to consider the possibility of sticky wage dynamics. However, this would have also added to the complexity of the model.

It is worth noting that our model, in the tradition of many sticky-price DGE models, continues to treat taxation as non-distortionary (lump-sum). The lump-sum taxation assumption is one which is maintained by the majority of the recent DGE literature, including recent attempts to endogenise fiscal policy[10]. This is in contrast to the theoretical modelling approach[11] of Schmitt-Grohé and Uribe (2001), which explicitly assumes that governments only have access to distortionary income taxes or the inflation tax.

3.2 Monetary and Fiscal Rules

Our estimated monetary rule for the nominal interest rate $\widehat{i}_t$ follows a form similar to the standard[12] forward-looking Taylor rule specification which has become commonplace in the literature (see Clarida, Galí and Gertler, 1998, 2000; Muscatelli, Tirelli and Trecroci, 2002a; Giannoni and Woodford, 2002a, 2002b),

$$\widehat{i}_t = \phi_0 + \phi_1 E_t \widehat{\pi}_{t+q} + \sum_{i=0}^{m} \phi_{2i} \widehat{y}_t + \phi_3 \widehat{i}_{t-1} \tag{11}$$

where the rule also allows for interest-rate smoothing if $\phi_3 \neq 0$. In general we find that the best fit for this model is found for the specific case where $q = 1$[13].

As far as fiscal policy is concerned, we estimate simple backward-looking models. This captures the more realistic sluggish response of fiscal policy to macroeconomic variables, partly because of the frequency with which fiscal policy is set, but also because a major component of fiscal policy reaction will be due to automatic stabilizers. We estimate separate models for government spending and taxation, and in each case we also allow the variables to respond to output; we also include a stabilization mechanism that captures the impact of the lagged budget deficit to GDP ratio on current policy,

$$\widehat{g}_t = \sum_{i=1}^{m} \delta_{1i} \widehat{g}_{t-i} + \sum_{i=0}^{m} \delta_{2i} \widehat{y}_{t-i} + \psi_1 (bd)_{t-k} \tag{12}$$

$$\widehat{\tau}_t = \sum_{i=1}^{m} \varphi_{1i} \widehat{\tau}_{t-i} + \sum_{i=0}^{m} \varphi_{2i} \widehat{y}_{t-i} + \psi_2 (bd)_{t-k} \tag{13}$$

where bd_t is the budget deficit to GDP ratio. As we shall see below, we generally find that setting $k = 4$ for the deficit-correction term provides a good fit, whilst only a few lags (typically one or two) are needed on the autoregressive terms and on the output terms. Theoretical models of fiscal-monetary interactions postulate that the two policymakers' objective functions are defined over identical objectives, typically inflation and the output gap (Dixit and Lambertini 2000, 2001). In contrast with this approach, Taylor (2000a, b) estimates a fiscal reaction function where the fiscal stance index targets the output gap and the debt/GDP ratio, finding that countercyclical fiscal policy is almost entirely characterized by the working of automatic stabilizers. Similarly Bohn (1988) finds a relationship between primary fiscal *deficits* and the debt/GDP ratio.

Our fiscal rules, which allow for autoregressive components and for a delayed response to the output gap, are inspired to the work of Taylor (2000a, b). We have also chosen to estimate separate equations for taxes and expenditures, in order to characterize the effects of expenditures on the output gap. Our use of the deficit/GDP ratio as a 'correction mechanism' instead of the debt/GDP ratio is motivated by the fact that the former is found to be much more significant[14]. Because of the absence of the debt/GDP ratio from our fiscal rules our simulations do not include debt-deficit dynamics. This raises the question of whether our fiscal rules pin down the deficit/GDP ratio to a sustainable level. Below we demonstrate that in historical simulation our fiscal rules track the actual evolution of the debt-GDP ratio quite closely and imply a stable path for debt.

4 Empirical Results

4.1 Data and Scope of the Study

We now turn to the empirical results[15]. We estimate the New-Keynesian model jointly with the monetary and fiscal rules, comprising (5), (10), (11), (12) and (13). The model is estimated on US data. Note that the spending data excludes transfers. Although our data includes interest payments, the behaviour of $\widehat{g}_t$ appears very similar when one uses data excluding interest payments. The sample period is 1970(1)-2001(2). Although an estimated fiscal reaction function on quarterly data may seem unrealistic as a description of discretionary fiscal policy, it is worth bearing in mind that these fiscal rules will largely capture (as in Melitz, 1997) the effects of automatic stabilizers.

The data have been seasonally adjusted (X-11 method), and to capture the spirit of the NK models as log-linearizations, the data are transformed so that the variables are expressed in deviations from the 'steady state'[16]. Real variables are de-trended[17], whilst the series on inflation and the nominal interest rate are demeaned. Note that as the inflation rate and interest rate always enter the model together, all the equations are 'balanced' in terms of the levels of integration of the dependent and explanatory variables.

4.2 Estimation Methods

The New Keynesian model consists of equations that are non-linear in parameters. Following Hansen (1982) a model with rational expectations suggests some natural orthogonality restrictions that can be used in the generalized methods of moments (GMM) framework. Thus, (5), (10), (11), (12) and (13) make up a system of linear and non-linear equations of the form:

$$\mathbf{y}_t = \mathbf{f}(\boldsymbol{\theta}, \mathbf{z}_t) + \mathbf{u}_t \tag{14}$$

where $\mathbf{y}_t$ is the vector of dependent variables, $\boldsymbol{\theta}$ is the $(a \times 1)$ vector of unknown parameters to be estimated, and $\mathbf{z}_t$ is the $(k \times 1)$ vector of explanatory variables. The GMM approach is based on the fact that $\widetilde{\boldsymbol{\theta}}$, the true value of $\boldsymbol{\theta}$, has the property $E[\mathbf{h}(\widetilde{\boldsymbol{\theta}}, \mathbf{w}_t)] = 0$, where $\mathbf{w}_t \equiv (\mathbf{y}_t', \mathbf{z}_t', \mathbf{x}_t')$, and $\mathbf{x}_t$ is an $(r \times 1)$ vector of instruments that are correlated with $\mathbf{z}_t$. GMM then chooses the estimate $\boldsymbol{\theta}$ so as to make the sample moment as close as possible to the population moment of zero. In our estimates we use four lags of the dependent variables and the exogenous variables, plus four lags of commodity price inflation as instruments. The validity of these instruments can be tested using Hansen's J-test, which is distributed as a $\chi^2(r - a)$ statistic under the null of valid orthogonality conditions.

GMM or IV estimation has been used by a number of authors to estimate NK models[18]. One problem is that the estimated IS and NKPC equations are highly nonlinear in parameters, and the rank condition for identification is not met unless a number of parameters in these two equations are fixed. We follow Galí, Gertler and López-Salido (2001) and Leith and Malley (2002) in imposing restrictions on some of the parameters. We fix $\theta = 4$, implying a price-mark-up[19] of 30%, $1 - \alpha = 0.6$ in the NKPC equation. Moreover, in the output equation we impose the restrictions that $\left(\overline{C}/\overline{Y}\right)$ and $\left(\overline{G}/\overline{Y}\right)$

equal their sample average value.

However, it is worth noting that even with these restrictions, since there are no cross-equation restrictions, the parameter estimates are poorly defined. Therefore, as we note below, we had to impose additional restrictions in order to obtain parameter estimates that were statistically well-defined.

In a sense, the GMM approach consists of fixing some parameters based on theoretical motivations, or earlier empirical studies, and estimating some parameters freely. In this context, it might be better to recognize at the outset that the researcher is bringing some prior information to bear on the estimation exercise by making such priors explicit. This suggests that a Bayesian approach might be a more natural vehicle to estimate New Keynesian structural models, and this is the approach followed in Smets and Wouters (2002). In a current extension of this work, we are examining how our results change if one uses a Bayesian estimation approach.

The policy rules are more straightforward. For the monetary policy rule we find that a single lead for inflation and a zero lag on output fit the data best. For the fiscal rules we find that up to two lags on output and the AR term provided an adequate characterization of the fiscal variables, in addition to setting $k = 4$ so that the fiscal variables react to the previous year's budget deficit/GDP ratio.

4.3 Model Estimates

Table 1 below reports the estimated New Keynesian model using GMM over the full sample period. In estimating the NK output equation, we use the *ex ante* real interest rate ($\widehat{r}_t = \widehat{i}_t - E_t\widehat{\pi}_{t+1}$). As noted above, we found that the parameter estimates were relatively imprecise, even after imposing the restriction suggested by theory that $(\lambda, \beta, \gamma, \xi)$ should all be less than unity. We therefore conducted a grid search and fixed the discount factor at 0.89, a value consistent with that estimated by Galí, Gertler and López-Salido (2001). This improved the precision of the other parameter estimates.

Table 1: Model Estimates

Parameter	Estimate	Parameter	Estimate
λ	0.917 (0.026)	δ_{11}	0.881 (0.056)
ρ	1.528 (0.043)	δ_{12}	–
β	0.89 (–)	δ_{20}	0.607 (0.275)
ξ	0.517 (0.113)	δ_{21}	−0.794 (0.284)
γ	0.776 (0.169)	δ_{22}	–
ϕ_1	0.150 (0.044)	φ_{11}	0.930 (0.042)
ϕ_{20}	0.166 (0.048)	φ_{12}	–
ϕ_3	0.874 (0.041)	φ_{20}	0.422 (0.283)
		ψ_1	−2.283 (0.412)
		ψ_2	1.160 (0.340)

The R-squared for the output equation was 0.98, for the inflation equation 0.98, for the monetary policy rule 0.89, and for the government spending and taxation rules 0.92 and 0.67 respectively. Hansen's J-test has a value of 116.5, which is insignificant as it is distributed as a $\chi^2(125)$ statistic under the null of valid instruments[20]. The restrictions imposed on the model's parameters can be tested using the Newey-West D test, based on the differences in the criterion function between the unrestricted and restricted models, which in our case has a value of 0.458 and is distributed as a $\chi^2(4)$ under the null of valid restrictions.

Turning first to the structural equations, the estimated NKPC parameters are comparable to those obtained for the USA by Leith and Malley (2002) and by Galí, Gertler and López-Salido (2001), and are also consistent with similar estimates for the euro area by Smets and Wouters (2002) using Bayesian estimation techniques. The Calvo parameter ξ indicates on average an adjustment period of just over 2 quarters, but with a large proportion of firms indexing prices. By using an additive habit formulation, in contrast to Leith and Malley, we find significant habit persistence in US consumption behaviour, consistent with a coefficient of about 0.5 on lagged output. This conforms better with earlier empirical work on US consumption behaviour, which suggests considerable inertia. It should also be noted that, if one estimates the unrestricted form of the NK model without identifying the individual structural parameters from the parameter convolutions, the lagged output term in the IS equation is highly significant. The estimate for the coefficient of relative risk aversion ρ is not dissimilar to that estimated for the Euro area by Smets and Wouters (2002)[21].

Turning to our policy rules for the US, we see that, as is common with estimated interest rate reaction functions[22], there is a high degree of interest-rate inertia, $\phi_3 = 0.874$. The long-run response to inflation, even when the forward-looking policy rule is estimated over the full sample, is greater than unity (1.19), and the response to output is also significant (a long-run response of 1.317). Had we estimated the policy rule over the post-1980 sample, we would have found an even greater response to inflation, with the response on output dependent on the actual sub-sample used[23]. The form of the fiscal rules is very similar, except that the tax rule only responds to contemporaneous output. Interestingly, the government spending response to the contemporaneous output gap is not stabilizing, but taken together, the coefficients δ_{20} and δ_{21} imply a negative effect of the output gap on government spending. This short-run effect on government spending is smaller than that on taxation, which reacts more strongly and positively to the output gap. The magnitude of the taxation effect is more similar to that estimated by Taylor (2000a,b) for the US budget deficit. Both fiscal rules indicate a strong persistence, but a tendency for a correction to the previous year's deficit to GDP ratio. Given the short lags on the fiscal rules, the responses to output probably capture automatic stabilizer effects, with the correction to the deficit capturing discretionary policy, which acts with a longer (1-year) lag.

4.4 Dynamic and Stochastic Simulations

4.4.1 Dynamic Simulations

Having estimated our structural model, we now perform a number of dynamic simulation experiments to investigate the way in which fiscal and monetary policies interact in this simple NK model.

We perform three different simulation experiments[24]:

(i) A dynamic model solution, shocking each structural equation and policy equation in turn, to simulate the effects of a structural or policy shock on the other endogenous variables in the model. Essentially this involves simulating the model without any reference to actual data. The two exogenous variables in the labour-income share, $\widehat{s}_t$, i.e. the real wage ($\widehat{w}_t$) and employment ($\widehat{n}_t$), are simulated as follows. We assume that nominal wages are indexed to inflation with a one-period lag, whilst employment is determined by a log-linearization of the short-run production technology (6).

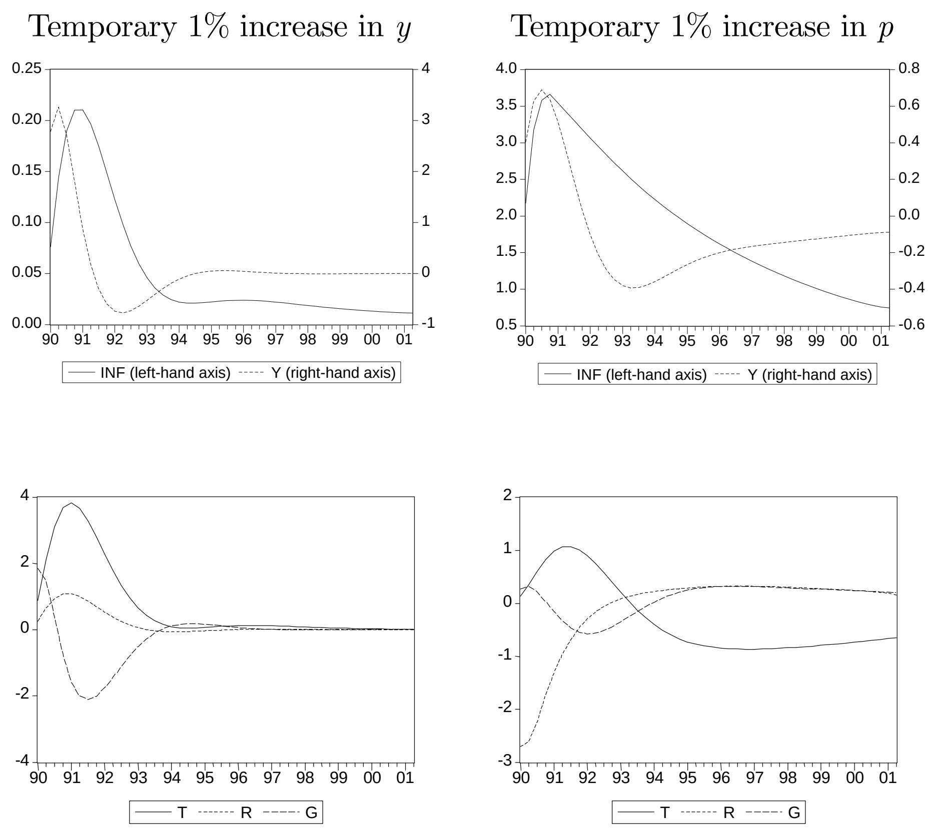
(ii) A historical simulation, setting all the policy shocks (deviations from systematic policy) equal to zero for part of our sample, but maintaining the implicit structural shocks implied by the residuals of the output and inflation equations, and using actual data on the exogenous variables (real wages and employment)[25]. We then examine the implications for the policy variables, inflation and output. This allows us to see the extent to which the deviations from policy can be really seen as 'destabilising', or whether they might in fact be interpreted differently.

(iii) A 'what if' historical simulation, in which we superimpose a policy shock (deviation from systematic policy) on a historical scenario, maintaining all the structural and policy shocks in place.

This will allow us to see the extent to which the observed co-movements in the fiscal and monetary instruments are due to the systematic policy rules, or are driven by the exogenous variables, or the structural and policy shocks.

The historical simulations involve us first creating a simulation base by producing a dynamic model forecast for part of our sample. We choose to do this over the latter part of the sample (from 1990(1) onwards), as it was a period in which both the structural and policy shocks were rather smaller than in the 1970s and 1980s. All the historical simulations will then be reported as deviations from this simulation base to see how the additional elements affect the model's simulation run. The results of the dynamic model solution are shown[26] in Figure 1. The results of historical simulation (ii) (no policy deviations) are shown in Figure 2. For reasons of space, the results of historical simulation (iii), adding a further shock to the historical shocks, are not shown in detail[27].

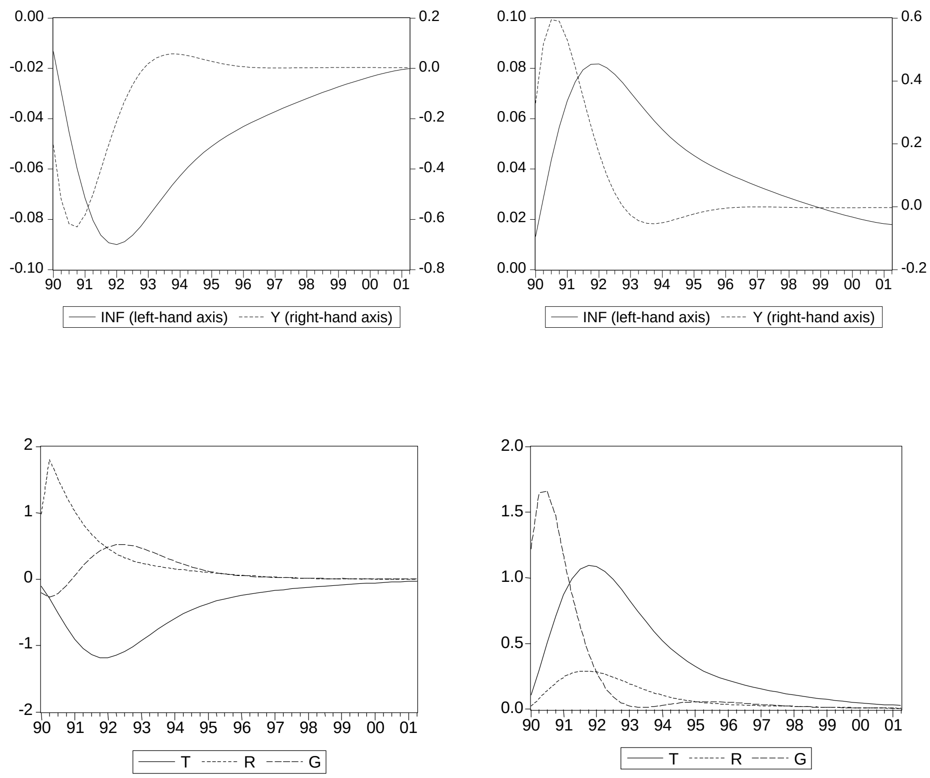
Figure 1: Dynamic Simulation (i) - Model Responses to Temporary Shocks



Note: The temporary shocks on the model are a 1% increase in the period of the shock, followed by an gradual reduction with an AR parameter of 0.5, until the shock disappears 1 year after its impact.

Figure 1 (cont'd): Dynamic Simulation (i) - Model Responses to Temporary Shocks

Temporary 1% increase in i | Temporary 1% increase in g



Note: The temporary shocks on the model are a 1% increase in the period of the shock, followed by an gradual reduction with an AR parameter of 0.5, until the shock disappears 1 year after its impact.

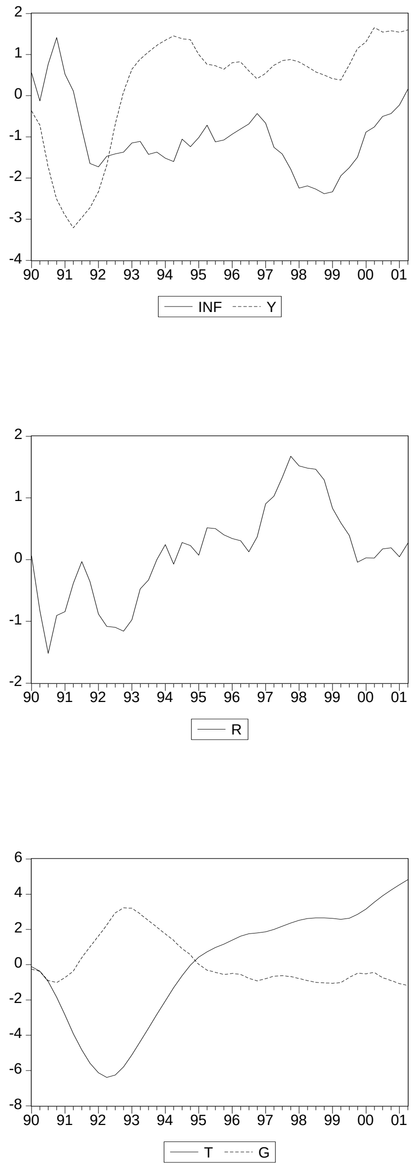
Before turning to the analysis of fiscal-monetary interactions, we can make some general remarks about the simulation properties of the estimated model. By looking at Figure 2 we see that by omitting the deviations from the systematic policy rules, the model accentuates the recession in the early 1990s. This in turn induces a cyclical adjustment in output and inflation (and hence the policy variables). It seems difficult to believe that such policy deviations can be interpreted as 'policy errors'. A more plausible interpretation is that interest-rate rules display non-linearities, either of the form of non-linear reactions to policy targets[28], or in the form of a variable interest-rate smoothing term, which causes the authorities to switch from periods of activism to periods of a 'wait and see' attitude. Alternatively, one might argue that estimated 'policy errors' might capture relatively frequent shifts in systematic policy rules. Clarida, Galí and Gertler (1998, 2000) highlight one particular shift in the monetary policy rule around the early 1980s, but Muscatelli, Trecroci and Tirelli (2002a) provide evidence that shifts may have occurred even after the Volcker years. Favero and Monacelli (2003) identify a number of different fiscal regimes in the USA.

We now look at the reactions of monetary and fiscal policy to various types of shock in the dynamic simulations (Figure 1). Following an output shock it is apparent that monetary and fiscal policies move in a similar direction (are complements), but tend to be slightly out of phase for the first few quarters for the NK model. In contrast, the systematic response of the two policies tends to be in the opposite direction (are substitutes) following an unanticipated deviation in either policy rule or in the case of an inflation shock.

Historical simulation (ii) shows that, for the 1990s, fiscal and monetary policies have become more complementary (Figure 2). This result confirms earlier evidence on complementarity during the 1990s obtained using VARs (see Muscatelli, Tirelli and Trecroci, 2001). Superimposing an 'as if' output and inflation shock on the historical simulations, in simulation (iii) does not markedly alter the picture supporting complementarity between fiscal and monetary policy over the cycle.

Another interesting aspect of the simulations is that, given the inertia effects in the monetary policy rule, the complementarity between policy instruments is only apparent for part of the adjustment process to an output shock in Figure 1. After an inflation shock (because of its impact on real interest rates and the inertia in monetary policy) the two instruments do tend to be out of phase and tend to be substitutes for a long period of time.

Figure 2: Historical Simulation (ii) 1990(i)-2001(ii) - All variables shown as deviations from baseline values

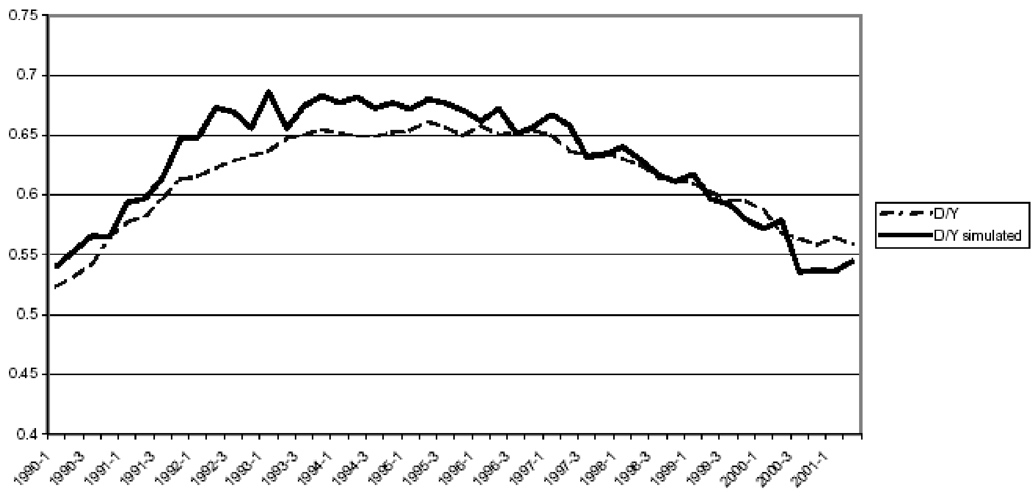


The intuition behind this is simple: with the real interest rate targeting inflation as well as output, whilst the fiscal rules depend essentially on output, the inflation shock triggers the reaction of monetary instruments, whereas fiscal variables simply adjust, with a lag, to the output effects of monetary contraction.

We can also use historical simulation (ii) to see how policy instruments should have deviated from a baseline simulation in which all the policy deviations were included. Here the NK model seems, at least for the early 1990s, to suggest a path for real interest rates which is close to the baseline. With the exception of the period 1997(2)-1998(4), where the policy rule suggests that interest rates should have been higher, the policy rule tracks the baseline quite closely. This suggests that US monetary policy was too expansionary in the late 1990s from the viewpoint of an NK model where the structural shocks are retained. As far as fiscal policy is concerned, the estimated model suggests a systematic deviation of government spending and taxation from the policy rule in the period 1992-94, which is probably connected to the deficit correction phase. In the longer run, the US fiscal rules capture the behaviour of fiscal policy in the late 1990s more precisely.

As discussed earlier, given that we do not model the feedback from debt accumulation to spending and taxation, one issue is whether our fiscal rules imply a dynamic path for government debt which is (a) sustainable and, in the case of the historical simulations, (b) close to the actual path. To verify this, we simulate the path of the debt/GDP ratio that is implied by the fiscal and monetary policy rules[29]. Figure 3 plots the actual path of the US debt-GDP ratio post-1990 and the simulated path resulting from historical simulation (ii). It is apparent that the model tracks the actual path of debt reasonably closely, whilst the simulated debt series captures the delayed adjustment in the deficit in the early to mid-1990s which is apparent in Figure 2.

Figure 3: Debt/GDP Dynamics for Historical Simulation (ii)



Overall, the general pattern which emerges from our simulations is one where fiscal and monetary policy are more complementary following output shocks than following policy shocks or inflation shocks. Historical simulations for the 1990s tend to support a greater complementarity for the two policy instruments in the USA, with a greater propensity for taxation to act in concert with real interest rates. We now verify whether these patterns for the 1990s may be due to a specific configuration of shocks during that period, by conducting some stochastic simulations.

4.4.2 Stochastic Simulations

To verify the importance of the structural and policy shocks in determining the pattern of fiscal and monetary responses over the whole sample period relative to the role of the structural models, we now conduct some stochastic simulations. Essentially we simulate the estimated models using 200 different replications of the shocks, which are drawn using the estimated variance-covariance matrix of residuals. In order to demonstrate that the main factor which seems to have changed in the relationship between monetary and fiscal policy during this period is the correlation between the underlying shocks, we repeat this procedure for three different replications of the shocks. For the first set of stochastic simulations we use the estimated variance-covariance matrix of residuals for the full sample. We then repeat the simulations using a variance-covariance matrix of shocks over the first 19 years of the sample (up to 1989), and then using the estimated variance-covariance matrix of residuals for the 1990s.

The correlation between the monetary and fiscal instruments for the average of the replications is reported in Table 2.

Table 2: Stochastic Simulations Using Estimated Variance-Covariance Matrix of Structural and Policy Shocks

Policy Instruments	Full Sample	1970-89	1990s
$\widehat{g}_t, \widehat{r}_t$	0.014 (-)	0.763 (-)	-0.401 (+)
$\widehat{\tau}_t, \widehat{r}_t$	-0.163 (-)	-0.387 (-)	0.298 (+)
$\widehat{\tau}_t, \widehat{g}_t$	0.463	0.242	0.538

The (-) sign indicates that the fiscal and monetary instrument are acting as strategic substitutes, whilst the (+) indicates that they are acting as strategic complements.

The pattern of results is striking: the tendency for fiscal and monetary policy to become strategic complements seems to be a phenomenon restricted to the 1990s with the full-sample estimates and especially the 1970-1989 period showing a tendency for fiscal and monetary policy to move in opposite directions over the cycle. Thus, the suggestion that monetary and fiscal policy have been acting in a more complementary way since the 1990s is probably just a function of the particular configuration of shocks during that period rather than due to the structure of the model, or the estimated variance-covariance matrix of the shocks over the full sample period.

5 Optimal Monetary Policy

So far our analysis has been strictly positive, focusing on the degree to which fiscal and monetary policy have acted in concert over the cycle. The question now is: how much does it matter for stabilization policy? Whilst a great deal of attention has been given in recent years to the problem of designing optimal monetary policy rules in the context of forward-looking models (see Giannoni and Woodford, 2002a for a comprehensive survey), very little attention has been paid to the issue of monetary-fiscal policy interactions over the cycle. Does a countercyclical fiscal policy assist the monetary policy-maker or does the lack of co-ordination between the two policies, especially when both are highly inertial, cause a reduction in welfare?

We now use our estimated models to consider how the introduction of endogenous fiscal rules might impact on monetary policy. We conduct two types of experiment. First we compute some optimal monetary policy rules, and consider how these are affected by the presence of endogenous fiscal rules. Second, we consider how our optimal monetary rules differ from the rules that emerge from an optimization exercise, and again verify what impact assuming endogenous fiscal policy has on the divergence between the estimated and optimal monetary policy rule. We compute the optimal rule using the standard optimal control approach[30] (see Currie and Levine, 1993, Rudebusch and Svensson, 1999).

Giannoni and Woodford (2002a,b) provide an alternative perspective to optimal monetary policy rules. Whilst rules derived using an optimal control approach are necessarily optimal vis-à-vis a particular pattern of exogenous disturbances, Giannoni and Woodford show that certain classes of monetary policy rules, such as our estimated rule, involving both a forward-looking element and an inertial element[31], turn out to be particularly robust to different types of exogenous disturbances. Whilst this suggests that considerable care has to be exercised in defining rules as optimal when they have not been tested for robustness against a variety of different stochastic disturbances[32], our aim here is more limited. The optimal control exercises are merely benchmarks to examine what difference introducing endogenous fiscal policy makes to monetary policy reactions. Whether our estimated policy rules turn out to be optimal from a wider perspective is an issue that we leave to further work.

We derive our optimal monetary rules using the following intertemporal loss function for the monetary authorities (see e.g. Rudebusch and Svensson, 1999):

$$L = \sum_{j=0}^{\infty} \left(\widehat{\pi}_{t+j}^2 + \Phi_1 \widehat{y}_{t+j}^2 + \Phi_2 (i_{t+j} - i_{t+j-1})^2 \right) \tag{15}$$

As our model has forward-looking variables, we need to consider whether to focus on the optimal policy under pre-commitment or discretion. We focus on the optimal policy under pre-commitment. Again, as we are simply benchmarking our estimated and optimal policy rules under two different scenarios (endogenous and exogenous fiscal policy), this choice should not markedly affect our results.

We consider the monetary policy responses under two alternative structural shocks (a temporary output shock and a temporary inflation shock) using both the estimated monetary policy rule, and three possible optimal policy rules, corresponding to different values of the parameters of the loss function (15):

(i) Optimal Policy Rule I: $\Phi_1 = \Phi_2 = 1$ (equal weights on loss function terms).

(ii) Optimal Policy Rule II: $\Phi_1 = 1, \Phi_2 = 0.5$ (lower weight on interest-rate adjustment)

(iii) Optimal Policy Rule III: $\Phi_1 = 0.1, \Phi_2 = 0.5$ (low weight on output).

For each shock and the four different types of monetary policy rule, we consider two scenarios: first, one where the endogenous fiscal policy equations are switched on in the model simulations; and second, one where fiscal policy is kept exogenously fixed.

Table 3 shows the loss function value under each scenario and each structural shock, for the four policy rules. For the estimated policy rule, the loss column shows three values, indicating the losses under the loss function parameterizations underlying the three optimal policy rules. We also show the detailed interest rate responses under the four monetary policy rules for both fiscal policy scenarios under one shock. Figures 4 shows the interest-rate response to an output shock assuming endogenous fiscal policy, and Figures 5 is the corresponding simulations keeping fiscal policy exogenously fixed.

Figure 4: Endogenous Fiscal Policy, Interest Rate Reaction to Output Shock

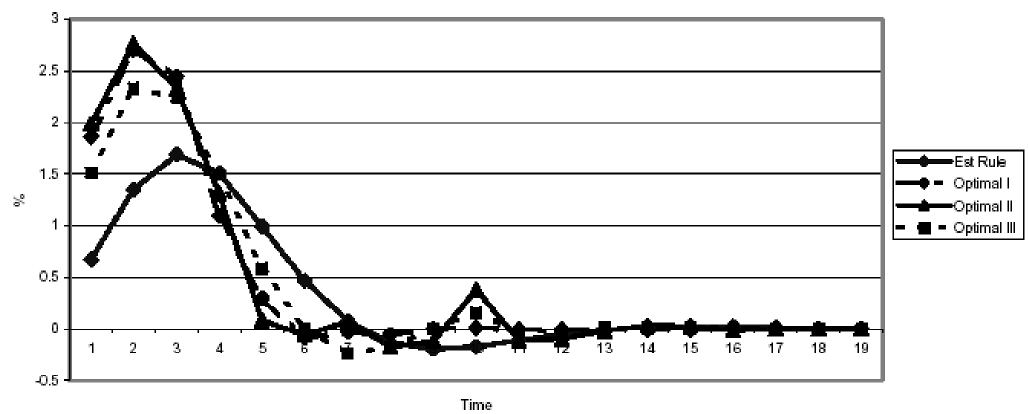


Figure 5: Exogenous Fiscal Policy, Interest Rate Reaction to Output Shock

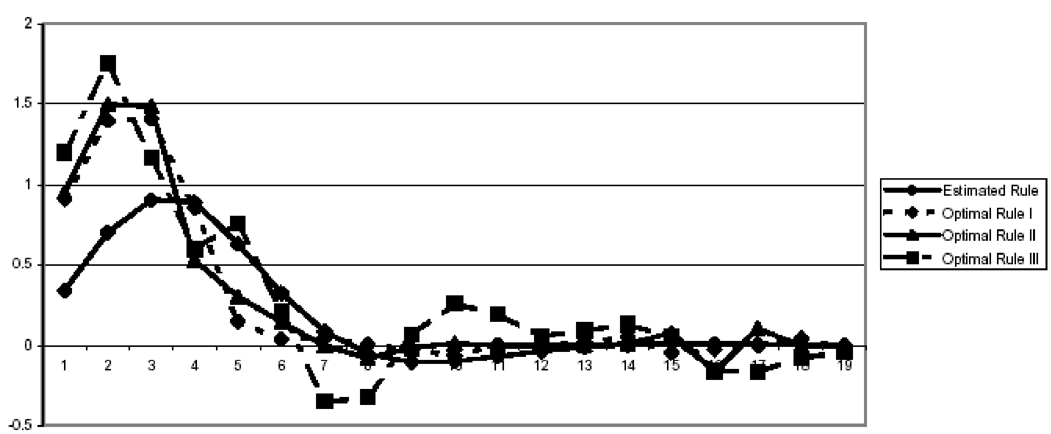


Table 3: Optimal Monetary Policy Responses to Fiscal Scenarios

	Shock	Rule	Value of Loss Function
Endogenous Fiscal Policy	$\widehat{y}_t$	Estimated Rule	87.8/83.4/12.6
	$\widehat{y}_t$	Optimal Rule I	7.4
	$\widehat{y}_t$	Optimal Rule II	4.3
	$\widehat{y}_t$	Optimal Rule III	2.9
	$\widehat{\pi}_t$	Estimated Rule	264.6/247.3/78.7
	$\widehat{\pi}_t$	Optimal Rule I	59
	$\widehat{\pi}_t$	Optimal Rule II	48
	$\widehat{\pi}_t$	Optimal Rule III	44
Exogenous Fiscal Policy	$\widehat{y}_t$	Estimated Rule	25.9/24.6/5.9
	$\widehat{y}_t$	Optimal Rule I	2.1
	$\widehat{y}_t$	Optimal Rule II	1.6
	$\widehat{y}_t$	Optimal Rule III	3.8
	$\widehat{\pi}_t$	Estimated Rule	131.0/122.7/59.1
	$\widehat{\pi}_t$	Optimal Rule I	52
	$\widehat{\pi}_t$	Optimal Rule II	53
	$\widehat{\pi}_t$	Optimal Rule III	57

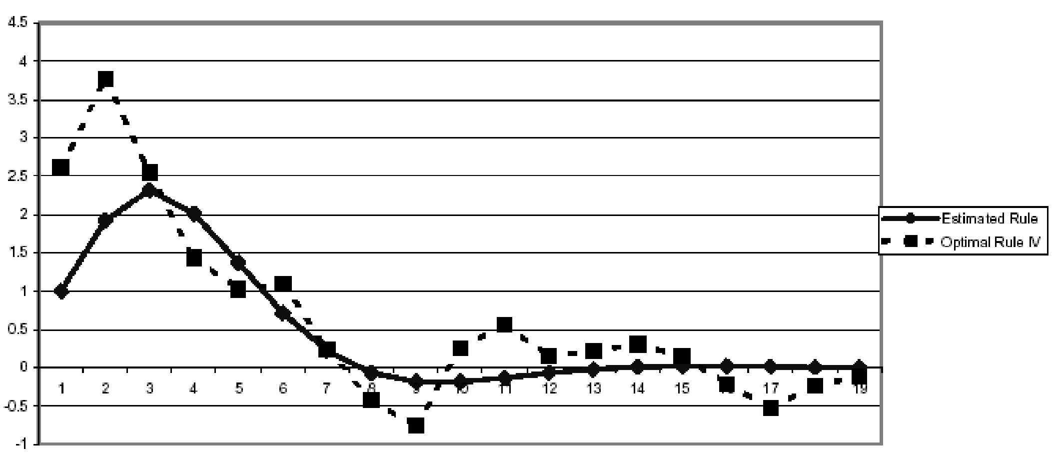
Table 3 shows quite clearly that the welfare loss under the estimated policy rules is greater in the presence of endogenous fiscal policy rules than when fiscal policy is kept exogenously fixed, as the fiscal policy response reduces the welfare to the monetary authorities. This is despite the fact that, in some instances, especially following output shocks, the two policy instruments move together. The intuition behind this result is essentially that the fiscal rules are highly inertial, and thus will not act to stabilize output according to the monetary authorities' optimal path.

Thus the endogenous fiscal response to the structural shock causes the monetary authorities to react more vigorously. The simulation plots provide some quantitative insights into the importance of this effect: comparing Figures 4 and 5 we see that the estimated rule predicts an interest rate response with endogenous fiscal responses during the first few quarters which is 30-100 basis points greater than with fiscal policy kept exogenously fixed. Under the optimal policies the increased response with endogenous fiscal policy is even greater, reaching 80-100 basis points under Optimal Rule III.

Another point to note is that with an endogenous fiscal policy it is very difficult for the policy rules to bring output quickly under control: this is less evident with the optimal policy rule, but more evident with our forward-looking estimated rule, where endogenous fiscal policy seems to add considerable output instability in the first few quarters.

Next, we should note that the optimal rules produce patterns of adjustment for the instrument and the target variables which are very different from those obtained using the estimated rule. Whilst this may seem sub-optimal, the smooth adjustment which obtains using the forward-looking and inertial rule is evidence of the robustness of these responses to different shocks, a point emphasized by Giannoni and Woodford (2002a,b). To emphasize this point, consider what happens if one induces a smoother adjustment to the optimal policy rule by raising the costs of interest-rate adjustment (setting the parameters $\Phi_1 = 1, \Phi_2 = 5$, which we label Optimal Rule IV), and simulating the interest-rate reaction to an output shock (Figure 6), assuming an exogenously fixed fiscal policy. Although the adjustment of the instrument is quite close to that predicted by the estimated rule, especially over the first few quarters, the interest-rate adjustment under the inertial forward-looking rule is much smoother than the solution under pre-commitment.

Figure 6: Exogenous Fiscal Policy, Interest Rate Response. Optimal Policy Rule with High Adjustment Costs



Naturally, the estimated impact of fiscal policy on monetary policy reactions here is dependent on the fact that the two policies interact exclusively through the aggregate demand channel rather than through distortionary taxation effects on consumption, substitution effects between government and private consumption, or tax-wedge effects on price- and wage-setting behaviour and on debt-servicing costs. Adding these channels would produce a richer picture of monetary-fiscal interactions, and might suggest a very different response to endogenous fiscal policy. However, providing that both rules contain a large inertial component, the sub-optimality from not co-ordinating fiscal and monetary policies will probably still be very significant, even in a different structural model.

6 Conclusions

The main contribution of this paper has been to provide a structural econometric interpretation to the macroeconomic interactions between fiscal and monetary policies. We have estimated a New Keynesian model of inflation and output jointly with monetary and fiscal rules using data from the US, to provide some understanding of the way in which different macroeconomic policy instruments interact over the business cycle.

The existing evidence on monetary-fiscal interactions over the cycle suggests that, whilst over a panel of countries the two policy instruments do tend to counteract each other over the cycle (Melitz, 1997, 2000, Wyplosz, 1999), there is increasing evidence of complementarity over the period since 1980 (Muscatelli, Tirelli and Trecroci, 2001), or at least asymmetric complementarity (Von Hagen, Hughes Hallett and Strauch, 2001).

The evidence from this paper substantiates the conjecture in Buti, Roeger and int' Veld (2001) that the nature of the interaction between the two policy instruments should depend on the nature of the shocks hitting the system. Indeed, we have shown that for the case of output shocks fiscal and monetary policies tend to act in harmony, whereas they are used as substitutes following inflation shocks or shocks to one policy instrument. Furthermore, the apparent shift to policy complementarity observed in the 1990s is mainly due to the specific configuration of shocks observed in that period.

We further showed that the perspective on fiscal-monetary interactions also depends critically on the type of structural model fitted to the data. Again, this is an important point, as the existing literature relies on reduced-form models or VAR analysis which cannot disentangle the role played by different structural interpretations and by shocks to the correlation between the two policy instruments.

Finally we provide some preliminary normative analysis of the impact of fiscal policy on the design of optimal policy rules. Perhaps surprisingly, it turns out that the presence of an endogenous fiscal policy rule is welfare-reducing. The reason for this seems to be the inertial nature of the fiscal and monetary policy rules. There is however a substantive distinction between the two policy rules. In fact monetary policy rules are explicitly designed for stabilization purposes, whereas the design of automatic stabilizers is generally driven by concern for distributional issues (Taylor, 2000a). Perhaps the time has come for fiscal policymakers to reconsider the issue, taking into account both the countercyclical role of fiscal policy and the need for better coordination in the design of policy rules. This would seem to be a profitable area of further research.

The biggest shortcoming of the approach followed here is that it allows very limited scope for the two policy instruments to interact, focusing exclusively on the aggregate demand channel. By building in the impact of distortionary taxation, substitution of private and government consumption, tax wedge effects on pricing and wage-setting, and the impact of interest-rate policy on deficit financing, a richer picture will doubtlessly emerge. This is left to future work.

Notes

[1]See for example Leith and Wren-Lewis (2000), and more recently Perez and Hiebert (2002) and Zagaglia (2002), who have experimented with DGE model simulations which include some fiscal closure rules, Schmitt-Grohé and Uribe (2002), Benigno and Woodford (2003)

[2]See Dixit and Lambertini (2000, 2001).

[3]The number of contributions applying VAR techniques is still scarce. This may be due to the critique in Mountford and Uhlig (2002) that true fiscal policy surprises may be difficult to detect in a VAR model.

[4]Arguably, the open-economy considerations are less important to the USA, which is the focus of our analysis here. The extension of our modeling approach to the open economy is left to further work.

[5]This specification is based on the assumption of external habit as in Smets and Wouters (2002). Studies based on the assumption of internal habit test a more complex dynamic equation, but cannot find habit persistence in the US (Leith and Malley, 2002).

[6]See also Erceg, Henderson and Levin (2000), and Sbordone (2002).

[7]This was pioneered by Galí and Gertler (1999). Similar backward-looking elements can be introduced to the NKPC equation by introducing indexation of all non-re-optimised prices (Christiano, Eichenbaum and Evans, 2001, and Woodford, 2002, chapter 3).

[8]A similar specification for the New Keynesian Phillips curve can be obtained by making the indexation process part of the optimisation process (see Smets and Wouters, 2002).

[9]Galí, Gertler and López-Salido (2001) specify (10) in terms of average real marginal cost (mc). Note that, in levels:

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

[10]For instance, our modelling approach is not dissimilar to that adopted in Leeper (1991, 1993). Since writing the first draft of this paper we became aware of the work by Perez and Hiebert (2002) and Zagaglia (2002), who introduce endogenous fiscal actions in simulated theoretical DGE models.

[11]Which in turn builds on an earlier literature in models without nominal rigidities (see e.g. Chari, Christiano and Kehoe, 1991, 1999).

[12]The main difference is that we use contemporaneous and lagged values of the output gap (see Muscatelli, Tirelli and Trecroci, 2002) as opposed to

expected future values, as in Clarida, Gali and Gertler (1998, 2000). For a detailed discussion of these issues, see Giannoni and Woodford (2002a,b).

[13]See Giannoni and Woodford (2002b) for a justification of why a short inflation-forecast horizon might be optimal in cases where the degree of 'rule of thumb' indexation (γ) or inflation inertia is high.

[14]In general we did not find that the debt/GDP ratio was significant over the full sample in either the tax or the expenditure equation. One possible reason is that there might have been shifts in the fiscal regime, as suggested by Favero and Monacelli (2003). As in the case with our monetary policy rules we do not model regime switches, which is an aspect which we leave to further work.

[15]The estimation was carried out using RATS, version 5.

[16]Which is commonplace in this literature (see Smets and Wouters, 2002, Leith and Malley, 2002).

[17]We experimented with both a HP filter and regression on a polynomial (cubic) trend for the real variables, and using CBO and OECD data on potential output. The results reported here use a polynomial trend. Although there is some difference in the series, the estimated structural parameters in the NK models are not very different, and the lag structure of the backward-looking model does not seem to be affected. This implies that the monetary-fiscal interactions which emerge from the dynamic simulations will not be markedly different.

[18]For instance, Galì, Gertler and Lopez-Salido (2003), Leith and Malley (2002), Kara and Nelson (2002).

[19]This follows Erceg, Henderson and Levin (2000). It is a lower value of the elasticity of substitution than that used by Galí, Gertler and López-Salido (2001) and Leith and Malley (2002), but in practice the estimates of the other parameters did not seem to be very sensitive to changes in the value of θ. However, a higher mark-up does seem to be more sensible given that marginal costs exclude capital costs in this framework. In addition, a higher value of θ would imply an implausibly small direct effect of output on prices, through the marginal cost term.

[20]We also tried to estimate the model using sub-sets of the instruments, including estimating the models equation by equation. In all these cases the J-test does not reject the null.

[21]It is reassuring to find that in their celebrated paper, Campbell and Cochrane (1999) are able to track down the risk-free rate for the US by calibrating a model where $\beta = 0.89$, $\gamma = 2$, $\lambda = 0.94$.

[22]See Clarida Gali and Gertler (1998, 2000), Muscatelli, Tirelli and Trecroci (2002), Cukierman and Muscatelli (2001).

[23]For some evidence on time-variation in monetary policy rules, see Muscatelli, Tirelli and Trecroci (2002a).

[24]The model is solved using Winsolve version 3.0 (see Pierse, 2000), which provides numerical solutions for linear and non-linear rational expectations models. We solve our model using the Stacked Newton method in Winsolve. In solving the models with structural shocks and deviations from the policy rules ('policy shocks'), these are treated as unanticipated by economic agents.

[25]As all of our historical (counterfactual) simulations (ii) and (iii) are conducted using 1990s data there is little difference in using actual data on real wages and employment, as opposed to endogenising them as we do in dynamic simulation (i). This is because real wages and employment were far less volatile around their trend during the 1990s.

[26]Note that in the case of Figure 1 the dates on the horizontal axis are not relevant, as we are not using actual data to simulate the models.

[27]The interested reader is referred to Muscatelli, Tirelli and Trecroci (2002b), where these simulations are reported in full.

[28]For empirical evidence on this point, see Cukierman and Muscatelli (2001).

[29]We use the standard form of the government budget constraint, normalised by output:

$$(D/Py)_t = (1 + i_t)D_{t-1}/P_t y_t + (g/y)_t - (\tau/y)_t$$

where D is nominal debt. As our model is simulated in deviation from equilibrium form, in order to simulate the budget constraint we use additional equations linking real GDP, the price level and the levels of expenditure and taxation revenues to, respectively, the output gap, inflation, and the deviations in the fiscal variables. Clearly the one outstanding issue is that our framework only models the short-term policy rate, the federal funds rate, and not the average cost of debt. In addition, our expenditure data includes interest payments. However, the purpose of this additional simulation is simply as a check that our model does not imply an implausible path for government debt. The simulated debt series is not used in any of our policy experiments or policy analyses.

[30]Again, the results are computed using Winsolve.

[31]So that the optimal interest rate rule depends on its previous value. Indeed, Giannoni and Woodford (2002b) show that in certain circumstances the optimal policy rule involves superinertial dynamics.

[32]i.e. our estimated policy rule may not be 'sub-optimal' in the sense of Giannoni and Woodford.

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