The Interaction of Fiscal and Monetary Policies: Some Evidence using Structural Econometric Models[1]

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[1] We are indebted to Campbell Leith, and Jacques Mélitz and other participants at a conference held at the University of Trento in October 2002 for discussions on these issues, which helped shape this paper. We are of course responsible for all remaining errors and omissions.

Abstract

This paper examines the interaction of monetary and fiscal policies using both forward-looking (New Keynesian) and backward-looking structural econometric models. We estimate models for the US and Germany. In contrast to earlier work using VAR models, we are able to illustrate how the strategic complementarity or substitutability of the fiscal and monetary policy instruments depends crucially on the types of shocks hitting the economy, and on the assumptions made about the underlying structural model. Overall, we find evidence to suggest that there is only some degree of policy complementarity in response to output shocks. On the whole, there is considerable evidence to suggest that fiscal policy either did not move together monetary policy, or to some extent moved in the opposite direction.

JEL Codes: E58, E62, E63

1 Introduction

Despite the existence of a vast and still growing literature on monetary policy rules[1], 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[2], or game-theoretic models[3], but none of these models have been tested empirically.

The only major empirical contributions in this area are the studies by Melitz (1997, 2000), Wyplosz (1999), von Hagen et al. (2001), and Muscatelli, Tirelli and Trecroci (2001). The first three papers use cross-sectional or panel data to examine the relationship between fiscal and monetary policies over the cycle, considering whether the two tend to move together (i.e. they are strategic complements), or whether they tend to move in opposite directions to each other (i.e. they are strategic substitutes). Muscatelli, Tirelli and Trecroci (2001) examine the interaction between fiscal and monetary policy instruments using VAR models for several G7 economies, and look at the responses of fiscal and monetary policies to 'shocks' in the other policy instrument.

The main problem with the existing literature is that without a structural model it is difficult to interpret the empirical correlations between the two policy variables. In the work of Melitz (1997) and Wyplosz (1999) for instance, 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 VAR models 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.

The purpose of this paper is to provide a more systematic analysis of

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[1] See ***inserire riferimenti bibliografici a Rudebusch-Svensson e l'altra letteratura recente***, to cite but a few examples.

[2] 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, and Schmitt-Grohé and Uribe (2002). The political economy literature on monetary-fiscal interactions is of course one going back to, inter alia, Alesina and Tabellini (1987), Beetsma and Bovenberg (1998), Beetsma and Uhlig (1998).

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

the interactions between these two macroeconomic policy instruments. We jointly estimate small econometric models and monetary and fiscal policy rules for two major economies (the USA and Germany) over the sample period[4] 1970-2001. Two different specifications are considered for the macroeconomic structural models: a forward-looking, dynamic general equilibrium (DGE) model, based on the New-Keynesian paradigm, and a backward-looking non-microfounded model[5].

Using these small models we are able 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 can conduct a number of historical 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, and whether one has a New-Keynesian or 'backward-looking' interpretation of the underlying structural model. However, definite patterns emerge which allow us to reach some conclusions about the interaction between fiscal and monetary policies.

Finally we conduct some optimal policy experiments with our estimated models. This allows us to consider, for instance, whether the introduction of endogenous fiscal policy rules markedly changes the optimal monetary policy rule, and compares our estimated monetary policy rule with others that can be derived from an optimal control exercise.

The rest of this paper is organised as follows. In the next section we will briefly survey the existing literature. In Section 3, we outline the structure of the models we estimate and the empirical methodology. In Section 4, we report our estimated models and discuss our dynamic simulations. In Section 5 we conduct some optimal policy experiments. Section 6 concludes.

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[4] For Germany we use the sub-sample 1970(1)-1999(1) because the introduction of EMU represents a major shift in monetary policy and hence in the estimated monetary policy rule.

[5] See for example Rudebusch and Svensson (1999), Rudebusch (2002).

2 The Existing Literature

The nature of the interdependence between fiscal and monetary policy is a recurring theme in macroeconomics. The traditional analysis focuses on the optimal policy mix when both policy instruments are under the control of a single policymaker who aims at mutually inconsistent targets. In recent years, following the widespread shift to a separation of powers between fiscal authorities and independent central banks, theoretical research has turned to the analysis of fiscal/monetary policy interactions when the two policymakers' objectives differ.

Dixit and Lambertini (2000, 2001) explore the relation between fiscal discretion and monetary commitment in a model where the central bank has only partial control over inflation, which is also directly affected by the fiscal policy stance[6]. Not surprisingly, these authors find that in this case fiscal discretion destroys monetary commitment. Dixit and Lambertini also show that the tendency towards substitutability emerges when fiscal policy tends to increase both output and inflation, whilst complementarity could emerge where 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 the bank targets inflation and a nominal interest rate objective, whereas the fiscal authority pursues output and deficit targets. Supply shocks unambiguously induce conflicting policies, whereas the opposite holds true for demand shocks. An eclectic contribution to this literature can be found in Taylor (2000a). This study investigates the working of fiscal "Taylor rules", whereby a fiscal stance indicator targets the output gap and the debt/GDP ratio.

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, considering whether the two tend to move together (i.e. they are strategic complements), or whether they tend to move in opposite directions to each other (i.e. they

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[6] Furthermore, conflicting objectives between the two policymakers, where the central bank tries to achieve output and inflation levels below the fiscal authority's targets, lead to highly suboptimal Nash equilibria where monetary policy is too contractionary and the fiscal stance is insufficiently expansionary.

are strategic substitutes). Work by Mélitz (1997, 2000) and Wyplosz (1999) broadly supports the view that the two policies tend to move in opposite directions. By contrast, 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. Also, from the early 1990s these authors detect smaller fiscal responses to both monetary shocks and cyclical conditions.

The literature applying VAR techniques to the study of fiscal policy effects was initiated by Edelberg et al. (1998), Blanchard and Perotti (1999) and Fatas and Mihov (2001 a,b). The number of contributions is still relatively scarce. This may be due to the standard criticism raised in Mountford and Uhlig (2002) that true fiscal policy surprises may be difficult to detect in a VAR model. For instance, a government stance may determine the expectation of a fiscal policy shift well before the new fiscal decision is detected in the VAR. In our view, this criticism may be somewhat overstated. The specific features of a fiscal package are crucial in determining agents' reactions, and the details of these often remain uncertain until the legislative process has been completed. Muscatelli, Tirelli and Trecroci (2001) examine the interaction between fiscal and monetary policy instruments using VAR and Bayesian VAR models for several G7 economies, and show that the fiscal shocks identified in the VAR have significant effects. 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.

In our view, 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) for instance, 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 VAR models 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. Two alternatives are considered. First, a small forward-looking New-Keynesian DGE model, comprising a dynamic IS model for output and a 'New Keynesian Phillips Curve' specification for inflation[7]. Second, a backward-looking model for output and inflation in the Keynesian aggregative model tradition. We now outline each structural model in turn. We then consider the monetary and fiscal rules to be estimated.

3.1 A New-Keynesian Structural Model

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

$$E_t \sum_{s=0}^{\infty} \beta \left(\frac{1}{1-\rho} (C_{t+s}^i - H_{t+s}^i)^{1-\rho} - \frac{\varepsilon^l}{1-\rho} (1 - N_{t+s}^i)^{1-\rho} \right) \tag{1}$$

where C_t represents consumption of a basket of goods (to be defined below), H_t is an index of consumption 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. We assume that consumption habits are given by:

$$H_{t+s}^i = \lambda C_{t+s-1}^i \tag{2}$$

where the parameter λ denotes the importance of habits in the utility function. Where $\lambda = 0$, the problem collapses to the traditional textbook case and yields a standard Euler equation for consumption.

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

$$(1/r_t) a_{t+1}^i = a_t^i - C_t^i + w_t^i N_t^i + D_t - T_t \tag{3}$$

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[7] For simplicity we do not model wage stickiness as in Erceg, Henderson and Levin (2000), Christiano, Eichenbaum and Evans (2001), Smets and Wouters (2002), and Leith and Malley (2002). As we shall see, when we simulate our model, we can either assume that wages are an exogenous variable in the model, or that wages are indexed with a lag to prices.

where consumers hold their financial wealth (a_t^i) 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 are identical and that their initial holdings of financial wealth are identical, the problem can be solved as a dynamic optimisation problem and we can aggregate across consumers. Then, using the equilibrium condition for goods markets, given that we ignore investment and the external sector:

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

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)[8]:

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

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)[9]. 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 normalised to unity:

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

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[8] It should be noted that the form of the consumption function depends critically on the form with which consumption habits enter the utility function. With this specification the discount factor β does not enter the IS equation, even in the presence of consumption habits.

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

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:

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

Sticky prices are incorporated into this model, by assuming a Calvo pricing model, with some proportion of firms $(1-\xi)$ adjusting their prices every period, and of these a proportion (γ) indexing prices to inflation in the previous period[10], and the rest $(1-\gamma)$ setting their prices optimally to maximise expected discounted real profits[11] given technology, with a discount factor equal to that of consumers, β.

The firms' optimisation together with the assumptions about Calvo pricing and indexation lead to an expression for price-setting which can be log-linearized to yield[12]:

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

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[10] 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).

[11] 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).

[12] Excluding any technology shocks

where $\widehat{s}_t$ is the percentage change from steady state of marginal cost, which is given[13] by $\widehat{s}_t = \widehat{w}_t + \widehat{n}_t - \widehat{y}_t$.

Equations (5) and (10) constitute our structural model to be jointly estimated with the policy rule. It is important to note that in estimating (10), we treat real wages and employment as exogenous. Other recent contributions (Leith and Malley, 2001, 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. In conducting our dynamic simulations we can either treat real wages as exogenous, or assume a simple indexation mechanism of wages to inflation. As we shall see below, this choice seems to matter less for the latter part of our sample, which is the sample used for most of our historical simulations.

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[14]. This is in contrast to the theoretical modelling approach[15] of, for instance, Schmitt-Grohe and Uribe (2001) which explicitly assumes that governments only have access to distortionary income taxes or the inflation tax. Another possible extension of our framework is to permit some degree of substitutability of government and private consumption so as to allow some non-Keynesian effects of government spending (see Giavazzi and Pagano, 1990).

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[13] In levels it is given by:

$$s_t = \frac{w_t}{(1-\alpha)(Y_t/N_t)}$$

[14] 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.

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

3.2 A 'traditional' backward-looking macroeconomic model

Despite the popularity of New-Keynesian models, it is relatively recently that fully-estimated versions of models along the lines of equations (5) and (10) have emerged in the literature. Until recently New Keynesian DGE models tended, like their RBC counterparts, to be mainly the object of careful calibration.

In contrast, recent examples of simple backward looking models of output and inflation can be found quite commonly as a basis to evaluate monetary policy rules (see for instance Rudebusch and Svensson, 1999, and Rudebusch, 2002). Of course backward-looking models will suffer from the Lucas critique in the presence of forward-looking behaviour on the part of consumers and firms. However, they still offer a useful benchmark against which to assess the results from the New Keynesian models, given that the latter models impose considerable structure on the estimated equations and may underestimate other, non-modeled, but still substantial, source of inertia in the economy[16]. If this is the case, the backward-looking model may provide very different insights as to the interactions between fiscal and monetary policies.

We estimate the following IS (output) and Phillips Curve (inflation) equations:

$$\widehat{y}_t = \sum_{i=1}^{n} a_{1i}\widehat{y}_{t-i} + \sum_{i=0}^{n} a_{2i}\widehat{r}_{t-i} + \sum_{i=0}^{n} a_{3i}\widehat{g}_{t-i} + \sum_{i=0}^{n} a_{4i}\widehat{\tau}_{t-i} \tag{11}$$

$$\widehat{\pi}_t = \sum_{i=1}^{n} b_{1i}\widehat{\pi}_{t-i} + \sum_{i=0}^{n} b_{2i}\widehat{s}_t \tag{12}$$

where $\widehat{\tau}_t$ is the percentage deviation from steady state of taxation. Turning first to (11) it is worth stating that although it is possible to estimate a_{3i}, as in the case of the New-Keynesian model, this is a linearisation of the goods-market equilibrium equation, and hence it may be worth restricting the impact of $\widehat{g}_{t-i}$ on $\widehat{y}_t$ to be equivalent to $\left(\frac{\overline{G}}{\overline{Y}}\right)$. The presence of the taxation variable is more subtle: unlike the idealised assumptions of the New-Keynesian model with lump-sum taxation, this tests whether taxation might impact directly on output via effects on liquidity or other distortions.

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[16] Furthermore when we conduct our dynamic simulations we will not consider shifts in policy rules or anticipated deviations from the policy rule which might cause the Lucas critique to become operative.

Anticipating the empirical results presented below, it is reassuring to find that tax changes have a very limited impact on output in the US and are not significant for the German output equation. Equation (12) is a backward-looking Phillips Curve, equivalent to (10). The main difference is that we can experiment with different lags on different components of the marginal cost variable, such as the real wage and output, which allows us to capture the different proximate causes for variations in marginal costs over the cycle.

One final point to note is that, in estimating (11) and (12), we have to take into consideration potential identification issues once we add the monetary and fiscal rules. For instance, consider what would happen if one were to specify the monetary and fiscal rules as functions of current and lagged output and/or inflation. The result would be a semi-structural VAR model where we would need to impose some lag restrictions in order to ensure identification. The same problem does not arise in the joint estimation of the policy rules and the New Keynesian model because of the very restrictive dynamic structure suggested by the theory[17]. We can ensure identification in two ways: first by estimating a forward-looking monetary policy rule in the spirit of Clarida, Galí and Gertler (1998, 2000). It turns out that this is a better characterisation of monetary policy compared to a purely backward-looking monetary policy rule; and, second, by imposing zero or other restrictions (as noted above) on the impact of current real interest rates and the fiscal variables on output in (11)[18].

3.3 Monetary and Fiscal Rules

As noted above, our estimated monetary rule for the nominal interest rate $\widehat{i_t}$ follows a form similar to the standard[19] forward-looking Taylor rule specification which has become commonplace in the literature (see Clarida, Galí and Gertler, 1998, 2000, Muscatelli, Tirelli and Trecroci, 2002, Giannoni and

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[17] As we shall see below, in the case of the New Keynesian model there is still an identification problem because of the large number of parameters to be estimated in the non-linear equations.

[18] In further work we will consider the sign restriction methodology of Uhlig (2001), imposing the restriction that the impulse responses of the fiscal variables have a particular sign after the shock for a number of periods (Mountford and Uhlig, 2002).

[19] 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).

Woodford, 2002a, 2002b):

$$\widehat{i}_t = \phi_0 + \phi_1 E_t \widehat{\pi}_{t+q} + \sum_{i=0}^{m} \phi_{2i} \widehat{y}_{t-i} + \phi_3 \widehat{i}_{t-1} \tag{13}$$

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.[20]

As far as fiscal policy is concerned, we estimate backward-looking models of fiscal policy. 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. In each case we allow both variables to respond to output, and also include a stabilisation mechanism which captures the impact of the lagged budget deficit to GDP ratio on current policy.:

$$\widehat{g}_t = \delta_0 + \sum_{i=1}^{m} \delta_{1i} \widehat{g}_{t-i} + \sum_{i=0}^{m} \delta_{2i} \widehat{y}_{t-i} + \psi_1 (bd)_{t-k} \tag{14}$$

$$\widehat{\tau}_t = \varphi_0 + \sum_{i=1}^{m} \varphi_{1i} \widehat{\tau}_{t-i} + \sum_{i=0}^{m} \varphi_{2i} \widehat{y}_{t-i} + \psi_2 (bd)_{t-k} \tag{15}$$

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 policymaker's 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, finding that countercyclical fiscal policy is almost entirely characterised by the working of automatic stabilisers. Our fiscal rules, which allow for autoregressive components and for a delayed response to the output gap, might seem at odds with the standard objective functions usually assigned to fiscal policymakers. In fact our purpose here is

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[20] 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.

simply to let the data describe the inertia built in the working of automatic stabilisers. We have also chosen to estimate separate equations for taxes and expenditures, in order to characterise their distinct effects on the output gap.

Note that the policy rules structure implies that the fiscal and monetary instruments only respond to each other insofar as they influence the final objectives of macroeconomic policy (output and inflation): there is no direct response from each policymaker to the other policymaker's instrument. In dynamic simulations of our models, we consider the impact of spending and taxation decisions on the budget deficit to GDP ratio. We thus ignore the interactions between fiscal and monetary policy due to debt financing[21], to focus mainly on the aggregate demand channel as the major source of interaction. Although this may seem unrealistic, empirically this is likely to have been the major channel of interaction, and the one which the monetary authorities will have been most interested in. In practice, neither of the two countries we study faced major debt financing problems over the sample period, and the deficit term arguably will capture a large component of any attempt to stabilise the debt-to-GDP ratio. In future work to date we consider how adding the impact of interest-rate changes on budget deficit financing and distortionary taxation may alter our results.

4 Empirical Results

4.1 Data and Scope of the Study

We now turn to the empirical results[22]. The two alternative models to be estimated are: First, the New-Keynesian model jointly with the monetary and fiscal rules, comprising (5), (10), (13), (14) and (15). Second, the backward-looking semi-structural model, comprising (11), (12), (13), (14) and (15).

We estimate these models for the USA and Germany, using quarterly data. Note that the spending data excludes transfers. Although fiscal data is not available on a quarterly basis excluding interest payments, the behaviour

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[21] In contrast, Perez and Hiebert (2002) in their theoretical simulations consider taxation rules, where taxation is a 'jump variable' leading the macroeconomic system back onto the stable manifold. Zagaglia (2002) considers an autoregressive 'budget deficit' rule in his simulation model.

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

of $\widehat{g}_t$ is very similar if one uses interpolated half-yearly data[23]. The sample period is 1970(1)-2001(2) for the USA . For Germany we end our estimation in 1999(1) because of the advent of EMU. 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.

One issue which has to be considered at the outset is the fact that our structural models do not have any open-economy features. Although open-economy structural models are becoming more common, for instance estimated open economy New Keynesian Phillips Curves[24] (Kollman, 2001, Galí and Monacelli, 2002, Kara and Nelson, 2002, Leith and Malley, 2003), the transmission of monetary and fiscal policy in an open economy introduces additional complications[25], principally that of endogenising the real exchange rate, which are beyond the scope of this paper. The possible extension of our modeling approach to the open economy is left to further work.

The data have been seasonally adjusted, 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'[26]. Real variables are de-trended[27], 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.

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[23] We have also experimented with combinations of quarterly interpolations of interest-payments data and quarterly fiscal data. Again, the government spending series have very similar properties.

[24] Open economy features have been part of New Keynesian models for some time, see for example McCallum and Nelson (1999, 2000).

[25] For an analysis of monetary rules in an open economy see Clarida, Gali and Gertler (2001), Erceg (2002) and Obstfeld (2002). The precise form of the optimal rule is dependent on the open economy channels in the model (see also Kara and Nelson, 2002).

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

[27] 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.

4.2 Estimation Methods

The New Keynesian model consists of a number 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), (13), (14) and (15) make up a system of linear and non-linear equations of the form:

$$\mathsf{y}_t = \mathsf{f}(\boldsymbol{\theta}, \mathsf{z}_t) + \mathsf{u}_t \tag{16}$$

where y_t is the vector of dependent variables, $\boldsymbol{\theta}$ is the $(a \times 1)$ vector of unknown parameters to be estimated, and z_t is the $(k \times 1)$ vector of explanatory variables. The GMM approach is based on the property that $\widetilde{\boldsymbol{\theta}}$, the true value of $\boldsymbol{\theta}$, has the property $E[\mathsf{h}(\widetilde{\boldsymbol{\theta}}, \mathsf{w}_t)] = 0$, where $\mathsf{w}_t \equiv (\mathsf{y}_t', \mathsf{z}_t', \mathsf{x}_t')$ and x_t is an $(r \times 1)$ vector of instruments that are correlated with 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. 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[28]. 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[29] 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 average sample value.

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

[29] 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.

However, it is worth noting that even with these restrictions, because of the absence of any cross-equation restriction, 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 recognise 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 estimated 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 characterisation 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.

In the case of the backward-looking model, this is estimated using FIML. The lag lengths for the structural model are chosen by starting with four lags, and eliminating insignificant lags. In the case of the Phillips curve, we use the estimate of the labour share $(1 - \alpha = 0.6)$ to substitute out for employment in $\widehat{s}_t$, and estimate a variant in which the real wage and output enter the inflation equation separately. This involves estimating a variant of (12):

$$\widehat{\pi}_t = \sum_{i=1}^{n} b_{1i}\widehat{\pi}_{t-i} + \sum_{i=0}^{n} b_{2i}\widehat{w}_t + \sum_{i=0}^{n} b_{3i}\widehat{y}_t \tag{17}$$

Note that, given the expression for marginal costs[30], and again assuming the Cobb-Douglas technology in (6), estimating (17) will deliver an estimate for α as $\widehat{mc}_t = \widehat{w}_t + \alpha\widehat{y}_t$, and hence $\alpha = b_{2i}/b_{3i}$. One advantage of splitting the dynamics of the real wage and output is that this may capture some of the behaviour of the mark-up over the cycle.

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[30] In log-deviation form: $\widehat{mc}_t = \widehat{w}_t - (1 - \alpha)\widehat{y}_t + (1 - \alpha)\widehat{n}_t$

Finally, as noted above, we identify the model by assuming that interest rates and taxation do not contemporaneously impact on output ($a_{20} = 0, a_{40} = 0$), and that government spending has a contemporaneous impact given by $\left(\overline{G}/\overline{Y}\right)$.

When we estimate the two versions of the structural model, the lag lengths for the policy rules are found to be very similar. Unsurprisingly, given that the fiscal policy rules are backward-looking, and that the monetary policy rule is only forward-looking in inflation, it turns out that the optimal lag structure is reasonably similar across the two models, which implies that it is the very different lag/lead structure in the structural equations which drives the differences in the dynamic simulations of the two models. There are, however, some exceptions to this, as we shall see below.

4.3 Model Estimates

Table 1 reports the estimated New Keynesian model using GMM over the full sample period. We first turn to the US results. 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[31] at a value consistent with that estimated by Galí, Gertler and López-Salido (2001), 0.89. This improved the precision of the other parameter estimates. 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[32].

Turning first to the structural equations, the estimated NKPC parameters

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[31] Because of the way in which we model habit persistence, the discount factor β does not enter the output equation, unlike Leith and Malley (2002). One reason for choosing this specification is that, as we shall see, our estimated model suggests considerable habit persistence for the US, in contrast to Leith and Malley (2002). This conforms better with earlier empirical work on US consumption behaviour. It should also be noted that, if one estimates the unrestricted form for the NK model without identifying the individual structural parameters from the parameter convolutions, the lagged output term in the IS equation is highly significant.

[32] 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.

are comparable to those obtained for the USA by Leith and Malley (2002) and by Galí, Gertler and López-Salido (2001) over a shorter sample period, 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. 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. 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).

Turning to the policy rules for the US, we see that, as is common with estimated interest rate reaction functions[33], 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[34]. 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 stabilising, 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 (2000) 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.

Turning next to the estimates for Germany, we similarly fixed the discount factor using a grid search at a value of 0.90. The R-squared for the output equation was 0.92, for the inflation equation 0.97, for the monetary policy rule 0.88, and for the government spending and taxation rules 0.95 and 0.93

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

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

respectively. Hansen's J-test has a value of 58.7, which again is insignificant as it is distributed as a $\chi^2(125)$ statistic under the null of valid instruments. One problem with the German estimates is that the monetary policy rule produced very different results when the model was estimated over its full sample, including the 1970s, including a long-run coefficient on expected inflation significantly below unity. We therefore re-estimated this equation for the sub-sample 1980-1999(1), and the estimates reported in Table 1 relate to this sub-sample. Estimates for the habit term, the Calvo term and the relative risk aversion coefficient (λ, ξ, ρ)closely resemble those obtained for the US. Similar conclusions hold for the estimated interest rate functions. By contrast, German taxes and expenditures equations exhibit different degrees of inertia and responses to the output gap. This is probably due to the country-specific features of automatic stabilisers[35].

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[35] The striking similarities that we observe between the two interest rate functions suggest that, in these countries at least, the design of monetary rules was unaffected by the specific features of national fiscal policies.

Table 1: New Keynesian Model Estimates

Parameter	USA	Germany	Parameter	USA	Germany
λ	0.917 (0.026)	0.882 (0.100)	δ_{11}	0.881 (0.056)	1.265 (0.059)
ρ	1.528 (0.043)	1.500 (0.170)	δ_{12}	–	−0.366 (0.060)
β	0.89 (–)	0.90 (–)	δ_{20}	0.607 (0.275)	–
ξ	0.517 (0.113)	0.654 (0.134)	δ_{21}	−0.794 (0.284)	0.680 (0.129)
γ	0.776 (0.169)	0.668 (0.137)	δ_{22}	–	−0.653 (0.135)
ϕ_1	0.150 (0.044)	0.178 (0.078)	φ_{11}	0.930 (0.042)	1.078 (0.084)
ϕ_{20}	0.166 (0.048)	0.144 (0.032)	φ_{12}	–	−0.209 (0.081)
ϕ_3	0.874 (0.041)	0.809 (0.057)	φ_{20}	0.422 (0.283)	0.284 (0.053)
			ψ_1	−2.283 (0.412)	−0.606 (0.172)
			ψ_2	1.160 (0.340)	0.437 (0.143)

Table 2: Backward-Looking Model Estimates

Parameter	USA	Germany	Parameter	USA	Germany
a_{11}	1.738 (0.068)	1.364 (0.082)	δ_{11}	0.774 (0.056)	1.518 (0.076)
a_{12}	-0.790 (0.075)	-0.426 (0.085)	δ_{12}	–	-0.566 (0.075)
a_{20}	-0.065 (0.032)	–	δ_{20}	1.705 (0.628)	–
a_{22}	–	-0.100 (0.030)	δ_{21}	-3.303 (1.118)	-0.570 (0.168)
a_{41}	-0.056 (0.026)	–	δ_{22}	1.544 (0.583)	–
a_{42}	0.049 (0.024)	-0.019 (0.015)	φ_{11}	0.883 (0.030)	1.121 (0.093)
b_{11}	1.353 (0.086)	1.038 (0.088)	φ_{12}	–	-0.251 (0.087)
b_{12}	-0.501 (0.142)	-0.134 (0.083)	φ_{20}	0.492 (0.063)	–
b_{13}	0.363 (0.142)	–	φ_{22}	–	0.231 (0.059)
b_{14}	-0.227 (0.086)	–	ψ_1	-0.568 (0.244)	-0.075 (0.067)
b_{20}	0.188 (0.042)	0.008 (0.022)	ψ_2	0.612 (0.180)	0.139 (0.063)
b_{31}	0.047 (0.031)	0.103 (0.027)			
ϕ_1	0.141 (0.041)	0.178 (0.078)			
ϕ_{20}	0.814 (0.200)	0.144 (0.032)			
ϕ_{21}	-0.692 (0.196)	–			
ϕ_3	0.906 (0.041)	0.809 (0.057)			

We next turn to the estimates of the backward-looking models. These are reported in Table 2. For the USA, the R-squared statistics are 0.97 for the output equation, 0.97 for the inflation equation, 0.90 for the monetary policy rule, and 0.91 and 0.63 for the government spending and taxation rules respectively. For the US, we find a Phillips Curve with four significant AR terms, with a total coefficient close to unity (the 'vertical Phillips curve' property), which is very close to the estimates reported by Rudebusch and Svensson (1999), Ball (1999) and others. Interestingly we find that decomposing the marginal cost term into a real wage and output term produces a richer lag structure than in the forward-looking model, although the coefficient on output is only significant at the 10% level (but is has the correct sign). The implicit estimate of α is about 0.5, which is close to that imposed in the forward-looking model (0.6). The output equation has a significant real interest rate effect, but lagged two periods, in contrast to Rudebusch and Svensson who use an average real interest rate effect. There is strong persistence in output, and there is a significant (total) negative impact of taxation, which as noted earlier provides a separate channel for the influence of fiscal policy in this version of the model.

The monetary policy rule in the US case is very similar to that estimated with the New Keynesian model, except that the dynamics of the output term are slightly richer (there is an additional lag), and the taxation equation has the same lag structure. The major difference seems to be in the government expenditure equation, which has a slightly richer lag structure in output. However, the total impact of output on government spending is very similar. The main difference in the fiscal rules estimated here compared to those associated with the New Keynesian model is that the 'correction' effect of the lagged budget deficit is much smaller, suggesting a much slower correction of the deficit.

For Germany, the R-squared statistics are 0.94 for the output equation, 0.95 for the inflation equation, 0.88 for the monetary policy rule, and 0.96 and 0.92 for the government spending and taxation rules respectively.

It is interesting that the monetary policy rules are very close in the two countries, although one must bear in mind that they have been estimated over different sample periods. The main point to note about the fiscal rules is that the US rules react much more to the budget deficit than the ones for Germany. In contrast, both spending and taxation seems to be more reactive to output in Germany. The other main contrast between the two countries relates to the backward-looking Phillips Curve. In the case of Germany, the real wage effect is not significant (in contrast to the output variable), and a smaller number of AR terms is significant. As in the case of the US, there is a smaller 'deficit correction' effect in the backward-looking model.

4.4 Dynamic and Stochastic Simulations

4.4.1 Dynamic Simulations

Having estimated the two versions of our structural models and policy rules, we now perform a number of dynamic simulation experiments to investigate the way in which fiscal and monetary policies interact.

For each of the two countries we perform three different simulation experiments[36]:

(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, keeping the exogenous variables constant.

(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 the data on the exogenous variables. 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[37], or the structural and policy shocks.

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[36] The models are 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.

[37] In our dynamic model solutions (i), as we do not have a wage-setting equation, we simply assume that the nominal wage is indexed to lagged inflation. In the historical simulations we have data on the real wage, and it is treated as an exogenous variable. In

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 for the USA, and from 1992(1) onwards for Germany, to avoid the period immediately following unification), 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.

Turning first to the US, the results of the dynamic model solution are shown in Figure 1 for the NK model, and in Figure 4 for the backward-looking model[38]. The results of historical simulation (ii) (no policy deviations) are shown in Figures 2 and 5 for the NK and backward-looking models respectively. Finally, the results of historical simulation (iii), adding a further shock to the historical shocks, are shown in Figures 3 and 6 for the NK and backward-looking models respectively. For reasons of space, in the case of the dynamic model solution (i) we do not report the impact on the endogenous variables of a shock to the taxation equation, as the result are very similar in form (but with the opposite direction and different magnitudes) to those of a government expenditure shock. Also, in the case of simulation (iii), we only consider structural shocks to output and inflation, as opposed to deviations in the policy rules. The comparable Figures for Germany are Figures 7 and 10 for simulation (i); Figures 8 and 11 for simulation (ii); and Figures 9 and 12 for simulation (iii).

Before turning to the analysis of fiscal-monetary interactions, we can make some general remarks about the simulation properties of the estimated models. First, by comparing the general dynamic properties of the New Keynesian and backward-looking models following the exogenous shocks (Figures 1, 7 and 4, 10), we see the much greater persistence of the shocks which is normally associated with backward-looking models without consumption-smoothing behaviour. Second, by looking at Figures 2, 8, 5 and 11, we see that by omitting the deviations from the systematic policy rules, the model accentuates the recession in the early 1990s, in the case of the USA and in the case of the NK model in Germany. This in turn induces a cyclical

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practice as the historical simulations are carried out during the 1990s, when the volatility of the real wage is much less than it was in the 1970s and 1980s, it matters little whether the real wage is endogenised or not.

[38] Note that in the case of Figures 1 and 4, the dates on the horizontal axis are meaningless, as we are not using actual data to simulate the models.

adjustment in output and inflation (and hence the policy variables). This is especially visible in the case of Germany (Figure 8), although for the backward-looking model the opposite applies. It seems difficult to believe that such policy deviations can be interpreted as 'policy errors'. There are two possible interpretations of this: the first, following Muscatelli, Trecroci and Tirelli (2002), is that, in contrast to the proposition in Clarida, Galí and Gertler (1998, 2000), shifts in systematic policy rules are more frequent than one might think. Clarida, Galí and Gertler highlight one particular shift in the monetary policy rule around the early 1980s, but Muscatelli, Trecroci and Tirelli (2002) provide evidence that shifts may have occurred even after the Volcker years. Hence these policy deviations were actually systematic shifts. The second possible interpretation is that interest-rate rules display non-linearities, either of the form of non-linear reactions to policy targets[39], 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. A third, and related, point is that the degree of persistence in the interest-rate policy rule does cause the shocks to be very slow to die out, even in the forward-looking model (see Figures 1 and 4)[40].

We now look at the reactions of monetary and fiscal policy to various types of shock in the dynamic simulations (Figures 1, 4, 7 and 11). 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 case of the BL model, and 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. In order to summarise the results in a single table, we display the monetary and fiscal responses as shown in Tables 3 and 4, for different horizons after the shock occurs or the historical simulation begins.

Historical simulation (ii) shows that, for the 1990s, fiscal and monetary policies have become more complementary, especially in the case of the BL model, for both countries. For the New Keynesian model (Figures 2, 5, 8 and 11), this shows up quite clearly. Only in some cases for the NK model does $\widehat{g}_t$ tend to act in the opposite direction. These results tend to correspond to

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

[40] This issue would not have been addressed by re-estimating the policy rules only from the 1980s: this would have resulted in a slightly higher coefficient on inflation, but a lower coefficient on output, and still a high degree of persistence in the interest rate rule.

some of the earlier evidence on complementarity during the 1990s obtained using VARs (see Muscatelli, Tirelli and Trecroci, 2001).

Another interesting aspect of the simulations is that, given the inertia effects in the monetary policy rule, the complementarity between policy instruments only emerges with a lag of about 4 quarters after output shocks. After an inflation shock (because of its impact on real interest rates) the two instruments do tend to be out of phase and tend to be substitutes, even in the forward-looking model (Figure 1). 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 preliminary 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[41]. Here the NK model seems, at least for the early 1990s, to suggest a path for real interest rates which is closer to the baseline than the BL model for the USA, whilst the reverse is true for Germany. For the USA, 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. In contrast, the BL model suggests the opposite: that the policy rule tracks the baseline quite closely for the latter part of the sample. 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. The two models also tell different stories as far as the fiscal rules are concerned. For the USA, both the BL and NK model do not suggest a systematic deviation of government spending and taxation from the policy rule, although the NK model does experience a large deviation in the early to mid-1990s, which is probably connected to the deficit correction phase. In contrast in the case of Germany, the historical simulation overpredicts the reaction of fiscal policy to the behaviour of output towards the late 1990s, which is probably connected to the Maastricht convergence process. In the longer run, the US fiscal rules capture the behaviour of fiscal policy in the late 1990s more precisely.

Overall, the general pattern which emerges is one where fiscal and monetary policy are more complementary following output shocks than following

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[41] Note that we are not considering how policy instruments deviated from their actual values, but relative to our baseline simulation.

policy shocks or inflation shocks. Historical simulations for the 1990s tend to support a greater complementarity for the two policy instruments, 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.

Table 3: New Keynesian Model: Summary of Fiscal and Monetary Responses in Dynamic Simulations

Horizon: 0 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	-	+	0	+
(i)	$\widehat{\pi}_t$	+	-	0	-
(i)	$\widehat{i}_t$	+	-	0	+
(i)	$\widehat{g}_t$	-	+	-	+
(ii)	-	0	0	0	+
(iii)	$\widehat{y}_t$	-	+	0	-
(iii)	$\widehat{\pi}_t$	+	-	0	+

Horizon: 4 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	+	+	+	+
(i)	$\widehat{\pi}_t$	0	-	-	-
(i)	$\widehat{i}_t$	0	-	-	-
(i)	$\widehat{g}_t$	-	+	-	+
(ii)	-	-	+	+	+
(iii)	$\widehat{y}_t$	+	-	-	+
(iii)	$\widehat{\pi}_t$	0	-	+	+

Horizon: 8 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	+	+	0	+
(i)	$\widehat{\pi}_t$	-	-	0	-
(i)	$\widehat{i}_t$	-	-	-	-
(i)	$\widehat{g}_t$	-	+	+	+
(ii)	-	+	-	-	-
(iii)	$\widehat{y}_t$	+	-	-	-
(iii)	$\widehat{\pi}_t$	+	-	-	-

Horizon: 16 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	0	0	0	0
(i)	$\widehat{\pi}_t$	-	-	-	-
(i)	$\widehat{i}_t$	-	-	-	-
(i)	$\widehat{g}_t$	0	+	+	+
(ii)	-	-	+	-	+
(iii)	$\widehat{y}_t$	+	+	-	+
(iii)	$\widehat{\pi}_t$	+	+	-	+

A (+) indicates that the two policy instruments are both acting in a contractionary or expansionary fashion (i.e. they are complements) relative to the steady-state equilibrium or the model baseline; A (-) indicates that they are acting in opposite directions (i.e. they are substitutes). A (0) indicates that at least one of the instruments has returned to its equilibrium or baseline. The first sign indicates the correlation between $\widehat{g}_t$ and $\widehat{r}_t$, the second sign indicates the co-movement of $\widehat{\tau}_t$ and $\widehat{r}_t$.

Table 4: Backward-Looking Model:
Summary of Fiscal and Monetary Responses in Dynamic Simulations

Horizon: 0 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	-	+	+	-
(i)	$\widehat{\pi}_t$	0	0	0	0
(i)	$\widehat{i}_t$	0	0	0	0
(i)	$\widehat{g}_t$	-	0	0	0
(ii)	-	-	0	0	0
(iii)	$\widehat{y}_t$	-	-	0	0
(iii)	$\widehat{\pi}_t$	+	+	0	0

Horizon: 4 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	+	+	+	-
(i)	$\widehat{\pi}_t$	+	+	-	-
(i)	$\widehat{i}_t$	+	+	-	-
(i)	$\widehat{g}_t$	-	+	-	+
(ii)	-	-	+	+	+
(iii)	$\widehat{y}_t$	-	-	+	+
(iii)	$\widehat{\pi}_t$	+	+	-	+

Horizon: 8 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	0	0	+	-
(i)	$\widehat{\pi}_t$	0	0	+	+
(i)	$\widehat{i}_t$	+	-	-	-
(i)	$\widehat{g}_t$	0	+	+	+
(ii)	-	+	+	+	+
(iii)	$\widehat{y}_t$	+	+	-	-
(iii)	$\widehat{\pi}_t$	-	-	-	-

Horizon: 16 quarters after shock

Simulation	Shock	USA		Germany	
(i)	$\widehat{y}_t$	-	-	-	-
(i)	$\widehat{\pi}_t$	+	+	-	-
(i)	$\widehat{i}_t$	-	-	+	+
(i)	$\widehat{g}_t$	-	0	-	-
(ii)	-	+	+	0	0
(iii)	$\widehat{y}_t$	-	+	0	0
(iii)	$\widehat{\pi}_t$	-	+	+	+

A (+) indicates that the two policy instruments are both acting in a contractionary or expansionary fashion (i.e. they are complements) relative to the steady-state equilibrium or the model baseline; A (-) indicates that they are acting in opposite directions (i.e. they are substitutes). A (0) indicates that at least one of the instruments has returned to its equilibrium or baseline. The first sign indicates the correlation between $\widehat{g}_t$ and $\widehat{r}_t$, the second sign indicates the co-movement of $\widehat{\tau}_t$ and $\widehat{r}_t$.

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 (over the full sample period) from the NK and BL models to generate the shocks.

The correlation between the monetary and fiscal instruments for the average of the replications is reported in Table 5. The pattern of results is striking: with the exception of the BL model for the USA, there is (a) generally a tendency for the two policy instruments to be strategic substitutes and (b) a tendency for government spending to be slightly less correlated with monetary policy than the tax instrument. 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.

Table 5: Stochastic Simulation Using Estimated Variance-Covariance Matrix of Structural and Policy Shocks

Policy Instruments	USA FL Model	USA BL Model	Ger FL Model	Ger BL Model
$\widehat{g}_t, \widehat{r}_t$	0.014 (-)	-0.084 (+)	0.453 (-)	0.152 (-)
$\widehat{\tau}_t, \widehat{r}_t$	-0.163 (-)	0.448 (+)	-0.215 (-)	-0.236 (-)
$\widehat{\tau}_t, \widehat{g}_t$	0.463	-0.526	0.460	0.155

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

5 Optimal Monetary Policy

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 optimisation exercise and again verify what impact assuming endogenous fiscal policy has on the divergence between the estimated and optimal monetary policy rule. For reasons of space we focus only on one estimated model, the US forward-looking model, referring to the results obtained with the other model in the text.

We compute the optimal rule using the standard optimal control approach[42] (see Currie and Levine, 1993, Rudebusch and Svensson, 1999). Giannoni and Woodford (2002a, 2002b) 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[43], 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[44], 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 turns out to be optimal from a wider perspective is a matter which we leave to further work.

We derive our optimal monetary rules using the following intertemporal

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

[43] 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.

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

loss function for the monetary authorities:

$$L = \sum_{j=0}^{\infty} \delta^j \left(\widehat{\pi}_{t+j}^2 + \Phi_1 \widehat{y}_{t+j}^2 + \Phi_2 (i_{t+j} - i_{t+j-1})^2 \right) \tag{18}$$

In all our optimal policy derivations we focus on the particular limit case where $\delta = 1$ (see Rudebusch and Svensson, 1999). 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 (18):

(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, where fiscal policy is kept exogenously fixed.

Table 6 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 loss under the three loss function parameterisations underlying the three optimal policy rules. We also show the detailed interest rate and output responses under the four monetary policy rules for both fiscal policy scenarios under one shock. Figures 13 and 14 show the interest-rate and output responses to an output shock assuming endogenous fiscal policy, and Figures 15 and 16 are the corresponding simulations keeping fiscal policy exogenously fixed.

Table 6: 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 6 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 stabilise 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 13 and 15 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, comparing Figures 14 and 16, 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 intertial rule is evidence of the robustness of these responses to different shocks, a point emphasised by Giannoni and Woodford (2002a,b). To emphasise 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 17), assumng 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.

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.

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 both a New Keynesian and a backward-looking model of inflation and output jointly with monetary and fiscal rules to provide some understanding of the way in which different macroeconomic policy instruments interact over the business cycle, using data from the USA and Germany.

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 Hallet and Strauch, 2001).

The evidence from this paper substantiates the conjecture in Buti, Roeger and in t' Veld (2001) that the nature of the interaction between the two policy instruments seems to depend on the natureof the shocks hitting the system. Indeed, we have shown that, except for the case of output shocks, where fiscal and monetary policies tend to act in harmony, following inflation shocks or policy deviations, there is evidence of the two policy instruments acting in opposite directions. The evidence presented seems to suggest that it was largely the configuration of the shocks in the last decade which seems to have driven the two policy instrument to act in greater harmony.

We also show that the perspective on fiscal-monetary interactions also depends critically on the type of structural model fitted to the data. Our evidence suggests that the backward-looking model interpretation, especially for the case of the US, points towards greater complementarity of the fiscal and monetary policy instrument. 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 on the correlation between the two policy instruments.

Naturally this represents an early attempt to use estimated structural models in this way. 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.

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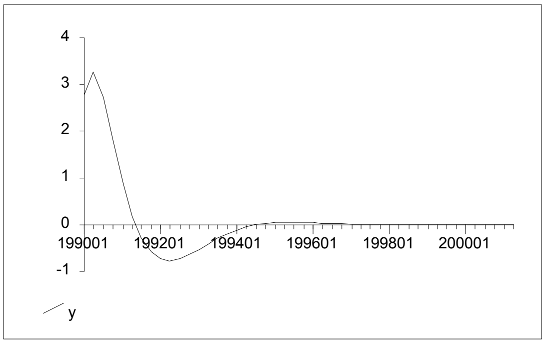
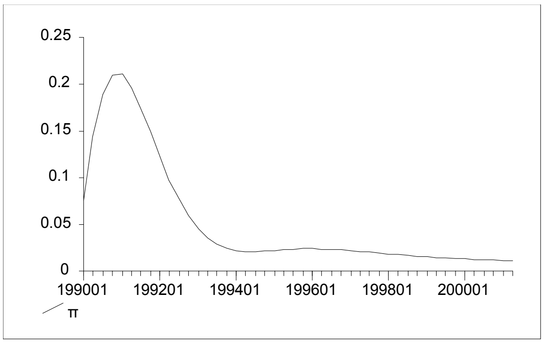
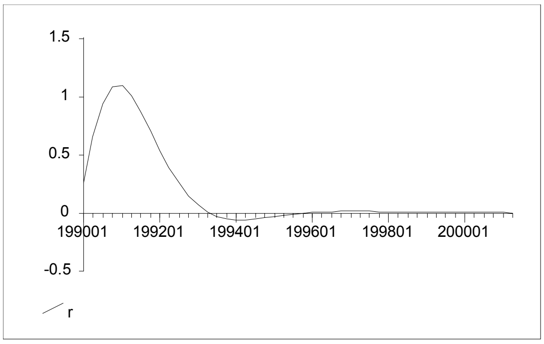
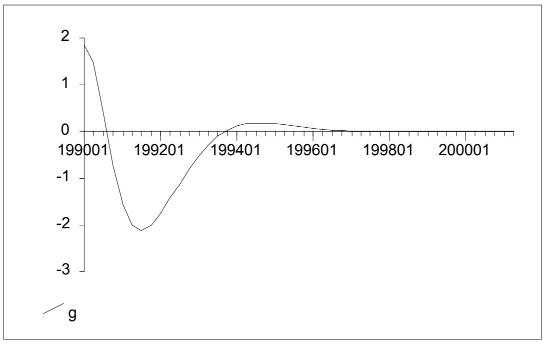
Figure 1A: USA - New Keynesian Model - Dynamic Simulation (i) - Temporary 1% positive shock in y, with AR decay parameter = 0.5:





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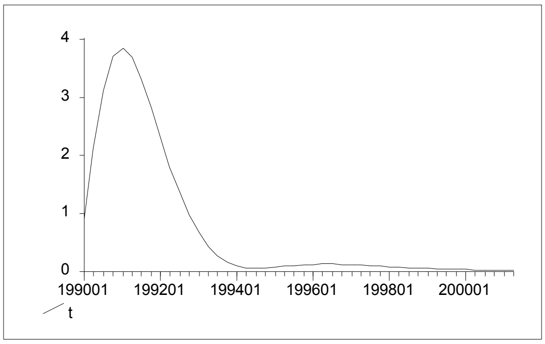
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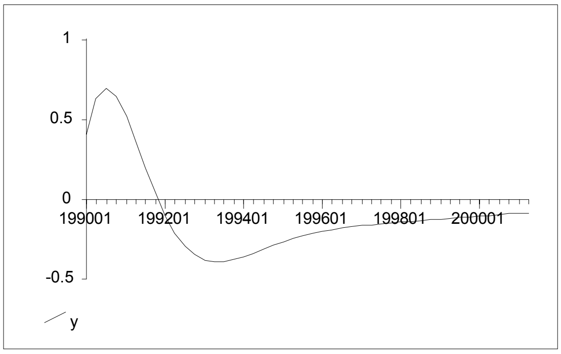

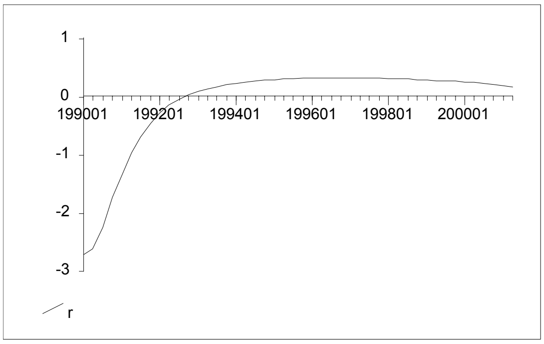

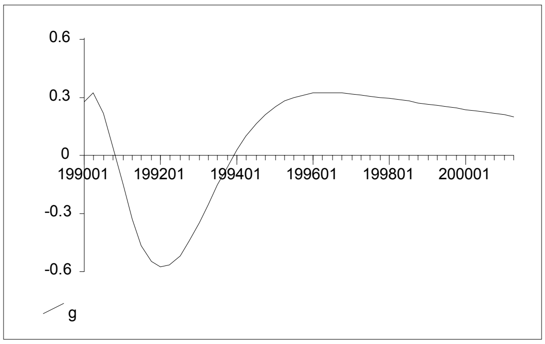
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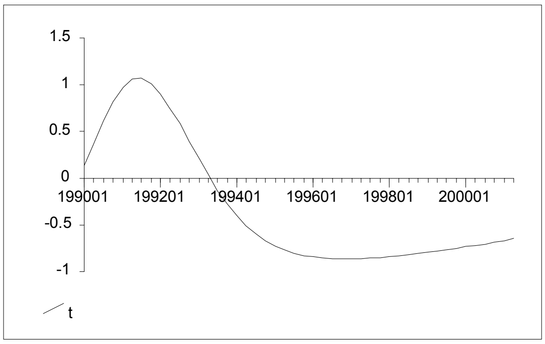
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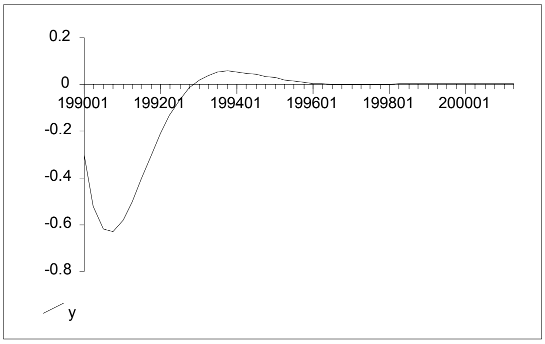
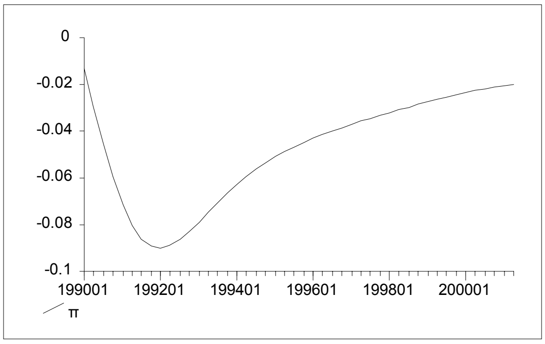
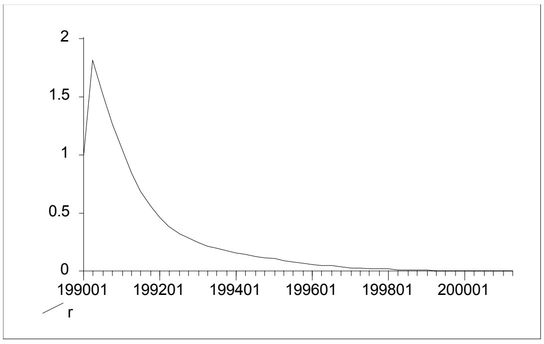
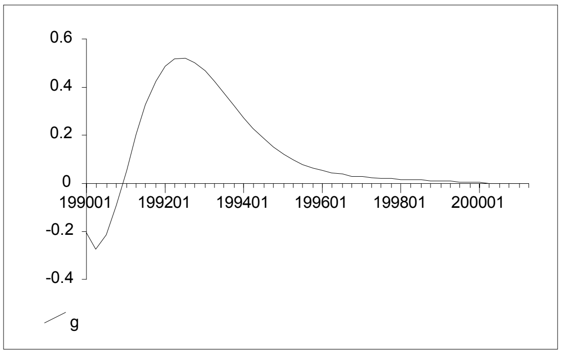
Figure 1C: USA - New Keynesian Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in i:





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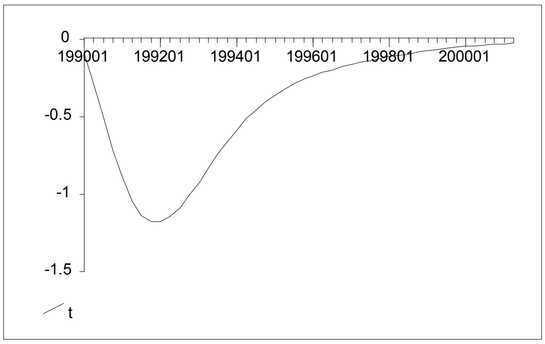
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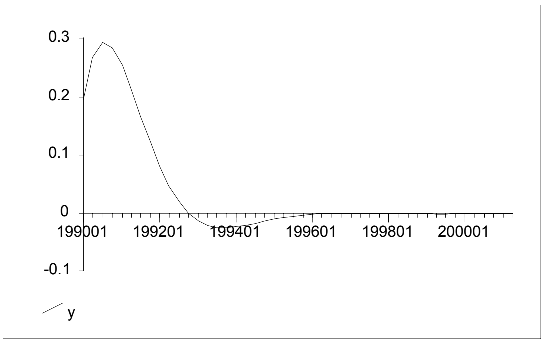
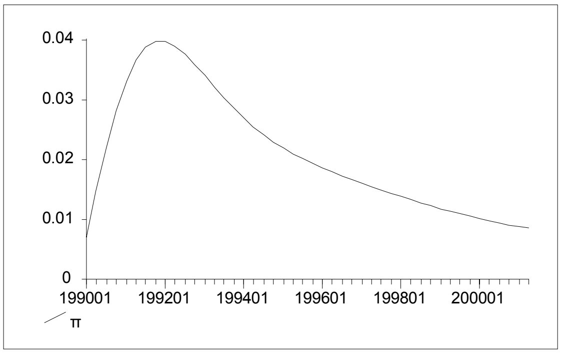
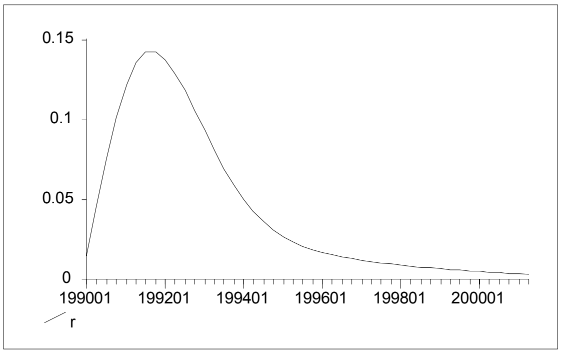
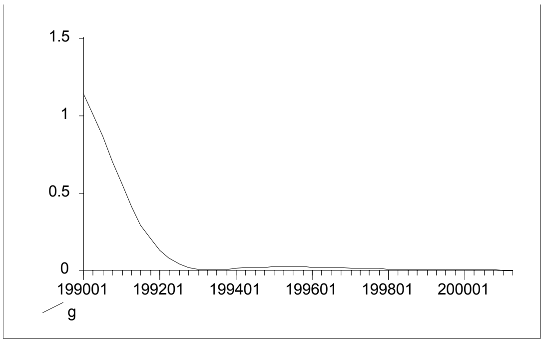
Figure 1D: USA - New Keynesian Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in g:





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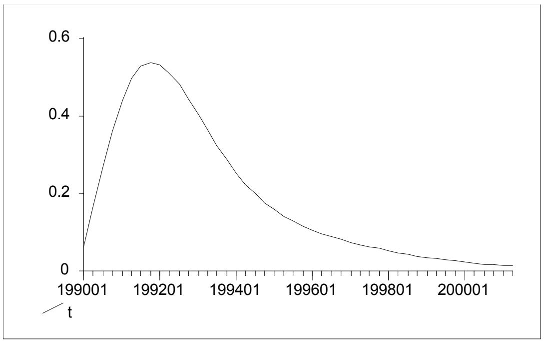
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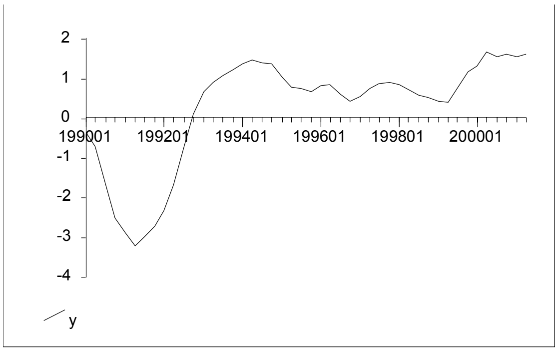
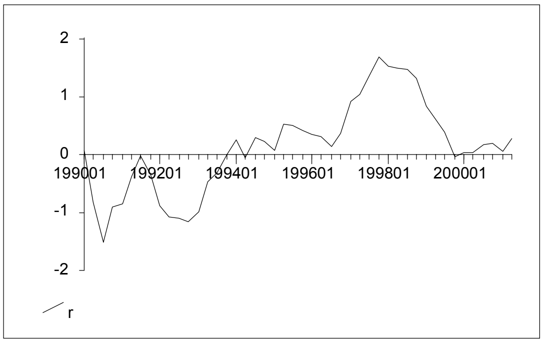
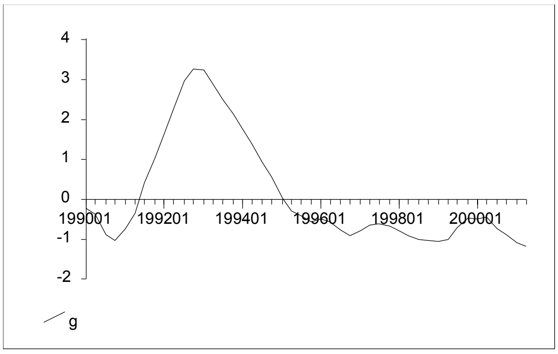
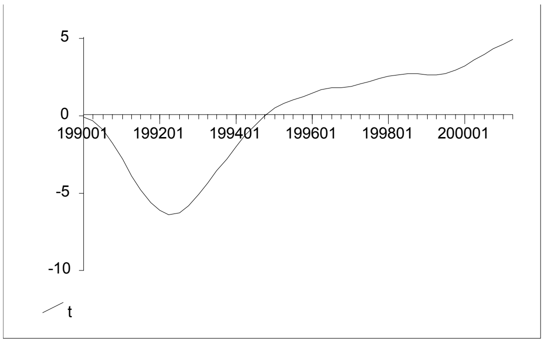
200001
t

Figure 2: USA – New Keynesian Model - Historical Simulation (ii) (1990(1)-2001(2)) – All variables shown as deviations from base:








5
0
-5
-10
199001
199201
199401
199601
199801
200001
t

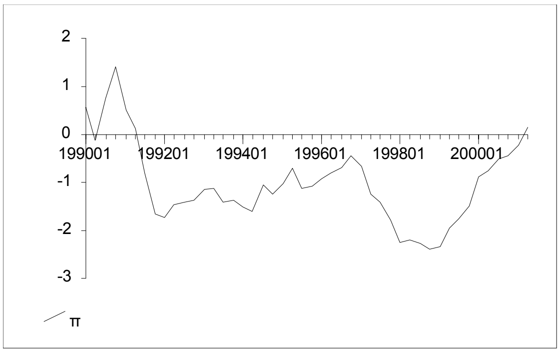

2
1
0
-1
-2
-3
199001
199201
199401
199601
199801
200001
π

Figure 3A: USA – New Keynesian Model - Historical Simulations (iii) (1990(1)-2001(2)): Temporary positive 1% shock in y, with AR decay parameter = 0.5, shown as deviations from simulation base:

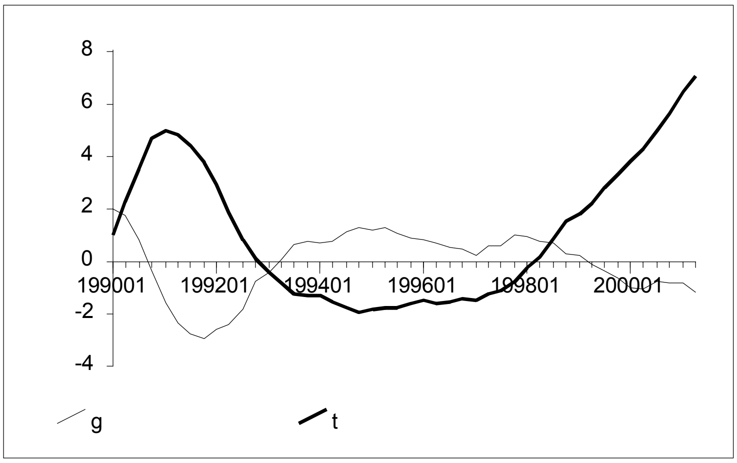
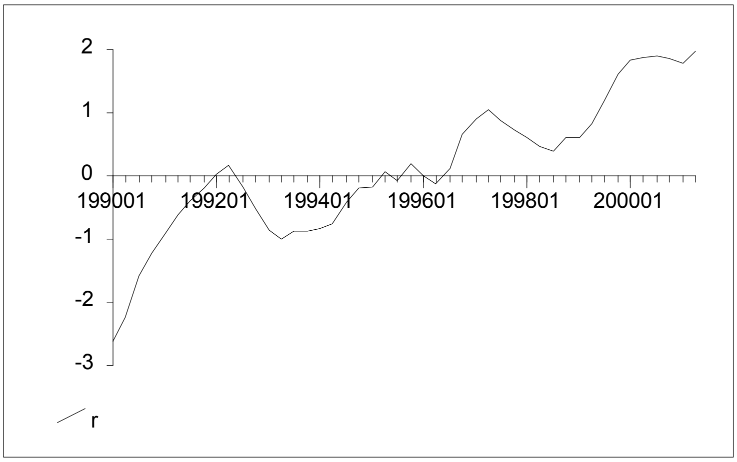


Figure 3B: USA – New Keynesian Model - Historical Simulations (iii) (1990(1)-2001(2)): Temporary positive 1% shock in π, with AR decay parameter = 0.5, shown as deviations from simulation base:



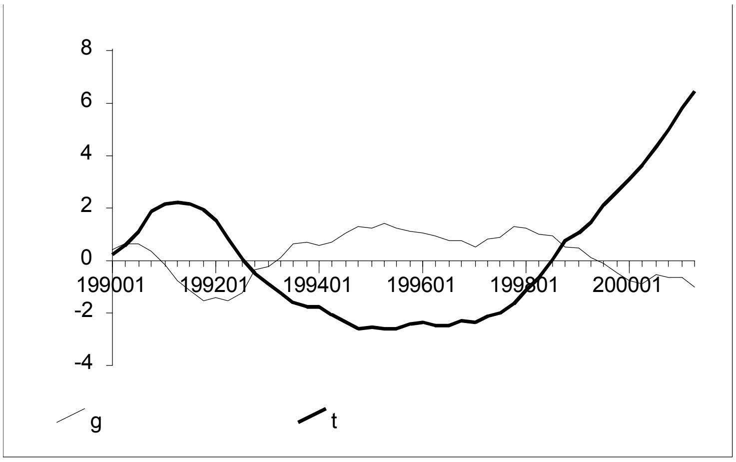
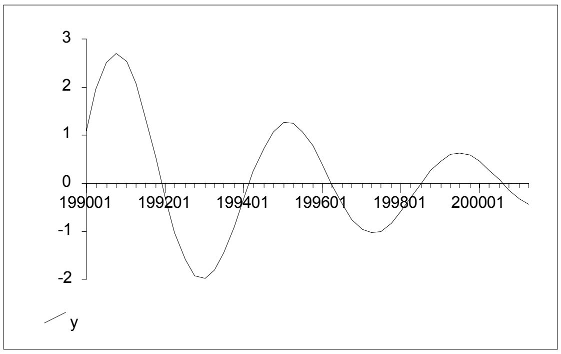
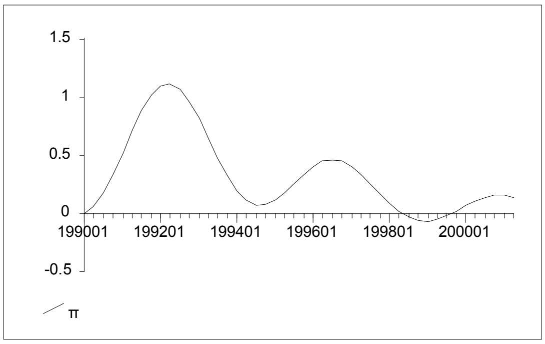
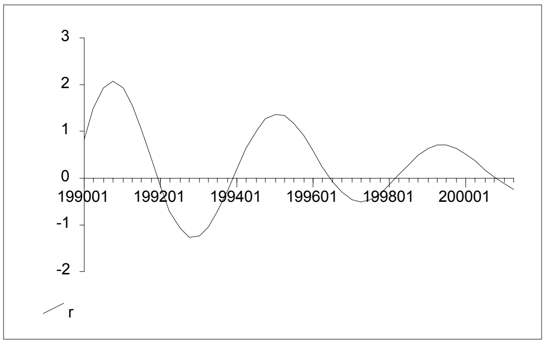
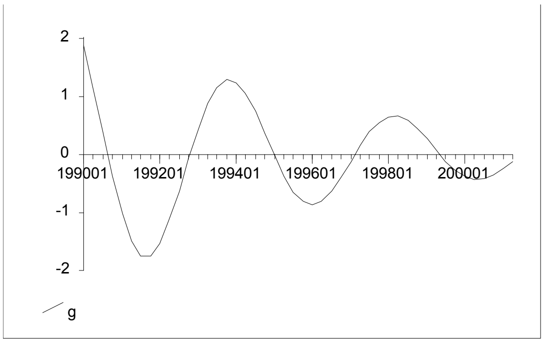


Figure 4A: USA - Backward-Looking Model - Dynamic Simulation (i) - Temporary 1% positive shock in y, with AR decay parameter = 0.5:








2
1
0
-1
-2
199001
199201
199401
199601
199801
200001
g

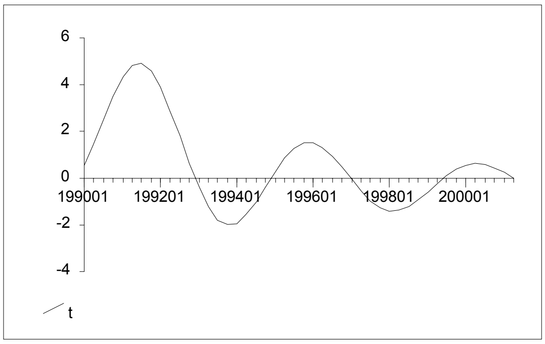
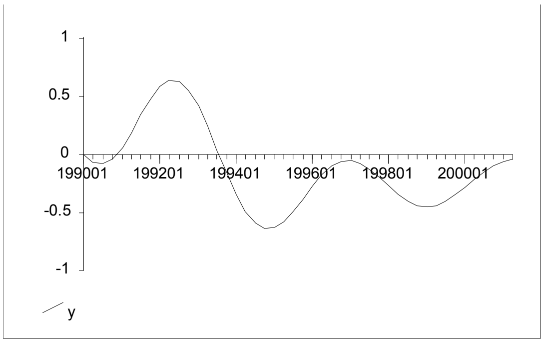
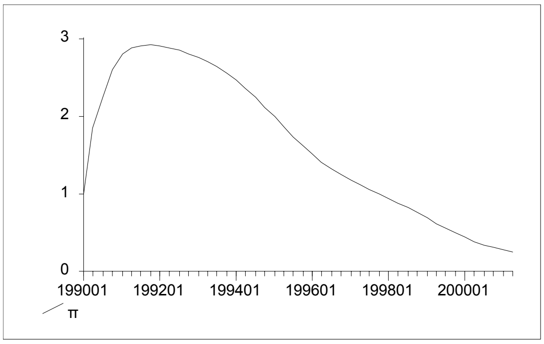
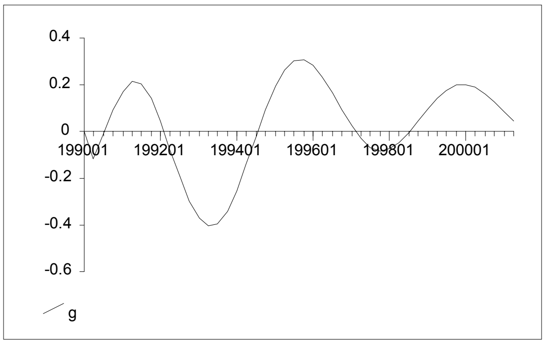

6
4
2
0
-2
-4
199001
199201
199401
199601
199801
200001
t

Figure 4B: USA - Backward-looking Model - Dynamic Simulation (i) - Temporary 1% positive shock to π, with AR decay parameter = 0.5:






0.4
0.2
0
-0.2
-0.4
-0.6
199001
199201
199401
199601
199801
200001
g

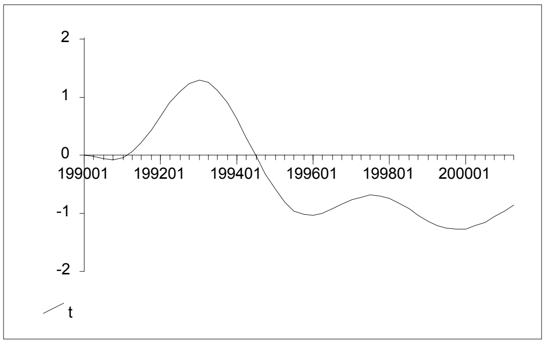
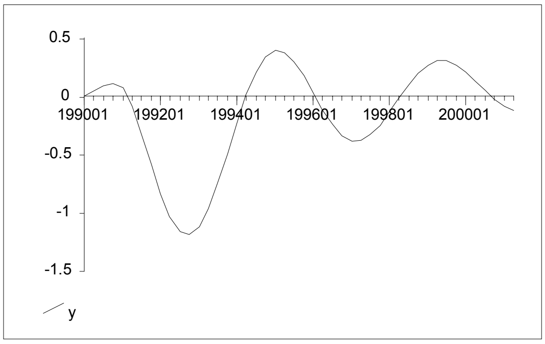
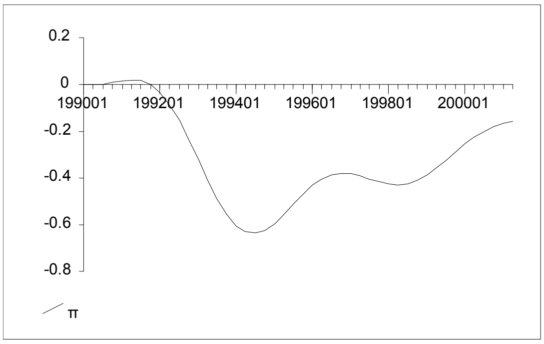
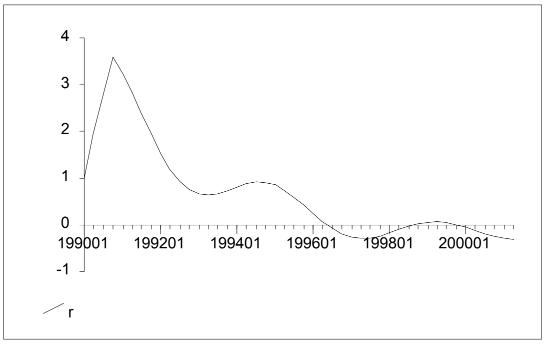
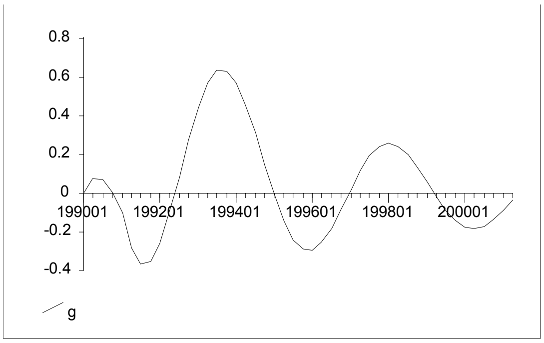

2
1
0
-1
-2
199001
199201
199401
199601
199801
200001
t

Figure 4C: USA - Backward-Looking Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in i:








0.8
0.6
0.4
0.2
0
-0.2
-0.4
199001
199201
199401
199601
199801
200001
g

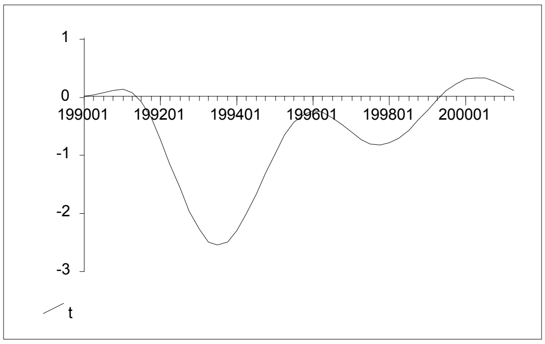
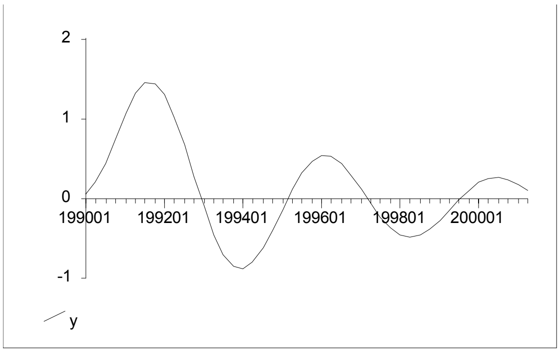
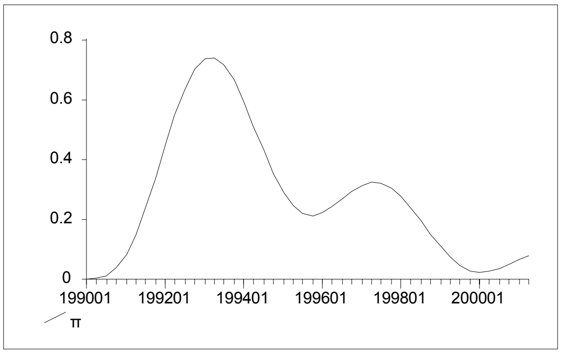
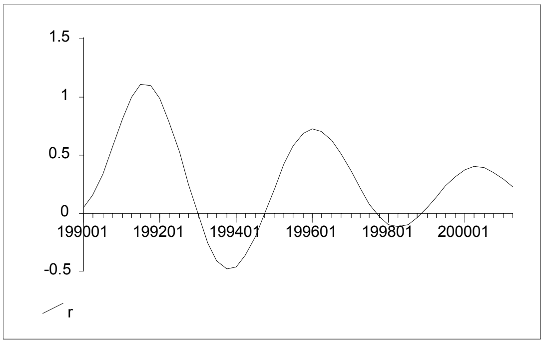
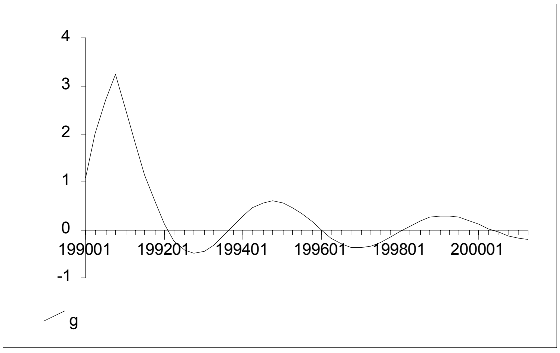

1
0
-1
-2
-3
199001
199201
199401
199601
199801
200001
t

Figure 1D: USA - Backward-Looking Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in g:








4
3
2
1
0
-1
199001
199201
199401
199601
199801
200001
g

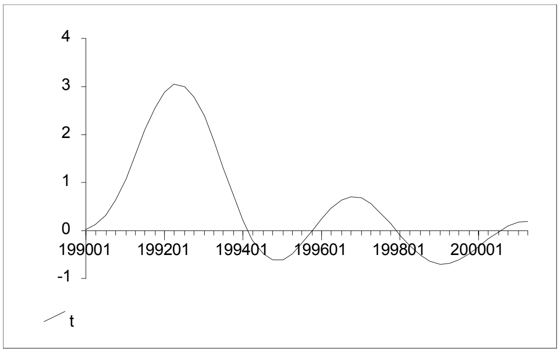
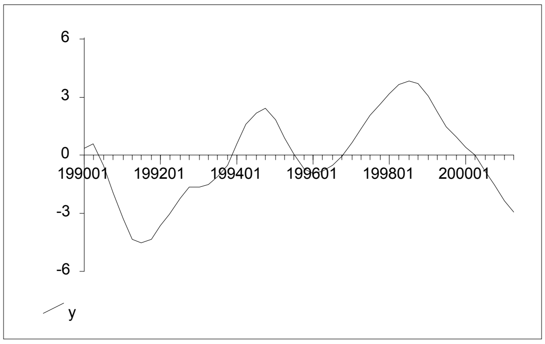
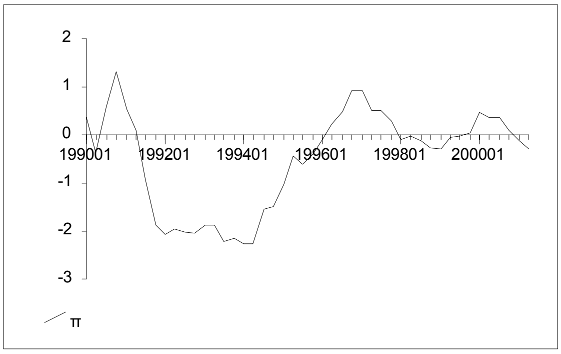
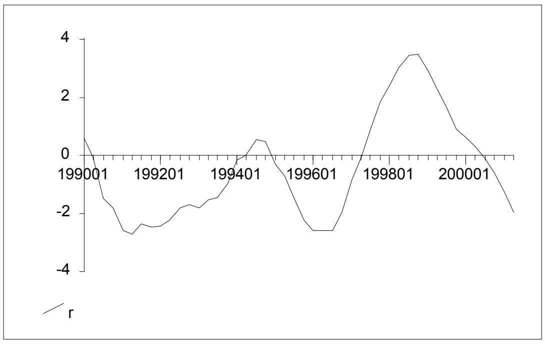
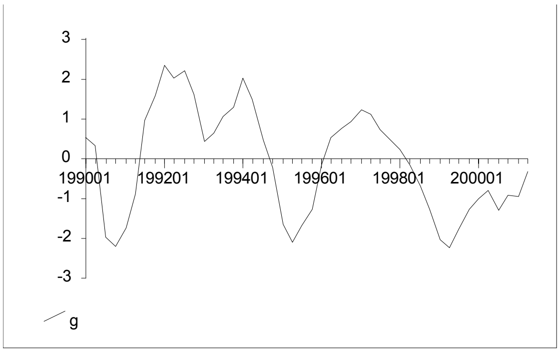

4
3
2
1
0
-1
199001
199201
199401
199601
199801
200001
t

Figure 5: USA – Backward-Looking Model - Historical Simulation (ii) (1990(1)-2001(2)) – All variables shown as deviations from base:








3
2
1
0
-1
-2
-3
199001
199201
199401
199601
199801
200001
g

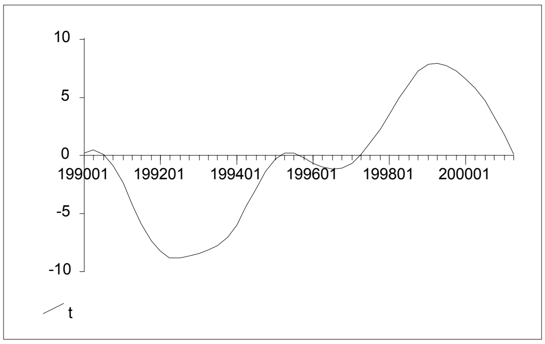
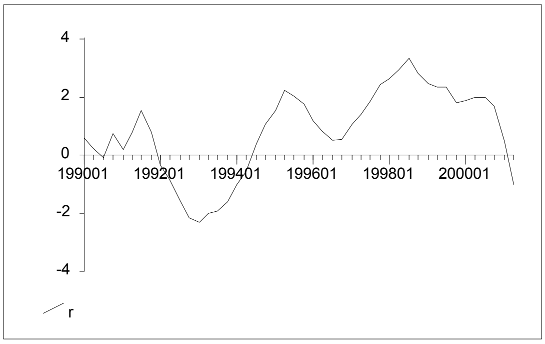

10
5
0
-5
-10
199001
199201
199401
199601
199801
200001
t

Figure 6A: USA – Backward-Looking Model - Historical Simulations (iii) (1990(1)-2001(2)): Temporary positive 1% shock in y, with AR decay parameter = 0.5, shown as deviations from simulation base:



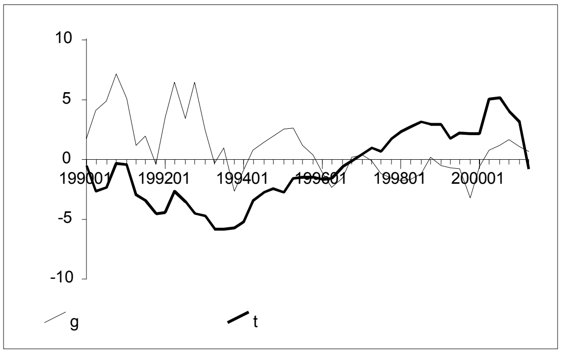
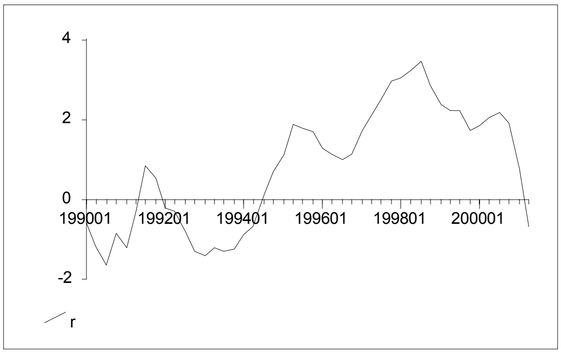


Figure 6B: USA - Backward-Looking Model - Historical Simulations (iii) (1990(1)-2001(2)): Temporary positive 1% shock in π, with AR decay parameter = 0.5, shown as deviations from simulation base:



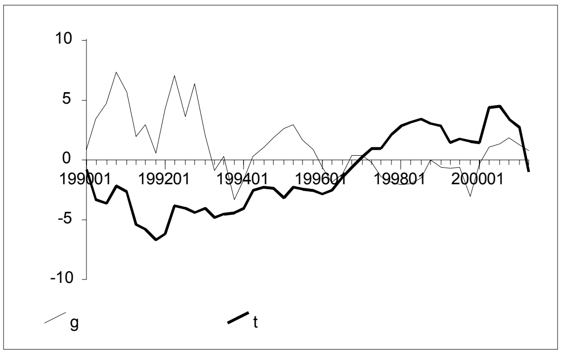
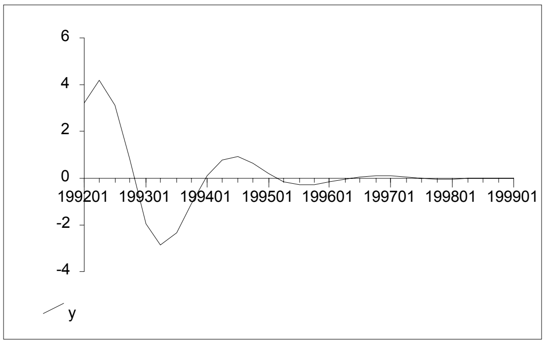
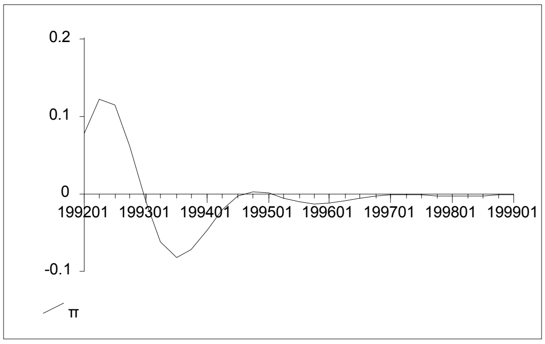
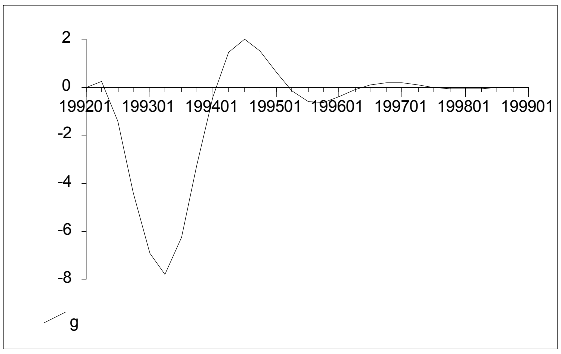


Figure 7A: Germany - New Keynesian Model - Dynamic Simulation (i) - Temporary 1% positive shock in y, with AR decay parameter = 0.5:






2
0
-2
-4
-6
-8
199201
199301
199401
199501
199601
199701
199801
199901
g

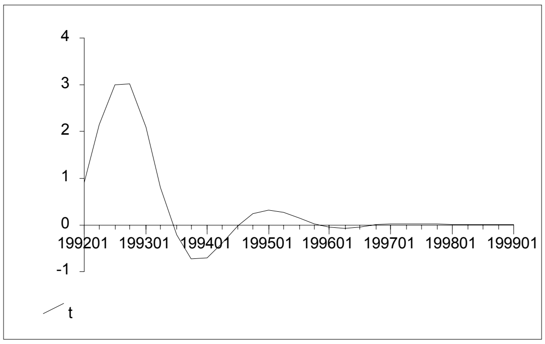
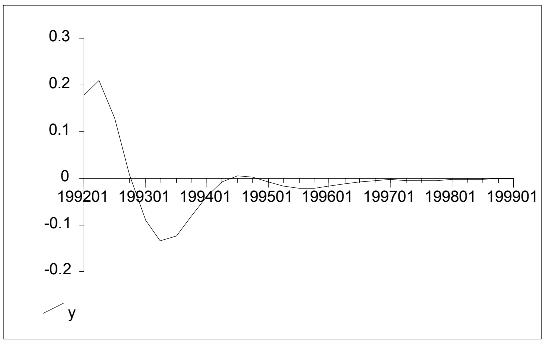
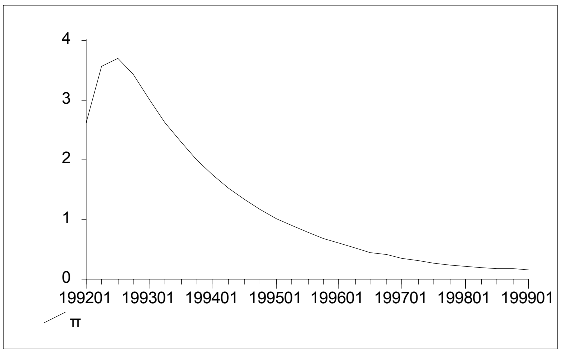
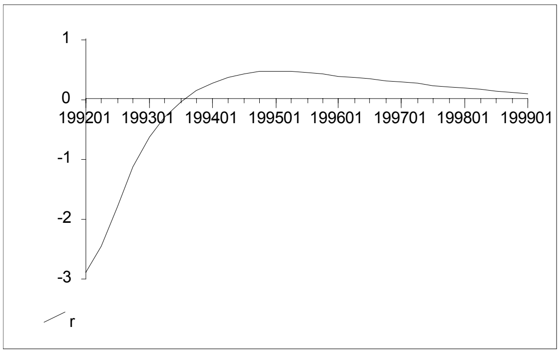
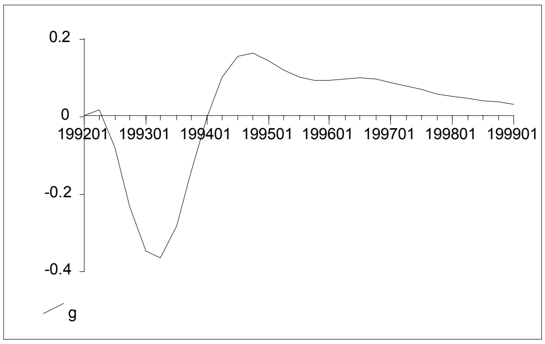

4
3
2
1
0
-1
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 7B: Germany - New Keynesian Model - Dynamic Simulation (i) - Temporary 1% positive shock to π, with AR decay parameter = 0.5:



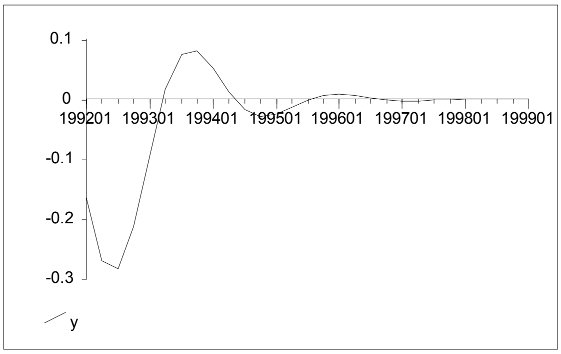


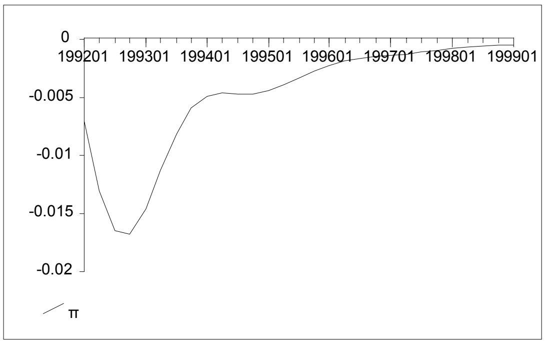


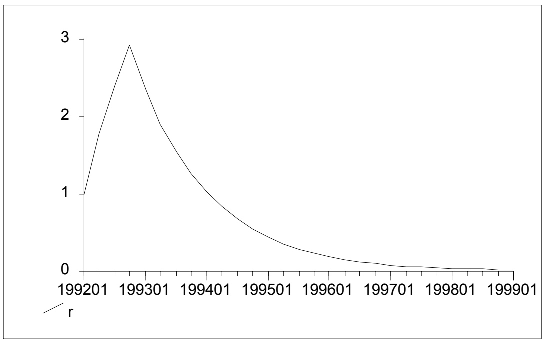

0.2
0
-0.2
-0.4
199201
199301
199401
199501
199601
199701
199801
199901
g

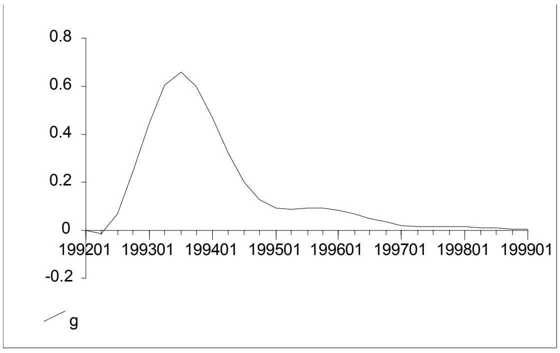

0.2
0.1
0
-0.1
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 7C: Germany - New Keynesian Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in i:



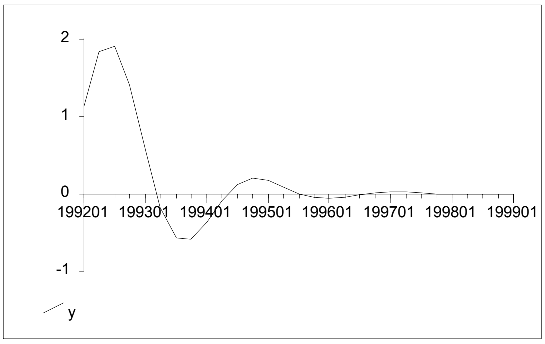


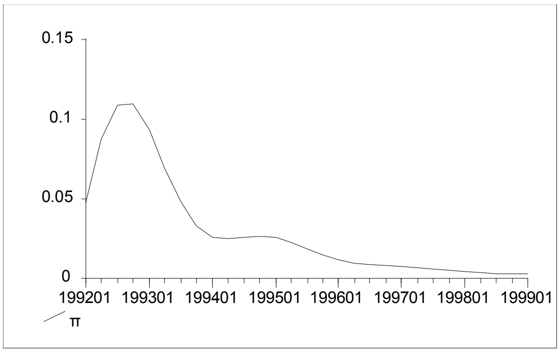


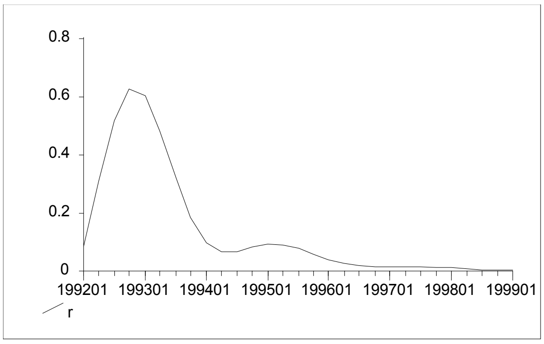

0.8
0.6
0.4
0.2
0
-0.2
199201
199301
199401
199501
199601
199701
199801
199901
g

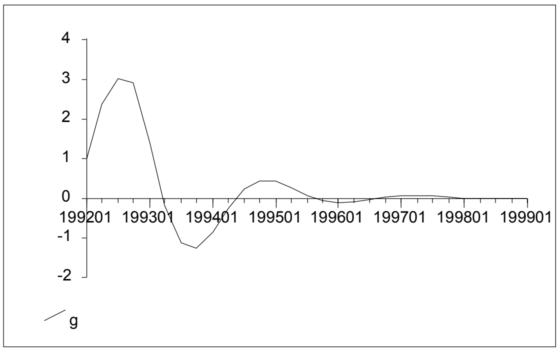

0
-0.1
-0.2
-0.3
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 7D: Germany - New Keynesian Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in g:








4
3
2
1
0
-1
-2
199201
199301
199401
199501
199601
199701
199801
199901
g

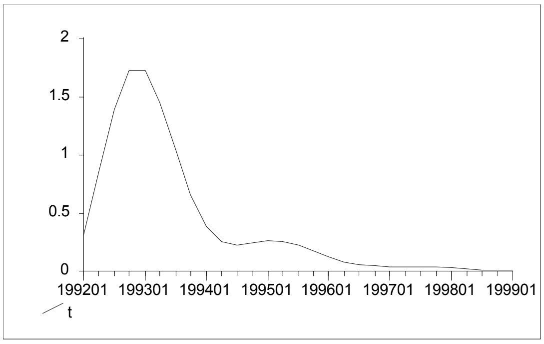
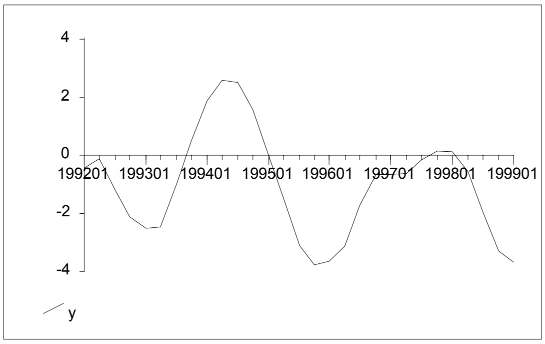
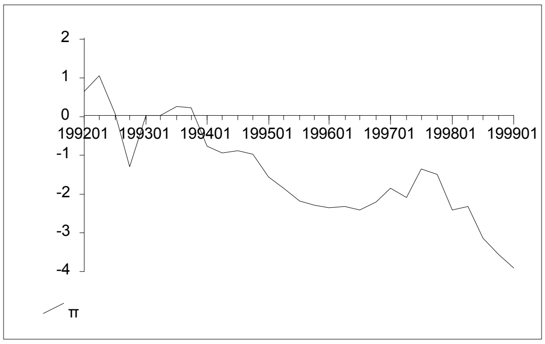
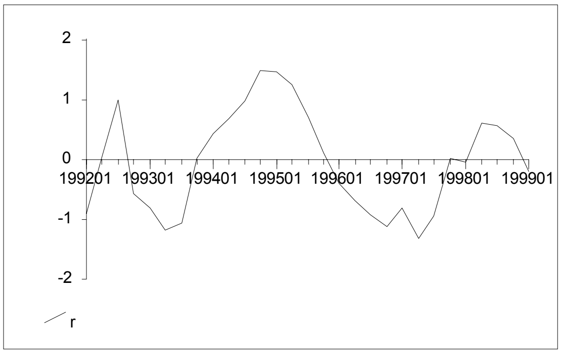

2
1.5
1
0.5
0
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 8: Germany – New Keynesian Model - Historical Simulation (ii) (1992(1)-1999(1)) – All variables shown as deviations from base:








10
5
0
-5
199201
199301
199401
199501
199601
199701
199801
199901
g

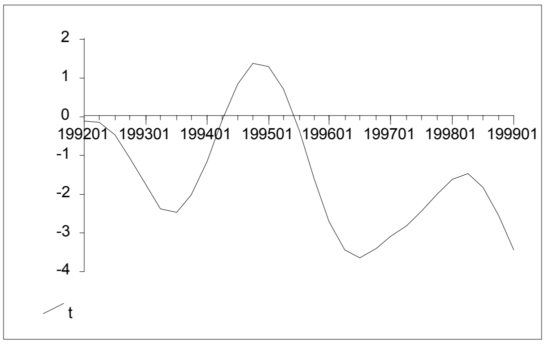
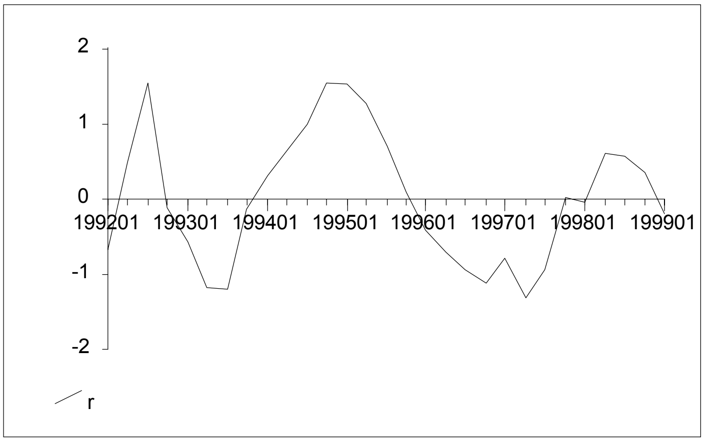

2
1
0
-1
-2
-3
-4
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 9A: Germany – New Keynesian Model - Historical Simulations (iii) (1992(1)-1999(1)): Temporary positive 1% shock in y, with AR decay parameter = 0.5, shown as deviations from simulation base:



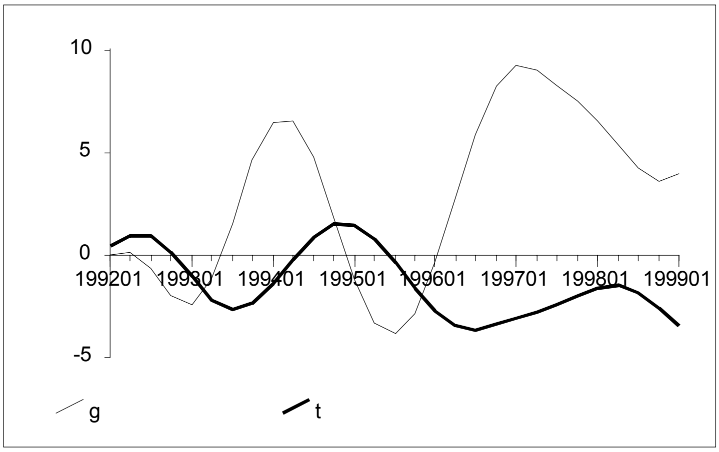
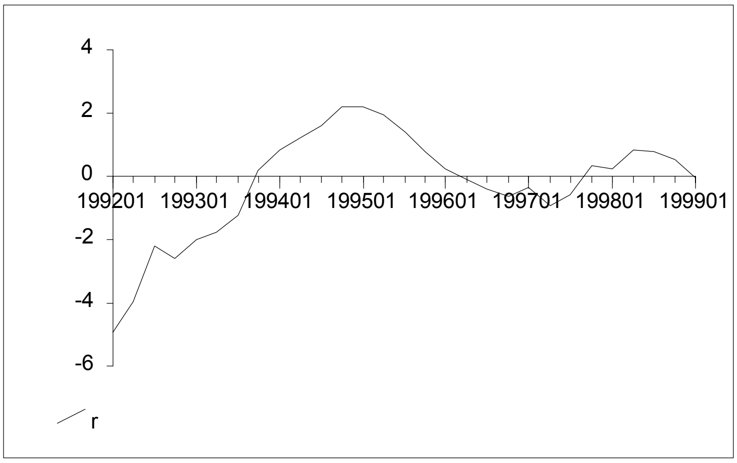


Figure 9B: Germany – New Keynesian Model - Historical Simulations (iii) (1992(1)-1999(1)): Temporary positive 1% shock in π, with AR decay parameter = 0.5, shown as deviations from simulation base:



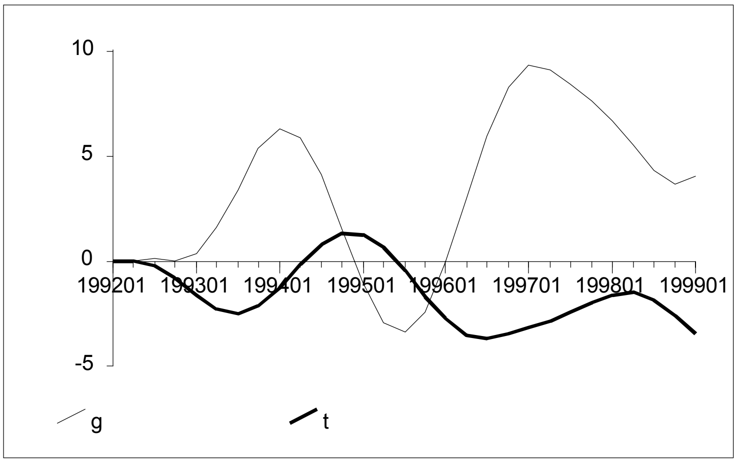
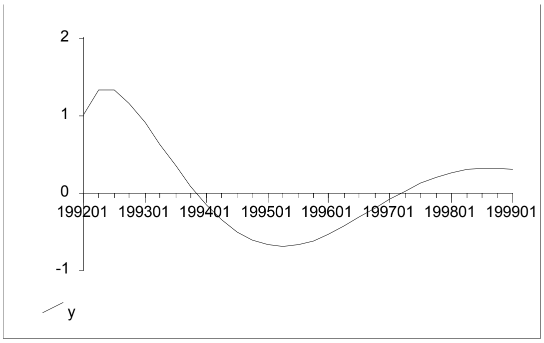
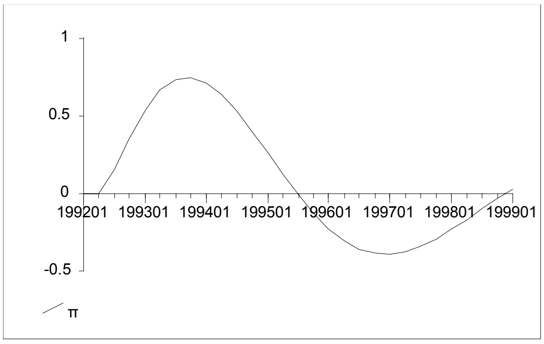
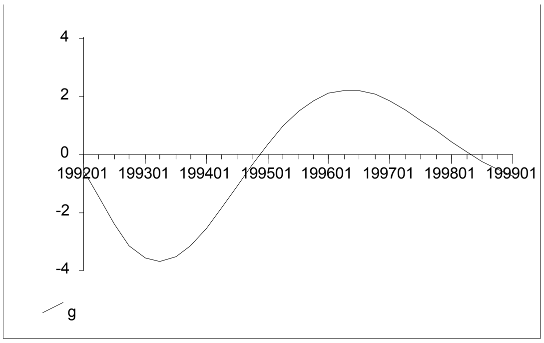


Figure 10A: Germany- Backward-Looking Model - Dynamic Simulation (i) - Temporary 1% positive shock in y, with AR decay parameter = 0.5:






4
2
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-2
-4
199201
199301
199401
199501
199601
199701
199801
199901
g

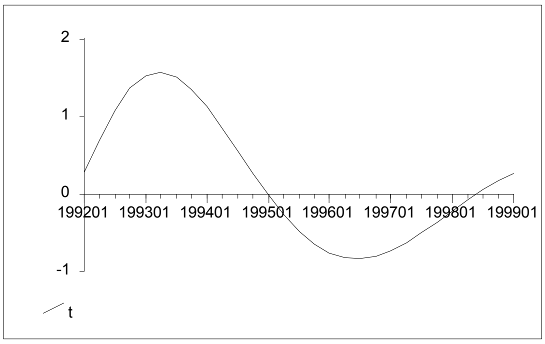
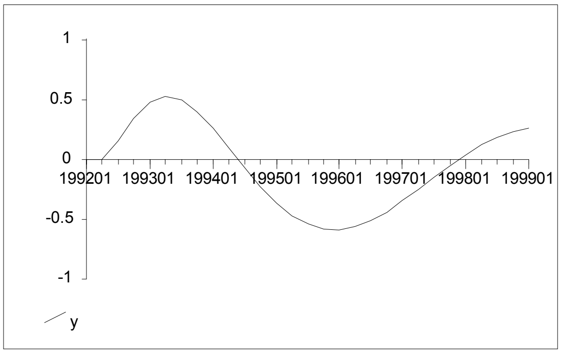
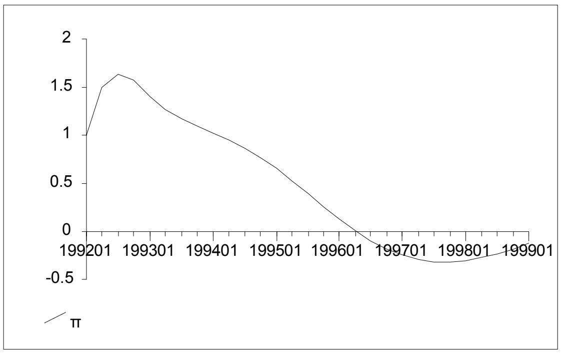
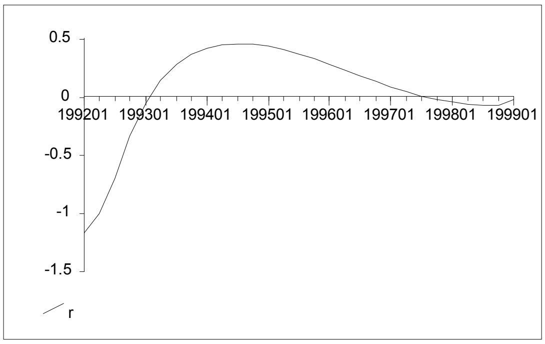

2
1
0
-1
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 10B: Germany - Backward-looking Model - Dynamic Simulation (i) - Temporary 1% positive shock to π, with AR decay parameter = 0.5:



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-1
-1.5
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199301
199401
199501
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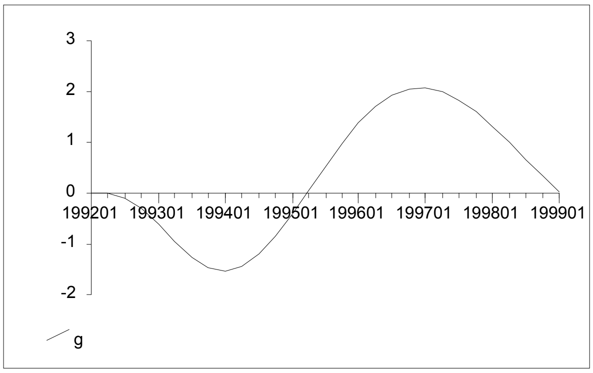
199701
199801
199901
r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-1
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199301
199401
199501
199601
199701
199801
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g

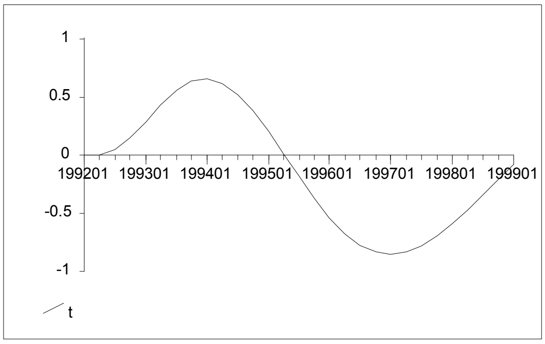
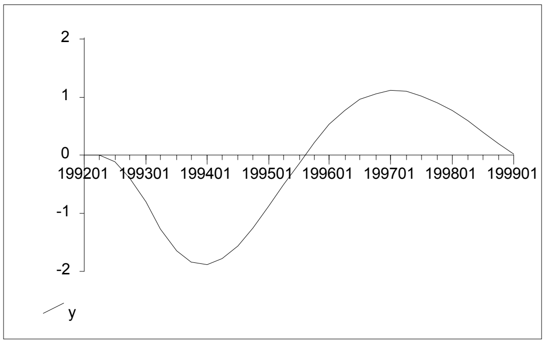
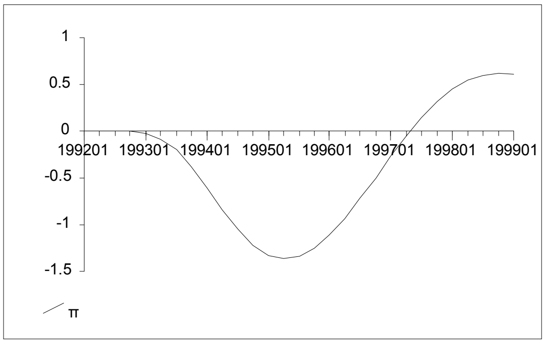
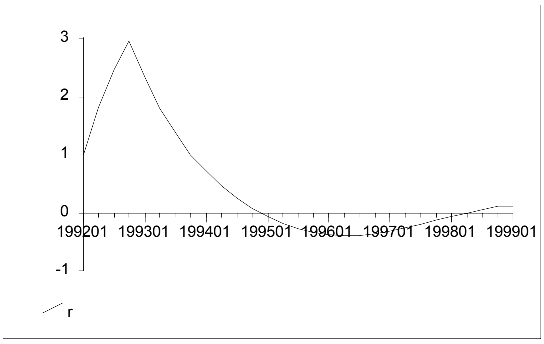
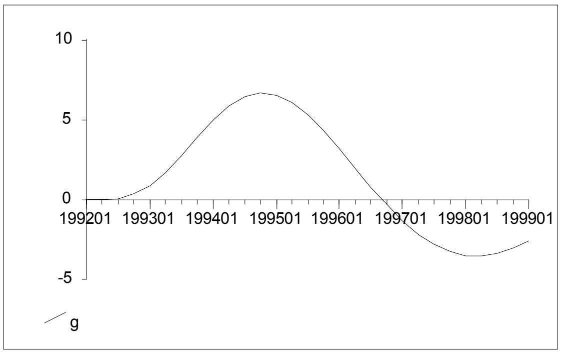

1
0.5
0
-0.5
-1
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 10C: Germany - Backward-Looking Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in i:





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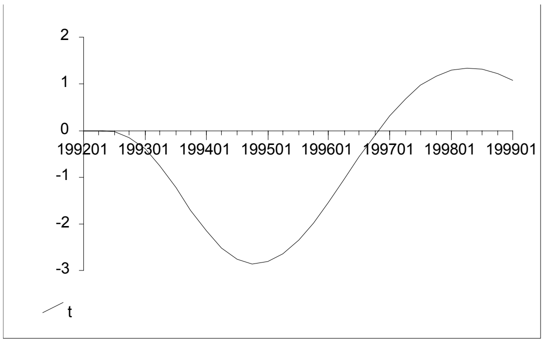
199601
199701
199801
199901
g


2
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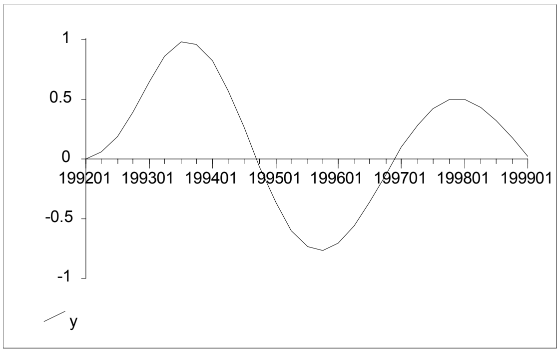
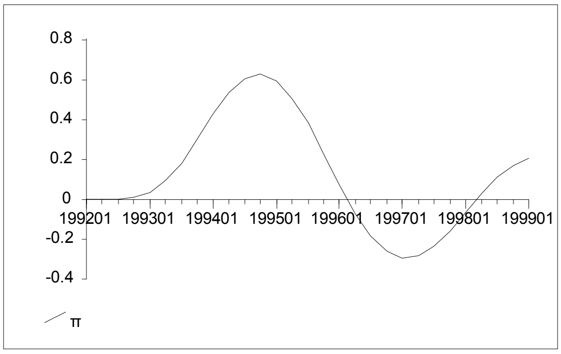
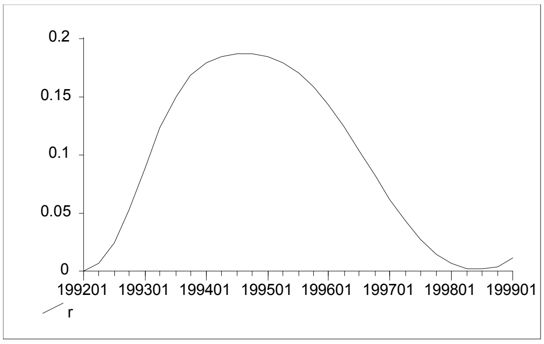
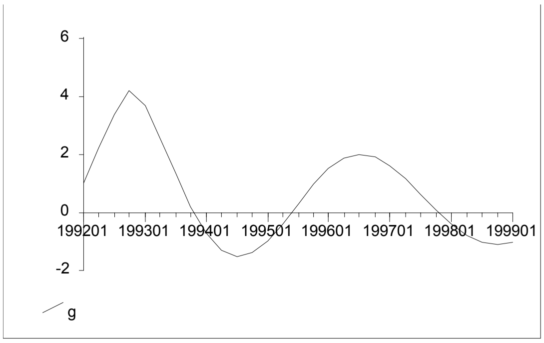
0
-1
-2
-3
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 10D: Germany - Backward-Looking Model - Dynamic Simulation (i) - Temporary 1-year 1% increase in g:





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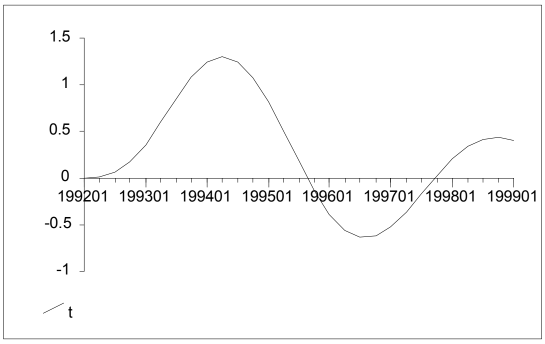
199501
199601
199701
199801
199901
g


1.5
1
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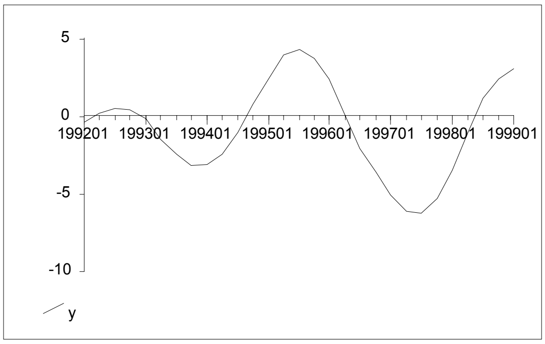
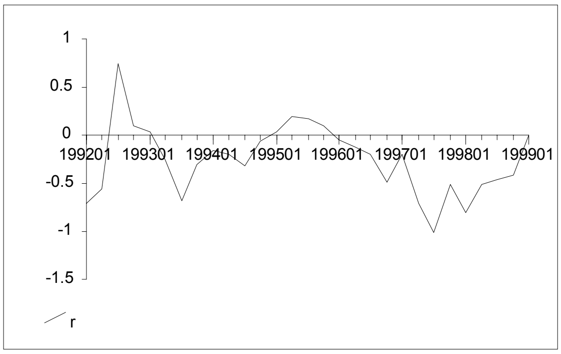
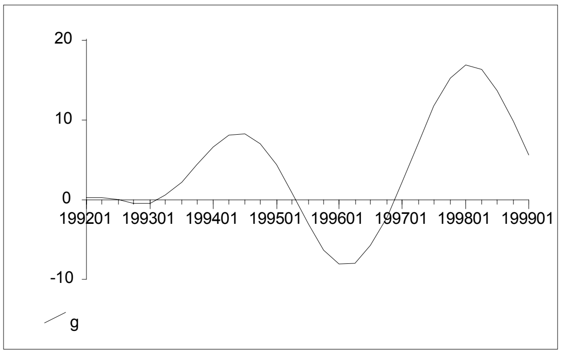
0
-0.5
-1
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 11: Germany – Backward-Looking Model - Historical Simulation (ii) (1992(1)-1999(1)) – All variables shown as deviations from base:



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199701
199801
199901
g

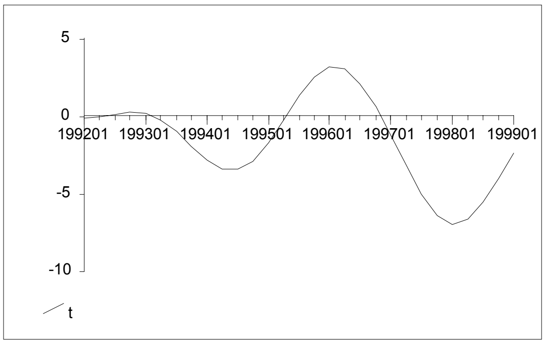
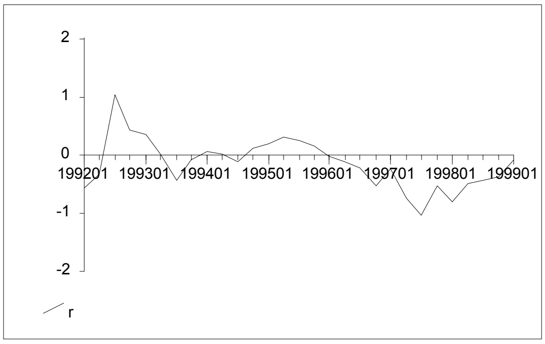

5
0
-5
-10
199201
199301
199401
199501
199601
199701
199801
199901
t

Figure 12A: Germany – Backward-Looking Model - Historical Simulations (iii) (1992(1)-1999(1)): Temporary positive 1% shock in y, with AR decay parameter = 0.5, shown as deviations from simulation base:



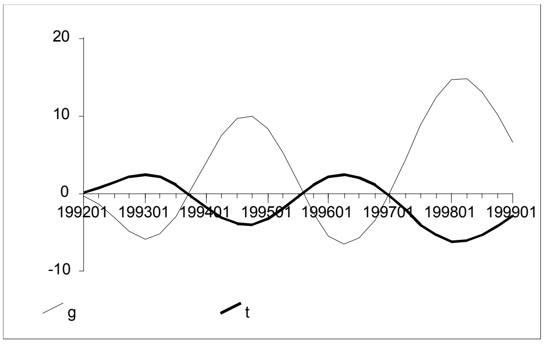
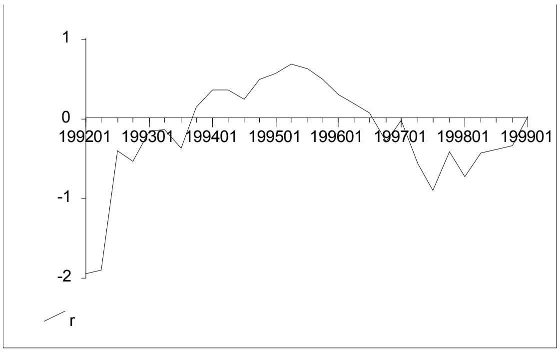


Figure 12B: Germany – Backward-Looking Model - Historical Simulations (iii) (1992(1)-1999(1)): Temporary positive 1% shock in π, with AR decay parameter = 0.5, shown as deviations from simulation base:



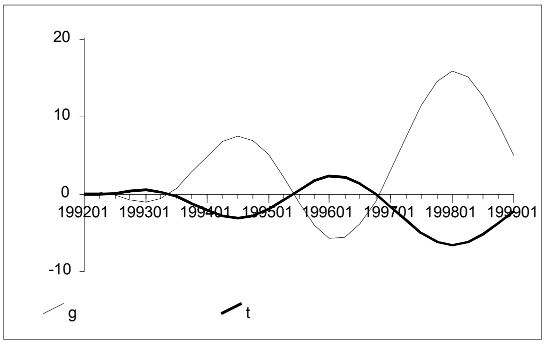


Figure 13: Endogenous Fiscal Policy: Interest Rate Reaction to Output Shock

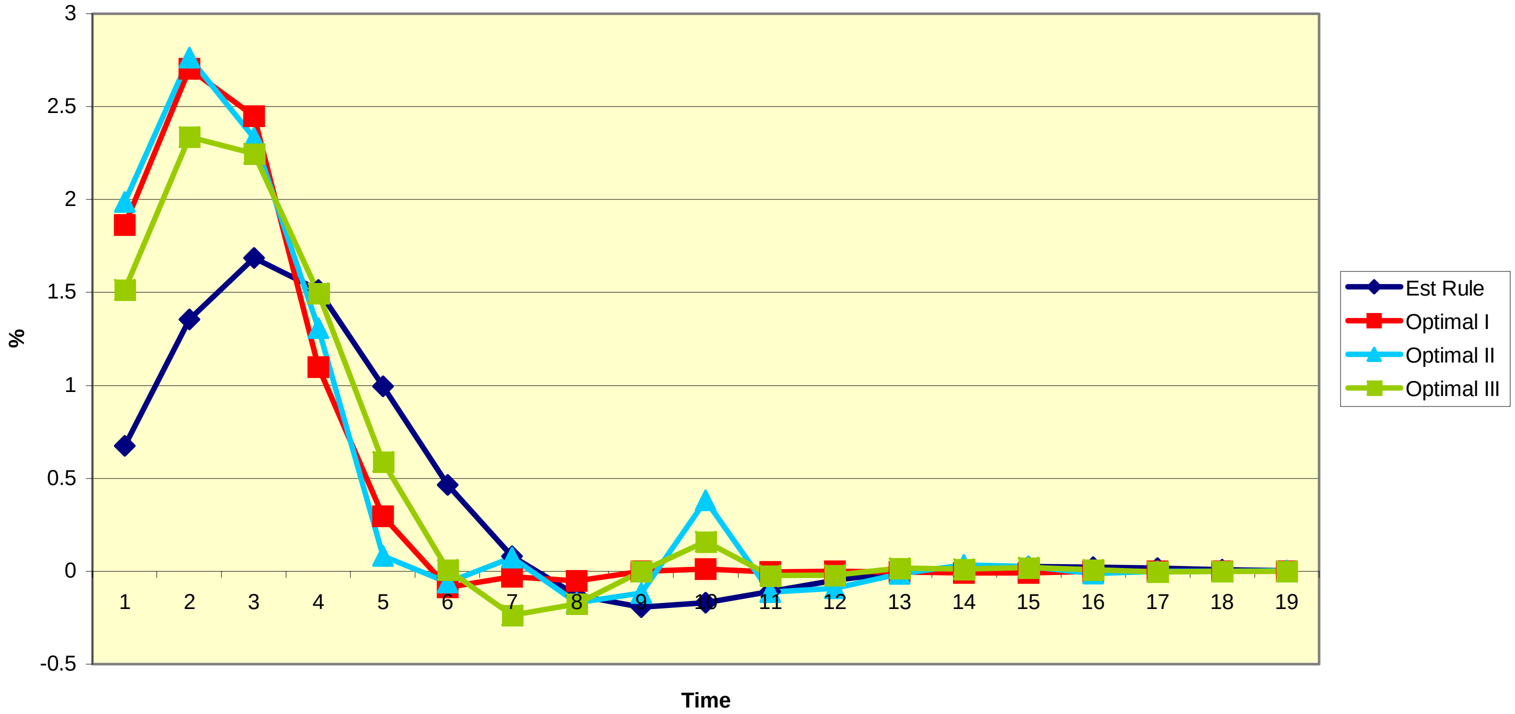


Figure 14: Endogenous Fiscal Policy:
Output Reaction to Output Shock

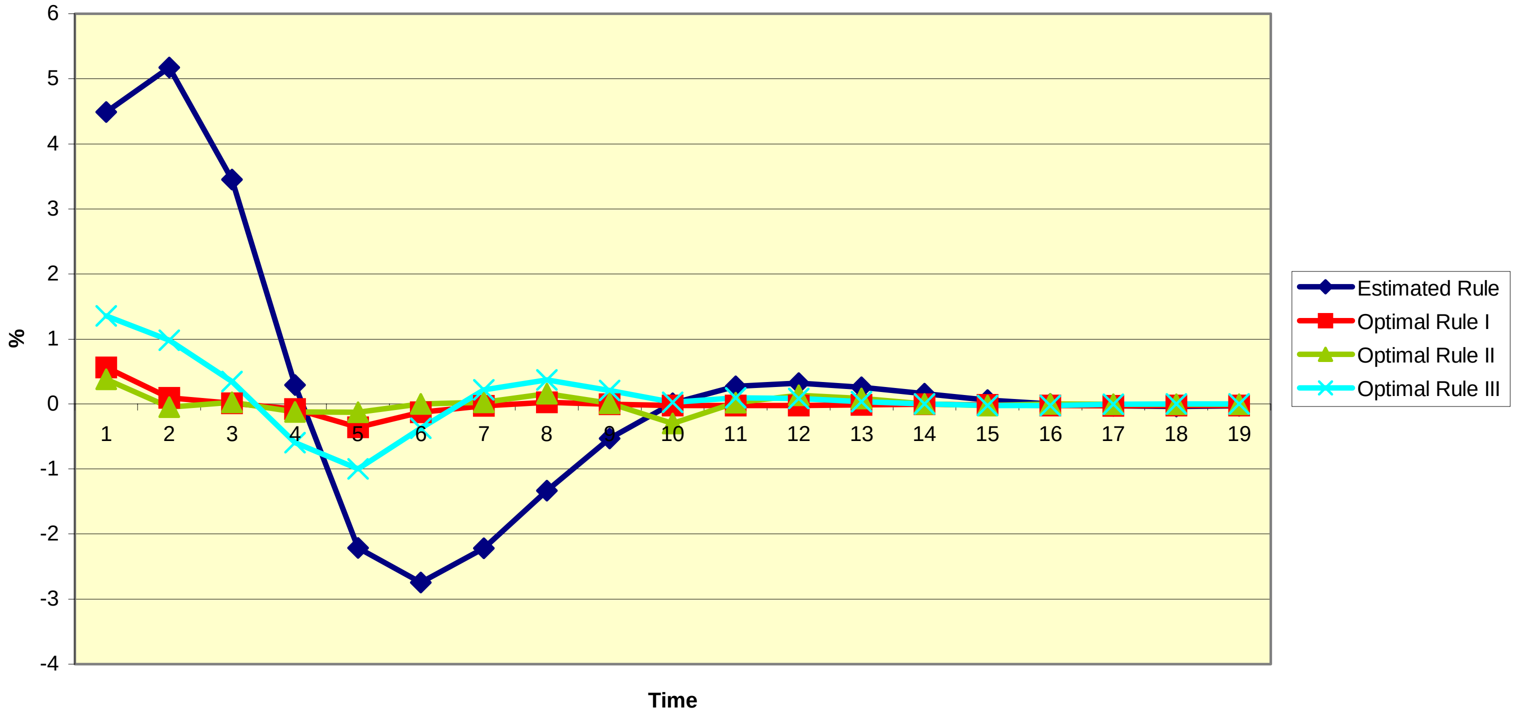


Figure 15: Exogenous Fiscal Policy: Interest Rate Reaction to Output Shock

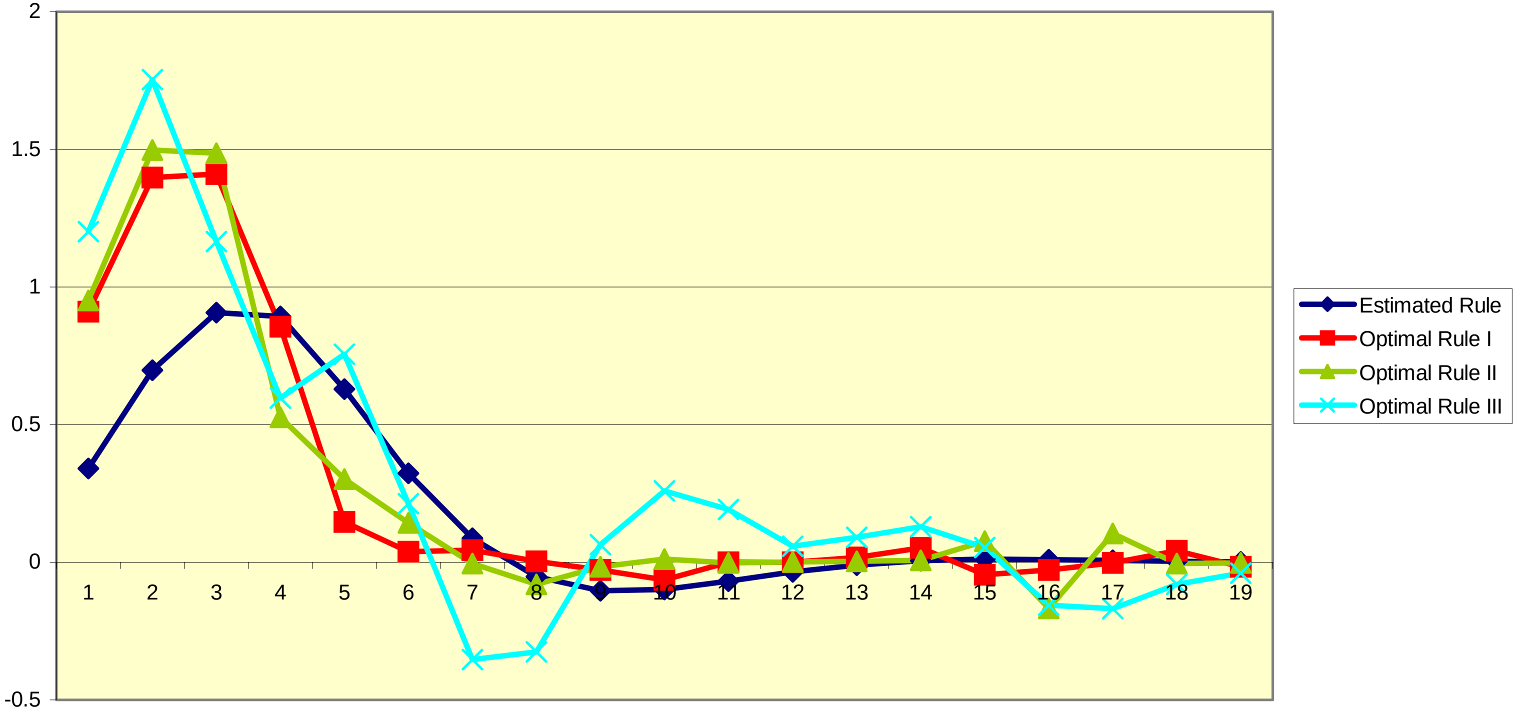


Figure 16: Exogenous Fiscal Policy: Output Reaction to Output Shock

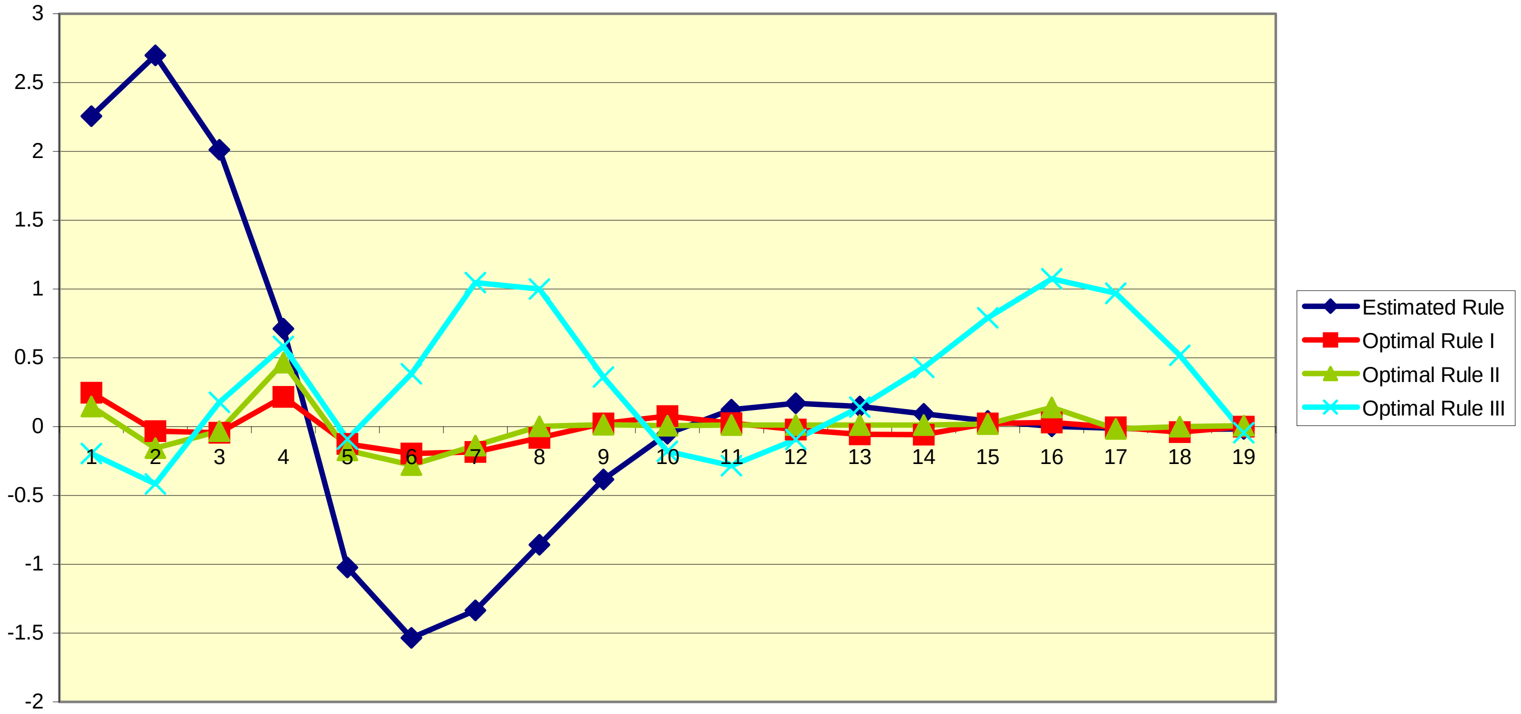


Figure 17: Exogenous Fiscal Policy: Interest Rate Response
Optimal Policy Rule with High Adjustment Costs