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THE MONETARY TRANSMISSION MECHANISM AT THE EURO-AREA LEVEL: ISSUES AND RESULTS USING STRUCTURAL MACROECONOMIC MODELS[1]

BY PETER McADAM AND JULIAN MORGAN*

December 2001

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The Eurosystem Monetary Transmission Network

This issue of the ECB Working Paper Series contains research presented at a conference on "Monetary Policy Transmission in the Euro Area" held at the European Central Bank on 18 and 19 December 2001. This research was conducted within the Monetary Transmission Network, a group of economists affiliated with the ECB and the National Central Banks of the Eurosystem chaired by Ignazio Angeloni. Anil Kashyap (University of Chicago) acted as external consultant and Benoît Mojon as secretary to the Network.

The papers presented at the conference examine the euro area monetary transmission process using different data and methodologies: structural and VAR macro-models for the euro area and the national economies, panel micro data analyses of the investment behaviour of non-financial firms and panel micro data analyses of the behaviour of commercial banks.

Editorial support on all papers was provided by Briony Rose and Susana Sommaggio.

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Abstract:

This paper addresses some of the issues faced by macroeconomic model builders in analysing the monetary transmission mechanism. These include the sensitivity of the policy simulation results to changes in the monetary and fiscal policy rule and the introduction of forward-looking behaviour in the model. To illustrate the importance of these issues the paper reports the results of variant monetary policy simulations at the euro-area level using the AWM and NiGEM models.

JEL classification: **C50, C52, E5**

Keywords: Monetary Transmission Mechanism, Euro Area, Macro Models.

Non technical summary

This paper looks at the monetary transmission mechanism at the euro-area level using macroeconomic models and examines some of the issues raised by such an exercise. The aim is to consider how important various aspects of model and simulation design are in determining the results from monetary policy simulations. In this paper we examine the effects of using monetary and fiscal policy rules and the importance of forward-looking behaviour. To illustrate the significance of these issues the paper reports the results of a number of variant simulations using the ECB's Area Wide Model and the National Institute Global Economic Model.

The paper takes as its starting point, the last major study of comparative properties of central bank models, which was carried out by the Bank of International Settlements (BIS) in 1995. The BIS study examined cross-country differences in the transmission mechanism of monetary policy involving a hundred basis-point increase in the short-term policy interest rate for 2 years. In this paper we examine some of the issues faced by macro model builders in examining the transmission mechanism by undertaking a number of variant simulations similar to that undertaken in the BIS exercise. A fundamental difference, however, is that we undertake these simulations at the euro-area level.

Our results highlight the importance of various aspects of model and simulation design in affecting the results from such monetary policy exercises. We find that the NiGEM and AWM models yield broadly similar results for the effect of monetary policy on output for the first 2-3 years when the forward-looking elements of the model are not used. This also holds true when monetary and fiscal policy rules are introduced into the simulations. Allowing forward-looking behaviour in the models tends to increase the initial impact of the monetary policy exercise but also hastens the return to baseline values, albeit with important differences between the two models in terms of the magnitude and timing of the effects. In both models, the user cost of capital tends to be the dominant channel of transmission in terms of its impact on GDP when a common monetary policy is implemented across all channels.

I. Introduction

This paper looks at the monetary transmission mechanism at the euro-area level using macroeconomic models and examines some of the issues raised by such an exercise. The aim is to consider how important various aspects of model and simulation design are in determining the results from monetary policy simulations – for example, the effects of using monetary and fiscal policy rules and forward-looking behaviour. To illustrate the importance of these issues the paper reports the results of a number of variant simulations using the ECB's Area Wide Model (AWM) – as described in Fagan et al (2001) - and the National Institute Global Economic Model (NiGEM).[2]

The paper takes as its starting point, the last major study of comparative properties of central bank models, which was carried out by BIS (1995). The BIS study examined cross-country differences in the transmission mechanism of monetary policy and considered the extent to which these could be due to differences in financial structure. Simulation experiments were undertaken on the models involving a hundred basis-point increase in the short-term policy interest rate for 2 years.[3] In this paper we examine some of the issues faced by macro model builders in examining the transmission mechanism by undertaking a number of variant simulations similar to that undertaken in the BIS (1995) exercise. A fundamental difference, however, is that we undertake these simulations at the euro-area level. Although there have been many studies of the monetary transmission exercise at national levels (see for instance Erhmann (2000)) there has be no corresponding exercise carried out at the euro aggregate level.

The paper is organised as follows. In section II we consider the nature of the monetary transmission mechanism in macro models in general and specifically in the AWM and NiGEM models. In section III we address the issue of how to decompose the results into individual channels of transmission. In section IV, we consider the issues around the design of simulation experiments whilst in section V there is a comparison of four variant simulations beginning with a completely backward-looking simulation with no policy rules and then gradually introducing policy rules and forward-looking behaviour. The results of the final simulation are also decomposed into the various channels of transmission. Section VI concludes.

[2] The April 2001 release of the NiGEM model was used.
[3] The results were summarised by Smets (1995).

II. The Monetary Transmission Mechanism

This section discusses which channels of monetary policy transmission can be identified in structural macroeconomic models. In general, in most large-scale macroeconomic models the transmission mechanism of monetary policy takes place primarily through the interest rate. The central bank chooses the short-term policy interest rate, which has a pass through to other market yields, asset prices and the exchange rate. Other than these financial linkages, the main effects typically emerge from output and prices via the impact on domestic spending (private investment and consumption) and on the external sector through export and import volumes. These effects are highlighted to differing degrees in both models and accordingly, we will first try to give an overview of the *general transmission* channels and then discuss those specific to our chosen models[4]

When considering typical monetary transmissions (and comparing them across two separate models) it is useful to have something like a core model in mind. To this end, we begin by considering an illustrative encompassing maquette (adapted from McAdam, 1999). The idea behind presenting this maquette is that it can serve to illustrate the standard channels in which monetary policy operates in large scale macroeconomic models. Indeed, the maquette is intended to be a broad approximation to not only the models used in this paper but also for other models in the class (such as the IMF's "Multimod" model or the Federal Reserve's Multi-Country Model). Of course the maquette can only provide a starting point as there are specific features of the AWM and NiGEM which differ from the maquette and have an important bearing on the impact of monetary policy. We discuss these specific features at the end of this section.

The maquette itself is straightforward to motivate: its long run is supply determined (B8) but the nominal inertia (B5) and lead expectations (B5, B17, B20) cause dis-equilibrium and overshooting results in the short run. Roughly half of the model comprises identities. Besides these, the model has standard features: classical optimality in investment (B3, B10), Blanchard-Yaari (Blanchard and Fisher, 1989) type consumption (B2), money demand (B7), a simple uncovered interest parity (B20) and term structure (B17), conventional trade equations (B19, B21, B22) and integral control policy rules (B15, B16).

[4] An overview of both models is given in Appendix 2.

Box: An Illustrative Encompassing Maquette

AGGREGATE DEMAND

B1 $Y_t = C_t + I_t + G_t + (X_t - IM_t)$: Demand Summation

B2 $\Delta c_t = c_1 + c_2(wealth/c)_{t-1} - c_3 RLR_t + c_4 \Delta(y_t(1-TX_t))$: Consumption

B3 $\Delta K^d{}_t = z\ ((MPK_t PY_t)/PK_t - UCOC_t)$: Investment

B4 $\Delta l^d{}_t = m(y - y^*)_t$: Labour Demand

B5 $\Delta wages_t = a_1 + a_2 \Pi^e_{t+1} + a_3 \Pi_{t-1} + a_4(y - y^*)_t - a_5(w - p - prod)_{t-1}$: Wages

B6 $WEALTH_t = WEALTH(K_t, B_t, M_t, \mathrm{NFA}_t.ER_t)$: Wealth

B7 $(m^d - p)_t = b_1 + b_2 y_t + b_3 y_{t-1} + b_4(m^d - p)_{t-1} - b_5 RL_t$: Money Demand

AGGREGATE SUPPLY

B8 $Y_t = Y(K_{t-1}, L_t)$: Production Function

B9 $I_t = K_t + (d - 1)K_{t-1}$: Capital Accumulation

B10 $UCOC_t = (RL_t + d - \Pi_t{}^e)(1 - TX_t)$: User Costs of Capital

B11 $PK_t = zP_t + (1-z)ER_t.PIM_t$: Investment Deflator

B12 $PY_t = jP_t - (1-j)ER_t.PIM_t$: Value-Added Deflator

B13 $P_t = n(W/MPL)_t + (1-n)ER_t.PIM_t$: Output Price.

POLICY SECTOR

B14 $\Delta B_t = (G - TX \cdot Y)_t + RL_{t-1}B_{t-1} - \Delta M_t$: Debt Accumulation

B15 $\Delta TX_t = TX(DEFICIT_t / Y_t)$: Tax Rate Rule

B16 $\Delta R_t = R(Y_t - Y_t^T, \Pi_t - \Pi_t{}^T)$: Monetary Policy Rule

B17 $1 + RL_t/100 = \prod_{i=0}^{I-1}(1 + R_{t+i}/100)^{\frac{1}{I}}$: Term structure

B18 $RLR_t = RL_t - \Pi_t{}^e$: Real Rate.

OVERSEAS SECTOR

B19 $CA_t / Y_t = \Delta NFA_t / Y_t = ((X.PX - IM.PIM)_t + R^?{}_{t-1}.\mathrm{NFA}_{t-1})/Y_t$: Current Account

B20 $er_t = er_{t+1} + (R - R^{**})_t + q\mathrm{NFA}_t$: Exchange rate.

B21 $im_t = e_1 y_t - e_2(er + pim - p)_t$: Imports

B22 $\Delta x_t = f_1 \Delta im_t^{**} + f_2(er + p^{**} - p)_t + f_3 \Delta(er + im + pim - p)_t$: Exports

Note: Capital letters symbolise variables in levels and lower-case for logarithms; starred (double starred) indicates full capacity (foreign) values. The superscript d indicates demand, T indicates target values and e denotes expectations. Appendix 1 lists variable names. I = term structure length. All parameters are positive. We omit the 'other' country.

The only direct effect of short-term interest rates is thus on the exchange rate (B20) and the term structure (B17).[5] Leaving these aside, indirect effects dominate in this particular model. To illustrate, consider the corresponding change in the nominal long rate given the term structure (B17) – and in turn the real rate (B18). This change (negatively) affects capital accumulation through the increased user cost of financing new investment (B10, B3), which in turn affects output (B1), employment (B4) and the trade balance (B19, B21, B22) etc. This long rate will also directly affect consumption (B2) since the real lending rate proxies its opportunity cost.[6] There is also an indirect effect of long rates on consumption through changes in net wealth (B2, B6). The net-wealth effects typically stem from such sources as changes in the stock of public debt, the capital stock, the monetary aggregate and, possibly, changes in equity prices. In the case of equity prices, a rise in interest rates is conventionally considered to lead to lower equity prices and thus a de-cumulation of wealth. On the stock of government debt, this is revalued in line with changes in the long rate: a rise in long rates will lead to a downward revaluation of holdings of government debt and hence lower net wealth. Finally, there is a role for interest rates to affect the monetary aggregate (B7), which feeds into government debt stock with a negative coefficient (B14) and thereby affects net wealth (B6). The short-term interest rate enters money demand negatively (B7). Notice that a wealth effect can come through net foreign assets (B19). If the home economy is large (small) enough the relevant interest rate there will effectively be the home (large country) one (B19).

Finally, there are a number of interest sensitive income effects. Government interest payments typically depend on long rates (B14) reflecting the term structure of government debt. Government interest payments feed into personal income (B6) (thereby affecting consumers' expenditure) and into the debits of interest, profits and dividends (thereby affecting net overseas asset accumulation – a component of net wealth, B19) in addition to affecting the government budget balance (B14, B15).

Comparing the AWM and NiGEM

An important feature of this paper – like that of Bryant et al (1993) and BIS (1995) – is that we do not specifically seek to harmonise the models. Although many valuable insights have been made from such exercises, we instead use each model with the baseline

[5] The complete feedback matrix of monetary policy is through equations. <u>R</u>: **16**, 17, 20, <u>RL</u>: 7, 10, 14, **17**, 18, 19, <u>RLR</u>: 2, **18**. Boldface indicates normalisation.
[6] As indeed in conventional macro-theory, the marginal utility of consumption is given by the consumer's discount rate, which is bounded by the real steady state interest rate, e.g., Blanchard and Fisher (1989).

and equations provided. This allows us to make a practical comparison of how the models – in standard mode – compare.

The AWM is a single country model of the euro area using aggregated euro area data – a full description of the model is provided by Fagan et al (2001). Thus, there is no country dis-aggregation, essentially no (modelled) international linkages and no national monetary or fiscal rules other than aggregate ones. In other words, the AWM treats EMU members as one country. NiGEM, by contrast, models each individual country separately and the euro area results that we report are based on a static aggregation of individual country results. Nevertheless, it is possible to run the model consistent with a monetary union in the euro area and thereby ensure common short and long-term nominal interest rates, no changes in the exchange rates between the residual currencies of the euro area and a common movement of the euro against third currencies.

Forward-Looking Behaviour

Lead relationships are typically always among the most important ones in a macro-model since they tend to advance the effects of shocks. In both models there is the possibility to allow for forward-looking behaviour in both the exchange rate and in long-term interest rates. In NiGEM, the standard model also allows for forward-looking behaviour in equity prices, and in the inflation terms used in monetary policy rules and in the wage equations. The role of these forward-looking terms is discussed in some detail in the remainder of this section. One general point is that – with the exception of the forward looking inflation terms in some of the NiGEM wage equations – forward-looking elements have not been introduced into behavioural equations but into calibrated ones. Therefore there is little difficulty in adapting these equations for forward-looking behaviour and essentially no need to re-estimate them. It is also worth noting that, expectations may also matter for other behavioural equations – see for example Sgherri (2000) who examines the importance of forward-looking behaviour of consumers. However, such forward-looking elements have not been introduced into the standard versions of these models.

Turning first to the potential for forward-looking behaviour in the exchange rate. As we know from the maquette, the link from interest rates to the exchange rate is a common one. It is also typically a very powerful one. The precise effect of that transmission depends on the exchange rate model. If the nominal exchange rate is fixed then of course there is no effect. If the exchange rate follows, say, a portfolio balance approach then the subsequent effect of monetary policy on real activity and potential output will matter. If the exchange rate follows a PPP closure then the effect of the change on relative prices will be the key and so on. Here, however, and largely in line with many other models, we only consider a fixed nominal exchange rate or one following forward-looking UIP. The latter implies that the expected appreciation of the home currency exchange rate is set equal to the short-term interest differential in favour of the home currency. This is often modified to include a term in either net foreign assets (NFA) or the current account to GDP ratio which proxies a risk premium: [7]

$$er_t = er^e_{t+1} + (r_t - r^*_t) + q\text{NFA}_t \tag{1}$$

This equation (being forward looking) needs a terminal condition to ensure a unique solution – often given by a net foreign asset closure. Solving (1) for the first period:

$$er_0 = er_T + \sum_{t=0}^{T}(r_t - r^*_t) + \sum_{t=0}^{T} q\text{NFA}_t \tag{2}$$

This defines the exchange rate's initial jump defined by its terminal value (er_T) and the sums of present and future interest rate differentials and net foreign assets. After this initial jump the exchange rate evolves as,

$$\Delta er_t = -[(r_t - r^*_t) + q\text{NFA}_t] \tag{3}$$

Notice, therefore, that modelling exchange rates as modified uncovered interest parity implies that the exchange rate jumps in response to any change in exogenous instruments with that change sufficient to clear any effect on net foreign assets brought about by the shock.

The other area of the financial markets where there is a clear potential for forward-looking behaviour is in the determination of long rates. As we saw from the maquette, long rates can be an important conduit of the monetary transmission. Both models have backward- and forward-looking options. The backward-looking options that we use in both models are relatively similar in that they both posit a moving-average weight of both short and long rates. For the AWM and NiGEM respectively they are (using our earlier notation):[8]

$$RL_t = 0.25 \cdot R_t + 0.25 \sum_{i=1}^{3} RL_{t-i} \tag{4}$$

[7] The UIP condition can of course be backward looking in which case there is simply a continuous depreciation.
[8] The backward looking long rate equation used in the AWM is not a standard feature of the model but has been used for illustrative purposes.

$$\Delta RL_t = RL_{t-1} + 0.8\Delta R_t + 0.2(R_{t-1} - RL_{t-1} + 0.5)^{9} \qquad (5)$$

However, in both models the forward-looking determination of long-term interest rates is:

$$\log(1 + RL_t / 100) = \frac{1}{40}\sum_{j=0}^{39} \log(1 + \frac{R_{t+j}}{100}) \qquad (6)$$

That is to say, both models directly embody a 10-year bond term structure.

Policy Rules

Both models enable users to implement the same Taylor rule:

$$R_t = a_1 + a_2 \tilde{\Pi}_t + a_3 \tilde{Y}_t \qquad (7)$$

Where R is (as before) the short-term interest rate, p is current inflation, y is real GDP, a tilde indicates deviation from (baseline) target (e.g., Π^T) and where a_2, a_3 are set at their standard weights. The NiGEM model also allows for the possibility of a forward-looking inflation term in the Taylor Rule. In this, the inflation term p becomes future rather than current inflation.

The NiGEM model also offers users a variety of other monetary policy rules including targets for (1) nominal GDP and inflation, (2) nominal GDP, (3) inflation and in addition it is possible to select (4) fixed real interest rates, (5) fixed nominal interest rates or different combinations of these rules for different countries and/or different time periods within the same country. [10] Both models incorporate a fiscal closure rule to maintain a deficit-output ratio to baseline by changes in the direct tax rate.

Further Specific Features of the Monetary Policy Transmission in the AWM and NiGEM Models

The maquette describes the transmission channels and structure involved in the *AWM* fairly well, although inevitably some exceptions apply. First, short (rather than long) rates enter consumption and drive the user cost of capital. Second, there is no endogenous foreign rate and thus the exchange rate (though modelled as UIP) is purely driven by movements in short-run rates relative to baseline. Also there is no deliberate coding of a

[9] The risk premium from holding bonds is assumed to be 0.5%.

[10] Of course, the AWM could, in principle, also accommodate all these rules but at the current juncture, the model properties using such rules have not been examined.

net foreign asset closure.[11] Third, and more specifically, the *income effect* is determined via the impact on government interest payments which are linked to changes in long-term interest rates. Fourth, the *wealth effect* is embodied through the capital stock and public debt. For public debt, as before, interest payments are linked to long term interest rates. In the case of wealth through capital accumulation, the accumulation of investment defines the capital stock. Finally, net foreign assets do not directly depend on any domestic interest rate in the current version of the model.

In relation to the domestic sector in NiGEM it is important to note that, although very similar, the set-up in each of the national economies within the euro area can be somewhat different. To an extent, this reflects the deliberate design of the model as the larger economies are modelled in somewhat more detail than the smaller ones. However, it also reflects the econometric evidence as – since the behavioural equations are estimated – interest rate effects have been found to be present in some equations in some countries but not in others. A good example of this is a direct interest rate effect in consumption, which is only present in the consumption functions of Italy, the Netherlands and Ireland. The interest rate used is also different, being the short-rate in Italy and the long-rate in the Netherlands an Ireland – although in all three cases the coefficient is negative implying that a rise in interest rates has a direct effect in terms of lowering consumers' expenditure.

However, indirect effects of interest rates on consumption – via changes in net wealth as described in the maquette – are present in each of the domestic sectors of these economies. The effects on net wealth stem from changes in equity prices, the stock of public debt and in some cases also changes in the monetary aggregate M1. It is worth making a few remarks on the equity price effects, as they are somewhat richer than outlined in the maquette. The model allows for backward or forward looking equity prices. In both cases a rise in interest rates should lead to lower equity prices although in the backward looking case this is via changes in the long-rate whilst in the forward looking case in is via the short rate. In the four largest euro area economies (Germany, France, Italy and Spain) there is a role for interest rates to affect M1, which feeds into the government debt stock with a negative coefficient and thereby affects net wealth. The short-term interest rate enters the M1 equation with a negative coefficient in these countries.

Turning now to investment, for most euro area countries in NiGEM, interest rates play a role through their impact on the capital stock via the user cost of capital variable as outlined in the maquette. However, in three of the euro area countries – Greece, Ireland

[11] In the AWM the stabilisation of net foreign asset comes through the real exchange rate, Fagan et al (2001)

and Portugal – the set up is a little different. Private sector investment is directly tied to the long-rate (with a negative co-efficient) and the capital stock is determined based on the last period's capital stock plus new investment minus depreciation. Finally, in NiGEM, the domestic short-term interest rate (and also the short rates of the US, UK, Japan and Switzerland) feeds into the rate of return on foreign liabilities. This in turn affects the current account by influencing the debits of interest, profits and dividends.

The final forward-looking element in NiGEM emerges because in the wage equations of some countries it is possible to introduce forward-looking inflation terms. When these equations were estimated they typically allowed for the possibility that past, current and future inflation developments could have an impact on current wages.[12] In estimation a significant role for expected inflation (with a lead of 1-quarter and instrumented by some backward-looking terms) was found in some – but not all – countries. When the model is used in simulation mode it is possible to choose between a term for expected inflation based on backward-looking variables or alternatively to allow for a truly forward-looking expected inflation term based on the model generated values for inflation in the next quarter. This choice has an impact on the dynamics of wages but leaves their long-run level unaffected.

III. Decomposing the Channels of Transmission

It is standard practice when reporting monetary transmission exercises to decompose the total effects into their various (transmission) channels. That is to say, we consider all the impacts short-term monetary policy changes have, then categorise each in an economically interpretable manner. Thus, for example, we might consider the sole effect of interest rate changes on investment/user cost (B3), exchange rates (B20) and consumption (B2) as sufficiently important to be separately reported. Other such channels include income and wealth effects as discussed above. Such a channel decomposition was also a feature of the BIS exercise. In this section we first discuss some of the theory behind the decomposition into channels before addressing the practical issues surrounding their implementation in the two models.[13]

In principle, the effect of each of these channels should sum to the total effect. To illustrate, consider the structural macro-model:

[12] In the long-run real wages are determined by labour productivity and the unemployment rate.
[13] Mauskopf and Siviero (1995) and Altissimo et al (2001) also examine the issue of decomposing the channels of transmission.

$$Y_t = p_1 Y_{t-1} + p_2 X_t + p_3 R_t + V_t \tag{8}$$

Where Y represents endogenous elements, X exogenous variables, R the exogenous monetary instrument and V a vector of residuals. Let us assume here for simplicity and without loss of generality – in contrast to the maquette – that R represents the only available monetary instrument. If we backward substitute this model to an arbitrary start, we more clearly see the interdependencies involved:

$$Y_t = p_1^t Y_0 + \sum_{j=0}^{t-1} p_1^j p_2 X_{t-j} + \sum_{j=0}^{t-1} p_1^j p_3 R_{t-j} + \sum_{j=0}^{t-1} p_1^j V_{t-j} \tag{9}$$

Equivalently, in matrix form, (2) becomes:

$$\begin{bmatrix} Y_1 \\ . \\ . \\ . \\ Y_T \end{bmatrix} = \begin{bmatrix} p_2 & 0 & 0 & 0 & 0 \\ p_1 p_2 & . & 0 & 0 & 0 \\ . & . & . & 0 & 0 \\ . & . & . & . & 0 \\ p_1^{T-1} p_2 & . & . & p_1 p_2 & p_2 \end{bmatrix} \begin{bmatrix} X_1 \\ . \\ . \\ . \\ X_T \end{bmatrix} + \begin{bmatrix} p_3 & 0 & 0 & 0 & 0 \\ p_1 p_3 & . & 0 & 0 & 0 \\ . & . & . & 0 & 0 \\ . & . & . & . & 0 \\ p_1^{T-1} p_3 & . & . & p_1 p_3 & p_3 \end{bmatrix} \begin{bmatrix} R_1 \\ . \\ . \\ . \\ R_T \end{bmatrix} + \begin{bmatrix} I & 0 & 0 & 0 & 0 \\ p_1 & . & 0 & 0 & 0 \\ . & . & . & 0 & 0 \\ . & . & . & . & 0 \\ p_1^{T-1} & . & . & p_1 & I \end{bmatrix} \begin{bmatrix} V_1 \\ . \\ . \\ . \\ V_T \end{bmatrix} + \begin{bmatrix} p_1 \\ p_1^2 \\ . \\ . \\ p_1^T \end{bmatrix} Y_0 \tag{10}$$

From this, we can derive key monetary multipliers. The Impact Multiplier of the change in the monetary instrument is $\frac{\partial Y_t}{\partial R_t} = p_3$, the Interim Multiplier, $\frac{\partial Y_{t+j}}{\partial R_t} = p_1^j p_3$ and the Dynamic (or total) Multipliers: $\sum_{t=t}^{T} \frac{\partial Y_t}{\partial R_t}$. Matrix p_3 thus defines the pure feedback whereas $p_1^j p_3$ defines the total effect. To return to our maquette example: if the interest rate only affects money demand (B7), this means that p_3 has a single non-zero element $(-b_5)$.[14] Since money demand affects Wealth (B6) which in turn affects Consumption (B2), Output (B1), Import demand (B21) and so on, these subsequent effects are embodied in p_1^j. Undoubtedly this will have some zeros (i.e., the monetary instrument will not affect *every* endogenous variable). Specifically, closing off all the channels relegates p_3 to be a null matrix. Systematic opening of one channel decreases its sparsity by one element or one block of elements. In a linear model, the sum of these effects is commonly understood to equal the global effect. In all of this, the linkages through p_1^j need not be controlled.

Although, on one level, straightforward to understand, channel decompositions can become complicated. First, because some channels of interest that are present in some models may be absent in others: this makes model comparisons (such as ours) difficult and imperfect. Second, since most macro-models are non-linear, the individual effects of

[14] Effectively this would mean dropping B17 from the maquette and taking RL as our monetary policy instrument.

the channels need not necessarily sum to the global one. Third, in some exercises, the summation of the channels is not logically defined. This is in fact a feature of some of our own results when using endogenous policy rules and lead expectations. In such circumstances, it may make more sense to view the channel decompositions and summations are as very broad comparisons and local approximations.

To illustrate, let us say we perform a global simulation where all channels operate (i.e. p_3 has minimum sparsity), this generates $\sum_{t=t}^{T} \frac{\partial Y_t}{\partial R_t} = A$ as well as the trajectory, $\{R_t\}_{t=1}^{T}$. If we allow monetary policy to operate after the initial two-year shock then $\{R_t\}_{t=1}^{T}$ will necessarily be channel-dependent (as indeed our later simulations show). Let us say we have I decompositions or channels. The first one is identified by, $\sum_{t=t}^{T} \frac{\partial Y_t}{\partial R_t} \Big| \overline{Y_{2t}}, ..., \overline{Y_{It}} = A_1$ which in turn generates $\{R_{1t}\}_{t=1}^{T}$. But $\exists i$ where $\{R_{it}\}_{t=1}^{T} \neq \{R_t\}_{t=1}^{T}$, then $\sum_{i=i}^{I} A_i \neq A$. In other words, if the monetary response is different in each channel, the complete aggregation is not defined. In fact, the same thing could be said for any fiscal policy response. Thus, we can consider three decompositions worth performing. First, allowing $\{R_t\}_{t=1}^{T} \neq \{R_{it}\}_{t=1}^{T}, \forall i$, second, imposing $\{R_t\}_{t=1}^{T} = \{R_{it}\}_{t=1}^{T}, \forall i$ and, finally, for each decomposition j, imposing $\{R_t\}_{t=1}^{T} = \{R_{it}\}_{t=1}^{T}, \{TX_t\}_{t=1}^{T} = \{TX_{it}\}_{t=1}^{T}, \forall i \neq j$. For reference, we show results for the first two of these.

Identifying the Channels in Practice

In the following we follow the channels identified in the BIS (1995) exercise:

- An income/cash flow channel, which measures the effect of interest rates on net interest payments.
- A wealth channel to capture the impact of interest rates on wealth.
- A direct interest channel on consumption.
- A cost of capital channel to capture the effect of interest rates on investment.
- An exchange rate channel to capture the effects of changes in the exchange rate due to changes in interest rates.

The approach taken was to simulate the model with all channels switched off except the one of interest. To identify the channels a somewhat eclectic approach was taken. Either we could exogenise whole equations –such as the Investment equation (B3) to capture the *user-cost* effect – or we could fix the interest rate effects entering individual equations to base value. In the AWM, the latter approach was adopted which involved substantial re-coding of the model. In NiGEM, the channels were removed by exogenising the equations where the short-or long-term interest rate first appear. This provided a relatively tractable way of identifying the channels without the need to significantly alter the model by removing the interest rate effects in particular equations. In some cases the results would have been identical to the approach undertaken in the AWM – for example as a separate user cost of capital variable was available which only affected investment via the capital stock it was possible to exogenise the user cost variable and thereby effectively remove the interest rate effect on investment without switching off the investment equation. However, in other cases – such as for Greece, Ireland and Portugal where there were direct interest rate effects in investment – it was necessary to exogenise investment to remove the effect of changes in interest rates.

Finally, in relation to the channels, one point that should be borne in mind is that the models used cannot account for a credit channel as they have neither credit equations nor lending interest rates.

IV. Design of Monetary Policy Transmission Simulation Experiments.

This section discusses how key aspects of both model construction and the design of simulation experiments have an important bearing on the estimated size of monetary policy effects in structural macroeconomic models. We begin by considering whether monetary and fiscal policies can really be treated as exogenous in model simulations. It has been common for model users to undertake 'what-if' exercises, which examine the consequences of changes in exogenous policy settings. However, it is now customary for modellers to include 'closure-rules' in their models, which explain the behaviour of monetary and fiscal policy.

Reflecting this, the first issue we address is whether monetary policy can be treated as exogenous or whether it is more appropriate to treat policy as endogenous via a policy rule. In the former case, monetary policy experiments can involve a shock to the policy interest rate. In the latter case, it is common to undertake monetary policy experiments via a shock to the policy rule – e.g. a change in the target for the inflation rate or the money stock. In principle, the shock to the policy rule can be calibrated in such a way as to yield the same change in the policy interest rate that could be imposed if the interest rate were treated as exogenous. For example, in the case of the BIS (1995) exercise of a 100 basis point increase in the policy interest rates in a model with a policy rule, it would be possible to identify a change in the policy rule that would induce a change in the policy interest rate of the same magnitude. However, it is important to bear in mind that when comparing results across models, a common shock to a policy rule can produce very different reactions of policy interest rates, a point that is illustrated in the following examples.

Mitchell et al (1998) compared three global models – MULTIMOD, MSG2 and NiGEM – undertaking a number of comparative simulation exercises involving a number of variant simulations with changes in fiscal and monetary policy. The latter was achieved via a permanent 5% increase in the money target variable in the models, which induced a reduction in the policy short-term interest rate. However, the reaction was rather different across models. This can be seen in the case of Germany where the same change in the money target lead to a fall in German short-term interest rates of just over 1% in MULTIMOD and NiGEM but over 2% in MSG2 in the first year. In all cases, the interest rates gradually returned to baseline thereafter, although the speed of the return noticeably varied across the models.

Similarly, Church et al (2000) examined monetary policy in models of the UK economy via a 0.5 percentage point reduction in the inflation target. In three of the five models examined, the change in inflation target initially induces a rise in the short-term interest rate ranging from 0.16 to 1.28 percentage points. However, in the other two models there is an immediate fall in the nominal interest rate of between 0.30 and 0.37 percentage points. The explanation for the difference is that the achievement of the new lower inflation target is achieved much more quickly in the latter models (inflation falls by around 0.4% in the first year) and hence interest rates need to be lower in order to return the real interest rate to its baseline value. [15]

An interesting related question is whether to keep monetary policy endogenous or exogenous after the completion of the initial monetary policy shock. If monetary policy is kept exogenous then there may be prolonged periods of dis-equilibria in many macroeconomic models. This point can easily be seen with reference to the example of a two-year hike in policy interest rates followed by a return to base. For example, in the initial period, output falls below base and a negative output gap emerges (measured

[15] Notably, in forward-looking models, with full credibility and no price-level stickiness, interest rates would fall immediately by 50 basis points.

relative to base). Even when interest rates return to baseline at year three, the negative output gap is likely to mean that inflation is also below base and hence real interest rates remain above base. This is likely to induce a further fall in output and in the absence of any prompt equilibrating mechanism in the model a downward spiral of falling output and inflation and rising real interest rates may continue for some time.

For this reason, there may be a case for allowing monetary policy to be endogenous following completion of the initial (fixed) monetary policy experiment. The precise response of monetary policy would depend on the type of rule in place. In the previous example, with a Taylor Rule, the negative output gap and lower inflation would be expected to result in interest rates falling below base for a period to allow the negative output gap to be closed and inflation to return to base. The drawback of such an approach is that it renders the results sensitive to the policy rule used and therefore limits the comparability of results across models if each model incorporates a different monetary policy response.

The use of fiscal policy rules in structural macroeconomic models raises some similar issues. It has long been recognised – e.g., Christ (1968) – that the government budget constraint is important. If a government deficit emerges in a simulation, it is necessary to have some financing assumption. Therefore, many models now incorporate fiscal closure rules, which aim to maintain some level of fiscal solvency through adjusting fiscal variables (often the direct tax rate but sometimes government expenditure) to achieve a target specified either in terms of the deficit or debt stock. Both models incorporate such a rule to maintain a deficit ratio to baseline by changes in the direct tax rate. In some situations, particularly in models with many forward-looking elements, such rules can help stabilise the model. In the above example, a decline in output stemming from the monetary policy tightening would be likely to result in a worsening of the fiscal position due to lower tax receipts and higher transfers. In such circumstances, a fiscal policy rule would seek to restore the original fiscal position through a tightening of policy (either on the revenue or expenditure side) and would therefore exacerbate the original fall in output.[16] The main argument against incorporating fiscal reaction functions is that they would undermine the comparability of the results across models.

An important feature of model design that will significantly affect the results of simulations is the treatment of expectations of variables such as long-term interest rates, the exchange rate and inflation. A traditional way of dealing with expectations in macro

[16] The extent to which the operation of the fiscal rule would reinforce the downturn would depend on the parameterisation of the rule.

models was to assume that they are determined as a function of current and lagged values of some observed variables – often in the form of adaptive expectations. However, reflecting the increased popularity of the notion of rational expectations in recent decades there has been a move to including expectations that are genuinely forward-looking in the sense that they are consistent with the future outcomes generated by the model. For this reason they are often called 'model-consistent' expectations.[17] As already discussed the AWM and NiGEM models allow, albeit to varying degrees, for forward-looking behaviour. In the next section we explore the implications of changing the extent of forward-looking behaviour in the models.

V. Simulation Experiments Using the AWM and the NiGEM Models

To illustrate the importance of the issues raised in the previous section, we now turn to a comparison of the results of a number of simulation exercises using the AWM and NiGEM.

The Comparative Simulation Experiments

(1) As a starting point we followed BIS (1995) and undertook a monetary policy experiment involving an increase of the short-term policy interest rates by 1 percentage point for two years (in our case 2001Q1-2002Q4 inclusive). Thereafter (i.e. from 2003Q1) a return to baseline values was assumed and no monetary policy rules were implemented. No fiscal rules were in operation either and the models were run in an entirely backward-looking mode with a fixed nominal exchange rate.

(2) The next simulation experiment was identical to simulation 1, except for the fact that a monetary policy rule was implemented at the end of the two-year initial shock (i.e. from 2003Q1 onwards). The form of the monetary reaction is the Taylor rule specified in equation (7) with Π^d and Y^d set at their baseline values.

(3) The next simulation was identical to simulation 2 but a fiscal policy rule was allowed to operate from the start of the simulation. As was discussed in the previous section the fiscal rule in both models adjusts the direct tax rate to achieve a target for the government budget balance as a proportion of GDP.

[17] There is, of course, a large literature on whether expectation formation can really be described as 'rational'. Roberts (1998) examines the evidence on inflation expectations and examines the rationality of US surveys of inflation expectations. He concludes that the expectations reported by these surveys represent an intermediate degree of rationality. As the issue of the appropriate degree of rationality in expectations formation is an open one we illustrate the importance of this question in the next section when we will undertake the monetary policy exercise with and without model-consistent expectations terms.

(4) The final simulation was identical to 3 but it allowed all the forward-looking elements of the models to operate.[18] For the NiGEM model, this meant that there was forward behaviour in the determination of the exchange rate, long rates, equity prices, wage formation and the inflation rate entering into the Taylor rule. In the AWM the forward-looking elements are the exchange rate and the long-term rate.[19]

For information, the GDP and inflation responses from one additional simulation are reported in Appendix 3 of this paper. These correspond to a simulation with the same movement in short-term interest rates, no monetary or fiscal policy rules and a pre-determined exogenous path for the exchange rate and the long rate. This experiment reflects the monetary policy experiment using national central banks models and the AWM reported in Van Els et al (2001).

The Results

The results of the simulation experiments are shown in Tables 1-4. In the first simulation, the rise in short-rates induces a rise in long-rates in both models but the pattern is rather different – reflecting the differences in the backward looking equations for the long rate (see equations 4-6). In NiGEM, the long rate increases by nearly as much as the short rate in the first two years and then immediately returns to close to the baseline thereafter. In the AWM, the immediate rise in the long rate is much smaller than the rise in the short rate.

In terms of the impact on activity, both the maximum and the average loss of output over the first three years are quite similar, but there are differences in the timing of the output loss. With the NiGEM simulation, output falls by 0.09% in the first year, dropping by 0.36% and 0.44% in the second and third years respectively. In the AWM simulation, the initial impact is somewhat larger with a fall in output of 0.23% in year 1 reaching to 0.46% in year 2 before moderating to 0.39% in the third year. Thereafter, in both models, there is a tendency for output to return to the baseline, and then to remain above the baseline for sometime. However, whilst both models show such a tendency, the reversion

[18] For reference, NiGEM was simulated using a (Gauss-Seidel) Fair-Taylor (e.g., Fisher, 1992) routine and the AWM with the Stack-Time algorithm (Juillard et al, 1998, McAdam and Hughes-Hallett, 1999).
[19] We do not report any simulations with endogenous monetary policy for the whole period – i.e. from 2001Q1 onwards. However, a number of additional simulations were undertaken on the NiGEM in which the policy rule was shocked in order to generate a rise in interest rates of around 1 percentage point for two years. For example, it was found that in a simulation identical to number (4) above except that monetary policy was determined by an inflation target rule a fall in the inflation target for the first 9 quarters of 1.35 percentage points would deliver a rise in short term interest rates of around 1 percentage point in the first two years. (The inflation target needed to be altered for 9 periods – i.e. one in excess of the desired monetary policy reaction – due to the forward-looking nature of the rule.)

to base is more protracted in the AWM due to the fact that the AWM involves relatively weaker feedbacks and error corrections leading to a slower speed of adjustment.[20]

Table 1: Simulation 1:

	GDP	PCE	U	S-Rate	L-Rate	Nom XR	Real XR	TBR	GBR
NiGEM									
1	-0.09	0.00	0.03	1.00	0.85	0.00	0.00	0.03	-0.21
2	-0.36	-0.03	0.15	1.00	0.94	0.00	0.00	0.11	-0.45
3	-0.44	-0.12	0.19	0.00	0.12	0.00	-0.02	0.11	-0.44
5	0.08	-0.34	-0.07	0.00	0.02	0.00	-0.17	-0.01	-0.19
10	0.10	0.03	-0.03	0.00	0.00	0.00	0.00	-0.03	0.07
AWM									
1	-0.23	-0.03	0.07	1.00	0.24	0.00	-0.04	0.17	-0.10
2	-0.46	-0.11	0.25	1.00	0.36	0.00	-0.15	0.27	-0.29
3	-0.39	-0.21	0.35	0.00	0.17	0.00	-0.24	0.13	-0.39
5	-0.17	-0.40	0.19	0.00	0.02	0.00	-0.45	0.01	-0.40
10	0.43	-0.06	-0.63	0.00	0.00	0.00	0.05	-0.16	-0.17

Notes: GDP is real GDP, PCE is the consumer's expenditure deflator, U is the standardised unemployment rate, S-Rate is the 3-month interest rate, L-Rate is the 10-year interest rate, Nom XR is the nominal exchange rate, Real XR is the real exchange rate, TBR is the Real Trade Balance and GBR is the government budget balance to GDP ratio. GDP, PCE, Nom XR and Real XR are all expressed as a percentage difference from baseline. The remaining variables are expressed as an absolute difference from baseline. A fall in the nominal or real exchange rate is a depreciation.

The government budget balance worsens in both cases as lower output leads to lower tax receipts and higher government transfers due to higher unemployment. However, the deterioration of the fiscal position in the first two years is more pronounced in NiGEM despite a more modest output loss over this period compared with the AWM. This reflects a greater sensitivity of the fiscal variables to changes in economic activity in NiGEM than in the AWM. It is also the case that changes in economic activity exert a larger impact on unemployment in the AWM, albeit with a somewhat longer lag than in NiGEM. After three years, the unemployment rate is 0.35 of a percentage point higher in the AWM compared with a rise of 0.19 of a percentage point in the NiGEM simulation. This is despite the fact that in year 3 output is further below its baseline in the NiGEM simulation than in the AWM one. However, the longer lag in the impact on unemployment is indicated by the fact that the peak in the rise in unemployment occurs after the trough in the fall in output in the AWM, in contrast with the NiGEM results when both effects occur in the same year.

[20] For instance, see McAdam (2001) for a frequency-domain analysis of euro-area data. There, it is suggested that the typical periodicity of euro-area output is around 37 quarters to 24 quarters in the US.

The response of prices reflects the developments in output, albeit with a marked lag due to conventional sticky price mechanisms in models. In NiGEM, prices do not fall significantly in the first couple of years, but by year 3 they are 0.12% below base and in year 5 they are 0.34% below and thereafter they return to base. In the AWM the fall in prices is more marked in the first two years (reflecting the larger initial output loss) and continues to gather pace during the reporting period for the simulation and in year 5 prices are 0.40% below base. In both models, by year 10, prices have moved close to their baseline levels. However, it is noteworthy that in the AWM simulation output is above its baseline level whilst the unemployment rate is still markedly below its baseline level. This indicates that there is still some further adjustment to take place before all variables have sustainably returned to their baseline levels. Therefore after year 10 there are still some oscillations in the AWM results, albeit of a gradually diminishing magnitude.[21] This effect is not present to a noticeable extent in the NiGEM model.

The fact that the simulations show a tendency to return to base partly reflects the fact that there is a fixed nominal exchange rate. The lower domestic prices mean that there is depreciation in the real exchange rate, which ultimately boosts output through trade. This is reflected in the trade balance, which improves as lower domestic activity reduces the demand for imports and lower domestic prices improve both import and export competitiveness.[22] This boost to net trade ultimately restores output and prices to their baseline levels.

In the second simulation, the first two years are identical but in the third year, the Taylor Rule begins to operate. Because output and prices are both below base there is a decline in the short-term interest rate in the third year in both models. In NiGEM the Taylor Rule leads to a decline in short term interest rates of 38 basis points whilst in the AWM the

[21] The precise nature of the apparent oscillatory behaviour in some of the AWM results (and to a lesser extent NiGEM) is beyond the scope and purpose of the present paper since we use both models in their given form. Technically, oscillatory behaviour can be traced and analysed using the linearised eigenvalues of the model equations. For instance, given a simple linear difference equation, $Y_t - \alpha Y_{t-1} - \beta Y_{t-2} = V$, we have the general solution, $Y_t = A_1\lambda_1^t + A_2\lambda_2^t + Y^{SS}$. As is well known (e.g. Chiang, 1974) roots (i.e., the λ_i's) less than one without (with) imaginary components generate stable non-oscillatory (stable oscillations) dynamics towards the steady state, and one stable and unstable root without (with) imaginary components yields unstable non-oscillatory (unstable oscillatory) dynamics. In more intuitive economic terms, the fact that in the AWM, employment is obtained by inverting the Cobb-Douglas production essentially gives rise to a larger than one employment-to-GDP elasticity and thus potentially to some "over reaction" of employment to changes in GDP in the short run, only compensated in the long run by changes in the capital stock. Similarly, the lack of a smoothing parameter (in both models) in the Taylor rule may engender a relatively high degree of interest-rate volatility. To illustrate, most empirical estimates of Taylor rules give estimates of such smoothing parameters of around 0.6-0.8.

[22] The current account balance (which is not shown in the table) in NiGEM actually worsens in the initial period as the rise in interest rates increases the magnitude of debits of interest profits and dividends.

decline is more modest. As the parameters of the Taylor rules are identical the difference in outcomes is due to the fact that when the rule begins to operate the output loss and fall in inflation are both greater in NiGEM than in the AWM. This is not immediately apparent from the table as in year 3 the change in prices is the same in both sets of results. However, to some extent this reflects the fact that the annual average figures mask intra-year changes and the larger fall in interest rates induced by the Taylor Rule in NiGEM has already begun to have an effect in boosting output and prices. When the rule is implemented in the first quarter of year 3 both output and inflation are further below base in the NiGEM simulation than they are in the AWM.

Inevitably the lower interest rates from year 3 onwards reduce the magnitude of the subsequent output losses – although the initial impact is not that large. In year 3 the output loss is reduced by about 0.05% in both the NiGEM and AWM simulations when compared with the first simulation. Some interesting contrasts then emerge between the results from the two models. In NiGEM short term interest rates are close to baseline by year 5, but this return to baseline takes longer in the AWM, reflecting the fact that output and prices are below base for longer. In both models the use of the Taylor Rule speeds the return of GDP towards the baseline. As both also generate a period of above baseline GDP, the Taylor Rule then works to reduce towards the baseline by raising short-term interest rates. This pattern can be seen quite clearly in Figures 1a and 2a.

Table 2: Simulation 2:

	GDP	PCE	U	S-Rate	L-Rate	Nom XR	Real XR	TBR	GBR
NiGEM									
1	-0.09	0.00	0.03	1.00	0.85	0.00	0.00	0.03	-0.21
2	-0.36	-0.03	0.15	1.00	0.94	0.00	0.00	0.11	-0.45
3	-0.40	-0.12	0.18	-0.38	-0.20	0.00	-0.02	0.10	-0.36
5	0.20	-0.30	-0.12	0.08	0.05	0.00	-0.14	-0.03	-0.08
10	0.03	-0.01	-0.01	0.04	0.05	0.00	-0.03	-0.03	-0.03
AWM									
1	-0.23	-0.03	0.07	1.00	0.24	0.00	-0.04	0.17	-0.10
2	-0.46	-0.11	0.25	1.00	0.36	0.00	-0.15	0.27	-0.29
3	-0.33	-0.20	0.33	-0.23	0.11	0.00	-0.23	0.09	-0.37
5	-0.09	-0.36	0.12	-0.10	-0.03	0.00	-0.39	-0.03	-0.32
10	0.13	-0.06	-0.40	0.53	0.20	0.00	0.02	-0.03	-0.17

In the third simulation, with the fiscal policy rule the effects on output are actually larger in the first few years as the fiscal rule seeks to close the widening government deficit through raising direct taxation. The initial impact of the fiscal rule on output is not that large, but it does increase in importance. The effect of the fiscal rule is initially slightly larger in NiGEM. This is because, as already discussed, the monetary policy shock has a larger initial impact on the public finances in NiGEM than in the AWM - reflecting a greater cyclical sensitivity of the fiscal variables in NiGEM. In the third year output is 0.59% below base in NiGEM whilst in the AWM it is 0.42% below base. Thereafter the standard pattern of output returning to base more quickly in NiGEM than in the AWM reasserts itself.

One notable feature of this simulation is that the fall in the price level is somewhat more pronounced – notably in the AWM where prices are 1.25% below base in year 10 – in this simulation. Reflecting the lower output induced by the fiscal contraction, the response of the Taylor Rule is to lower interest rates by a larger amount – 52 basis points in NiGEM and 31 basis points in the AWM – in the third year.

Table 3: Simulation 3

	GDP	PCE	U	S-Rate	L-Rate	Nom XR	Real XR	TBR	GBR
NiGEM									
1	-0.10	0.00	0.04	1.00	0.85	0.00	0.00	0.04	-0.17
2	-0.44	-0.03	0.18	1.00	0.94	0.00	0.00	0.14	-0.27
3	-0.59	-0.15	0.26	-0.52	-0.32	0.00	-0.02	0.15	-0.06
5	0.02	-0.46	-0.05	-0.13	-0.14	0.00	-0.19	0.02	0.14
10	0.01	-0.23	0.00	0.07	0.07	0.00	-0.18	0.05	0.00
AWM									
1	-0.23	-0.03	0.07	1.00	0.24	0.00	-0.04	0.17	-0.10
2	-0.48	-0.11	0.26	1.00	0.36	0.00	-0.15	0.28	-0.27
3	-0.42	-0.22	0.37	-0.31	0.09	0.00	-0.25	0.16	-0.28
5	-0.37	-0.49	0.33	-0.38	-0.12	0.00	-0.56	0.11	-0.05
10	-0.03	-1.25	-0.06	0.06	-0.01	0.00	-1.28	0.11	0.14

In the fourth simulation with forward-looking behaviour, the results are quite different from the preceding three backward looking simulations. A marked contrast is in the reaction of long term interest rates. This is not due to a different equation for long-term interest rates as the forward-looking condition is the same in both models. The reaction of long-rates in NiGEM is much more subdued – a rise of 10 basis points in year 1 and a return to baseline in year 2 – as the forward-looking condition takes into account that the initial hike in short rates will only last for 2-years but also that the Taylor Rule will subsequently ensure that interest rates will fall below baseline for a period after the initial rise. However in the AWM model the long rate actually falls significantly in the first year – by 31 basis points rising to 40 basis points in year 2 – as the forward-looking long rate reacts to the larger and protracted falls in short term interest rates from year 3 onwards.

It is worth noting, as discussed earlier, that the impact of long rates is rather different in the two models. In NiGEM long rates affect investment (via the user cost of capital), consumption in some countries and also affect some financial variables. A rise in long-rates will tend to lower economic activity through lower investment and to some extent also lower consumers' expenditure. In the AWM the only impact of the long-rate is on financial variables and in particular government interest payments to the personal sector. Nevertheless, the impact of this change in government interest payments generates strong income effects in the AWM which mean that a rise in long-term interest rates can have surprisingly strong *positive* short-term effects on personal income and thereby also economic activity.

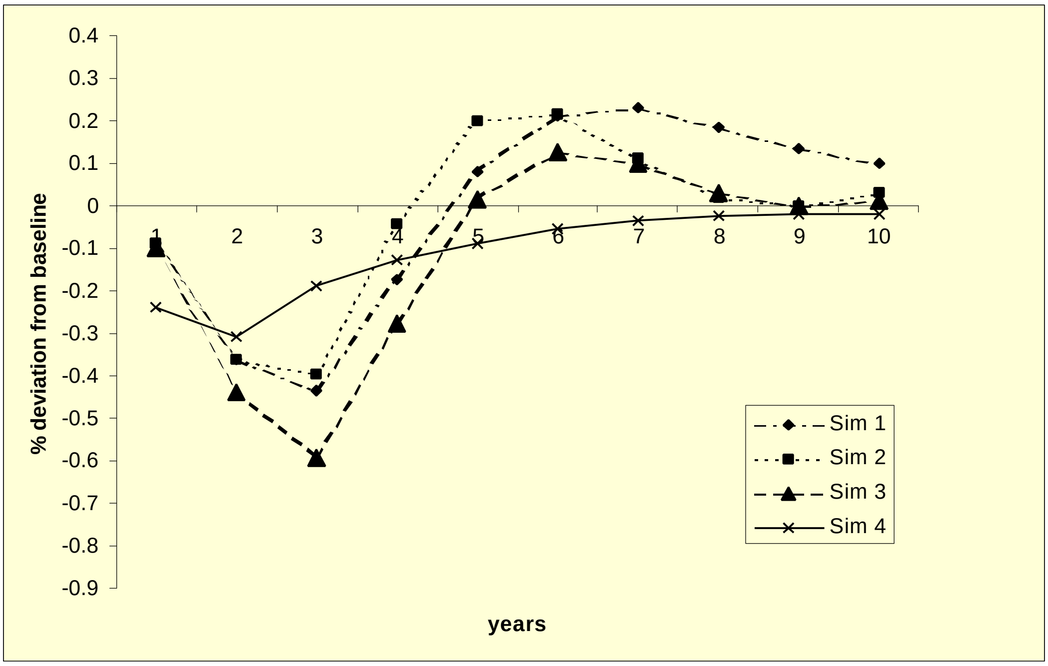
Table 4: Simulation 4

	GDP	PCE	U	S-Rate	L-Rate	Nom XR	Real XR	TBR	GBR
NiGEM									
1	-0.24	-0.05	0.08	1.00	0.10	1.11	1.05	0.05	-0.16
2	-0.31	-0.08	0.15	1.00	-0.01	0.26	0.13	0.04	-0.16
3	-0.19	-0.15	0.08	-0.24	-0.06	-0.16	-0.33	0.06	0.07
5	-0.09	-0.31	0.00	-0.12	-0.02	0.20	-0.15	0.03	0.05
10	-0.02	-0.37	0.01	-0.01	0.00	0.31	-0.01	0.01	0.01
AWM									
1	-0.41	-0.10	0.12	1.00	-0.31	0.88	0.80	0.24	-0.05
2	-0.86	-0.24	0.47	1.00	-0.40	-0.05	-0.35	0.47	-0.11
3	-0.83	-0.39	0.72	-0.60	-0.40	-0.42	-0.90	0.36	0.00
5	-0.61	-1.02	0.70	-0.86	-0.16	0.88	-0.24	0.11	0.17
10	0.04	-2.95	0.01	-0.09	0.27	3.72	0.91	-0.20	-0.03

Another important difference is the reaction of the exchange rate, which is no longer fixed. The rise in short-term interest rates now leads to a step appreciation in the exchange rate of 1.11% in the first year in NiGEM and 0.88% in the AWM. However, thereafter the exchange rate paths diverge with the NiGEM model generating a nominal exchange rate which remains relatively close to the baseline (+/- 0.3%) whilst the AWM initially generates some oscillations and leads to the nominal exchange rate being 3.7% appreciated compared with the base by year 10.

In terms of its effect on output in the first year, the exchange rate appreciation more than offsets the effect of lower long rates and output falls by 0.24% in NiGEM. Thereafter, the effects on output are smaller and the return to something closer to baseline is markedly faster and smoother in this simulation. This can be seen clearly in Figure 1a, which compares the GDP response in the four simulations. In the forward looking simulation there is a much smoother return towards the baseline without the overshooting seen in the other three simulations.

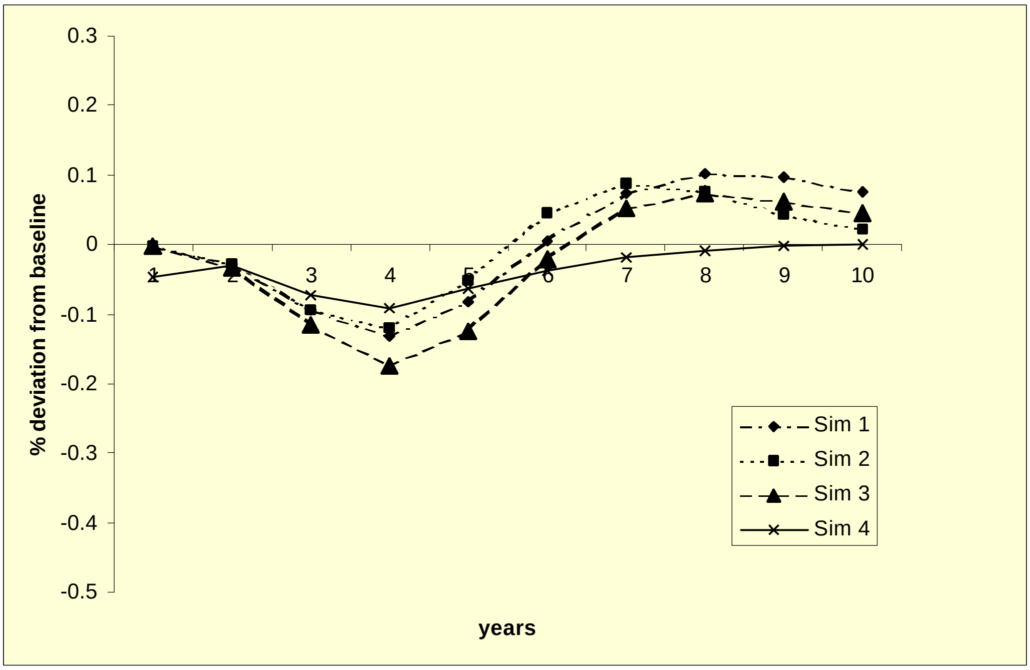
Figure 1a: GDP Response in NiGEM to the 4 Monetary Policy Experiments[23]



This pattern is also reflected in the development of prices as indicated in Figure 1b, which plots the deviation of inflation from baseline. Simulation 4 is notably different from the other three in that the inflation rate gradually asymptotes onto the baseline and there is no need for a period of above baseline inflation to restore the price level to its original level. In simulation 4 the price level is permanently higher, the nominal exchange rate is permanently appreciated but the real exchange rate is unchanged.

[23] The scales in Figures 1a and 2a are identical as are the scales in Figures 1b and 2b, to enable fair comparison to be made between the AWM and NiGEM results.

Figure 1b: Inflation Response in NiGEM to the 4 Monetary Policy Experiments



In the AWM, the initial output effect is also much larger due to the exchange rate appreciation and the fall in the long rate. Since the long-rate only feeds into public debt-related income-bearing assets the immediate effect is to reduce households' public debt-related income through lower interest repayments. Since – in the current version of the model – all such income is held domestically, this is clearly a significant (negative) channel. Output falls by 0.41% in the first year and by 0.86% in the second before gradually moving towards the baseline thereafter. The results from the simulations using the AWM are shown in Figure 2a. Although superficially, the AWM results look very different from the NiGEM results there is a similar broad pattern. Output effects in the forward-looking simulation are initially more pronounced than in simulation 3, but the forward-looking simulation settles down at the baseline level more quickly.[24]

[24] In the case of the AWM, the final reversion to baseline can not be seen clearly in Figure 2a as it occurs after 10 years. A chart comparing the reversion to baseline over a long time horizon is available from the authors upon request.

Figure 2a: GDP Response in AWM to the 4 Monetary Policy Experiments

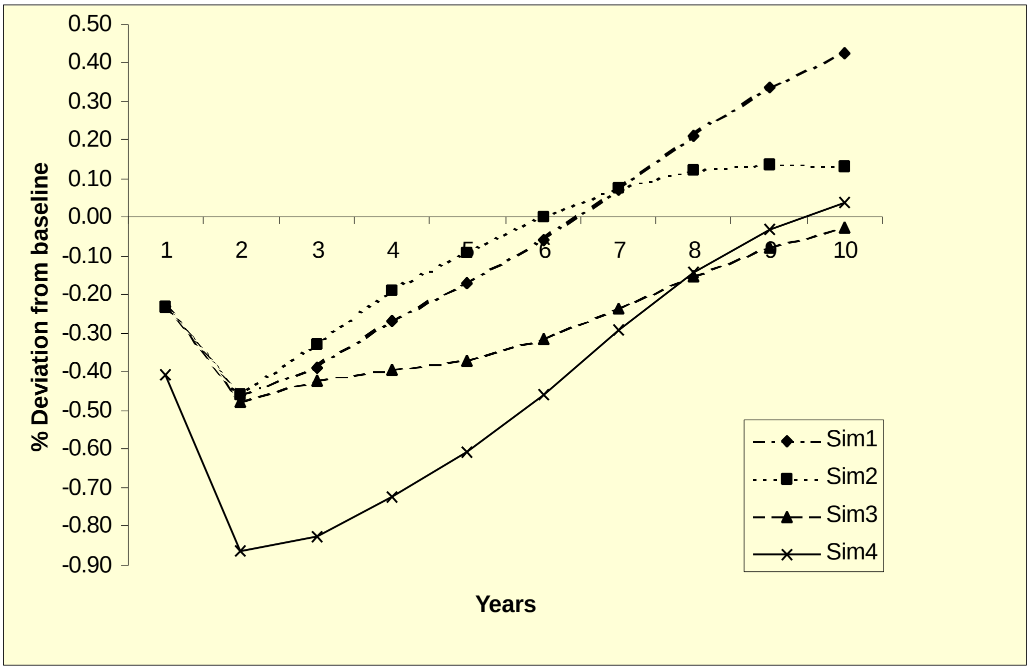
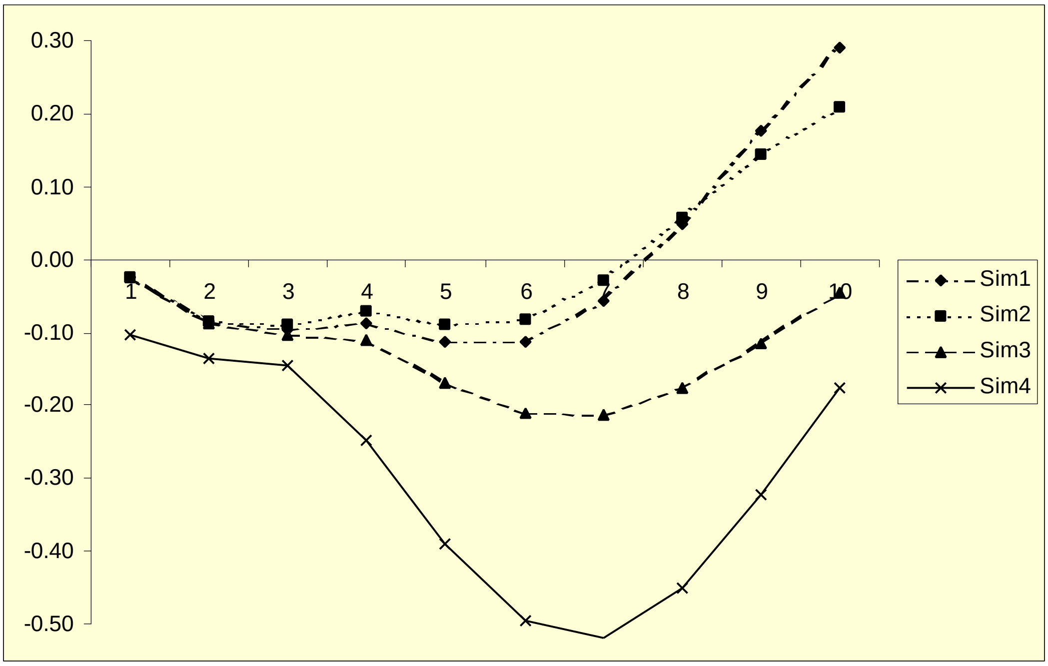


Figure 2 gives details of the response of inflation in the four AWM simulations. Reflecting the deeper fall in output in simulation 4, inflation falls further below baseline in the simulation 4, although by 10 years it is clearly moving back towards the baseline.

Figure 2b: Inflation Response in AWM to the 4 Monetary Policy Experiments



The considerably faster reaction of the NiGEM model in the forward-looking scenario reflects the far larger number of forward-looking elements within the NiGEM model. As already discussed, in addition to forward looking long rates and the exchange rate, NiGEM incorporates forward-looking behaviour in wage formation equity prices and the Taylor Rule takes into account expected prices. It is well known (e.g., Fisher, 1992)) that more forward-looking models tend to exhibit faster reactions compared to models with fewer forward-looking elements. In the absence of substantially more forward-looking elements in the AWM – the relatively larger initial demand effects in simulation 4 take some time to die out. Investigating the degree to which more forward-looking elements can be put in the AWM is the subject of ongoing research.

Since NiGEM has individual country blocks it is possible to decompose the euro area results by country. Although our main focus is on the euro area, the GDP responses from the fourth simulation are shown in Table 5 for information. In terms of the initial impact, it is noteworthy that the countries most exposed to trade with countries outside the EU[25] (Ireland, Finland, Belgium, Netherlands, Austria and Italy) all report an above average fall in GDP in the first year when there is a marked appreciation in the euro exchange rate. By the second year, when most of the initial appreciation has been reversed then the domestic channels are likely to assume greater importance. In this regard, in year 2 the greatest output loss is in Spain (-0.41%) which is also the country with the greatest interest sensitivity of the capital stock and hence investment. The output fall in Italy is also above the euro area average, reflecting the impact of short-term interest rates on consumers' expenditure.

After the initial monetary policy shock, the return to baseline is particularly slow in Finland and to a somewhat lesser extent also in Italy. These patterns of reaction to the monetary policy shock principally reflect different adjustment speeds of the estimated equations from the individual national blocks in NiGEM.

To put these NiGEM results in context, Figure 3 compares them with the country level results for the seven euro area countries reported in the 1995 BIS exercise. As the BIS exercise was conducted under different assumptions (which varied between countries) regarding monetary policy, the exchange rate and long rate such comparisons should be interpreted with care. The figure compares the average of the (annual) output losses in

[25] In terms of extra-EU exports as a proportion of GDP as reported in European Economy 2000.

each of the first two years (before the Taylor Rule begins to affect monetary policy in year 3).

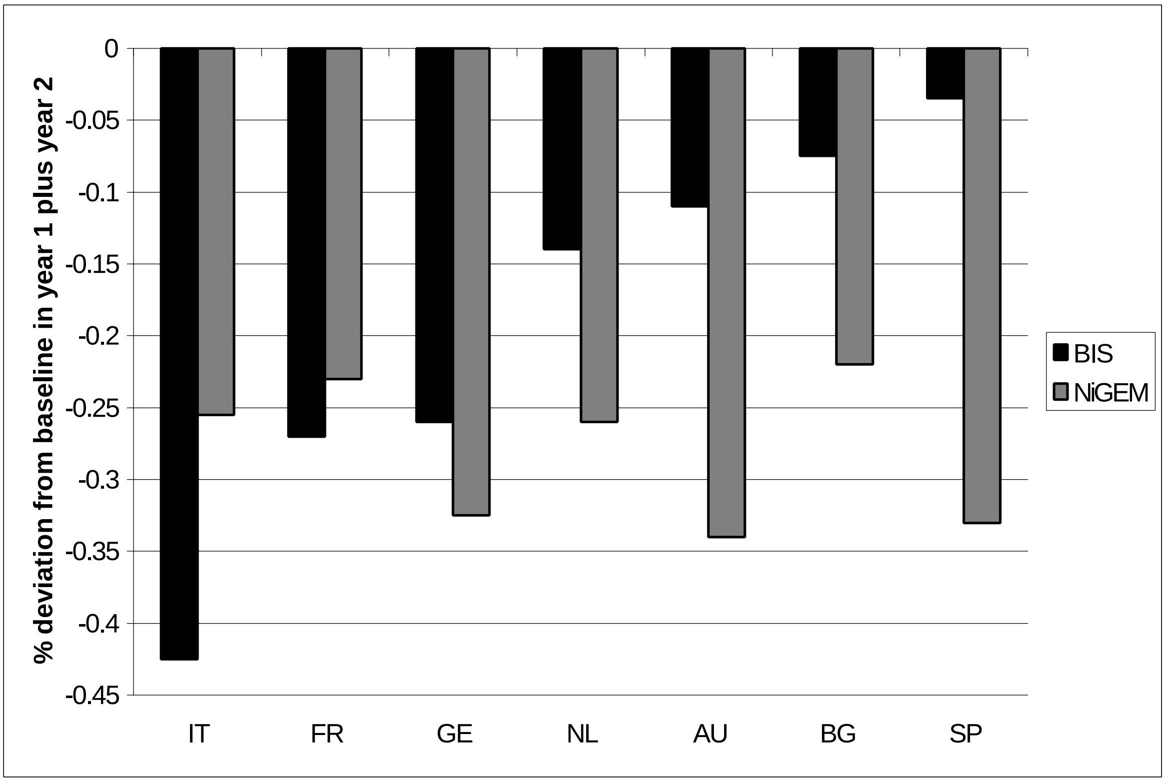
Table 5: GDP Response in Simulation 4 Decomposed by euro area Country

	1	2	3	5	10
Belgium	-0.27	-0.18	-0.14	-0.15	-0.02
Finland	-0.25	-0.36	-0.27	-0.21	-0.18
France	-0.17	-0.29	-0.20	-0.13	-0.01
Germany	-0.31	-0.34	-0.12	-0.08	-0.02
Greece	-0.18	-0.26	-0.10	-0.01	-0.04
Ireland	-0.28	-0.27	-0.08	-0.04	-0.04
Italy	-0.17	-0.34	-0.34	-0.15	0.00
Netherlands	-0.27	-0.25	-0.12	-0.14	-0.09
Austria	-0.45	-0.23	-0.08	-0.10	0.00
Portugal	-0.17	-0.06	0.02	-0.04	-0.04
Spain	-0.26	-0.41	-0.25	0.13	0.00
Euro area	-0.24	-0.31	-0.19	-0.09	-0.02

Not surprisingly the NiGEM results show a much greater consistency across countries, partly reflecting the fact that the exercise was genuinely harmonised across countries within NiGEM. Doubtless it will also reflect the greater degree of similarity in the individual country blocks in NiGEM than the 7 distinct models developed by the national central banks. Nevertheless, the impact on GDP for the two largest euro area countries – Germany and France – is very similar. For Italy the BIS reported a stronger loss in output whilst for the remaining 4 countries NiGEM reports stronger output effects. In some cases the weaker effects reported in the BIS may be due to the lack of inclusion of international spillovers which will be automatically taken into account in NiGEM. This is likely to be particularly important for the smaller more open economies – such as Austria, Belgium and the Netherlands – who may be significantly affected by the output losses in other European countries. Exports to other EU countries make up over 50% of GDP in Belgium, over 30% in the Netherlands and over 20% in Austria compared with around 15% in Germany and France and 11% in Italy.[26]

[26] Source: European Economy 2000

Figure 3: Comparison of the Average Output Loss in the First Two Years using NiGEM and the Results of the 1995 BIS Exercise



Channels of Transmission

The above simulations show only the overall effect of a change in monetary policy on the endogenous variables. But, as discussed, it is standard practice when reporting such results to decompose them into their various (transmission) channels. As highlighted in section III, we identify the following channels: (1) an *income/cash* flow channel, which measures the effect of interest rates on net interest payments; (2) a *wealth channel* to capture the impact of interest rates on wealth; (3) a direct interest channel on *consumption*; (4) a *cost of capital* channel to capture the effect of interest rates on investment and (5) an *exchange rate* channel to capture the effects of changes in the exchange rate due to changes in interest rates.

The results for GDP and prices are shown in Tables 6 and 7 and we have reported two sets of results for the channel decomposition, the first with a 'common monetary policy' and the second with a 'channel-dependent monetary policy'.[27] This reflects the earlier

[27] Following standard practice (see for instance BIS (1995) or Van Els et al (2001)), the results reported in Tables 6 & 7 refer to the contributions of each channel to the deviations in output and prices from their baseline levels in that year. It should be noted that an alternative approach would have been to examine the

discussion on the implications of the use of a monetary policy rule after the initial 2-year hike on the channel decomposition. In the case of the 'common monetary policy' we impose the identical path of interest rates and the exchange rate from the overall simulation 4 on all channels. In the 'channel dependent monetary policy' case we have allowed the monetary policy reaction from year 3 onwards to be different in each of the simulations to identify the channels. Therefore, we allow the reaction of the Taylor Rule to be endogenous for each channel so that channels which had the largest effects on output and prices would induce a bigger monetary policy response than those channels where the effects were more muted. This means that the path of interest rates from year 3 onwards is different for each channel. Another feature of this channel dependent monetary policy case is that we allow the exchange rate movement generated by the forward-looking UIP condition to be endogenous to the exchange rate only channel. For each year the dominant channel – i.e. the one with the largest impact – is shown in bold.

As shown in Table 6, in the case of the NiGEM model with the common monetary policy, the clear message is that in the initial period the exchange rate channel is the most important, accounting for 0.15% of the 0.24% fall in output in year one. Thereafter it gradually diminishes in importance reflecting the fact that the real exchange rate rapidly returns close to its baseline level. From year two onwards the domestic channels – and most notably the cost of capital in investment channel – gradually gain in importance. The direct interest effect in consumption has only a very modest impact reflecting the fact that such an effect is only present in three countries of the euro area. Nevertheless, the effects of the wealth channel are not that much larger, whilst the income channel assumes greater importance from year 3.

In the case of the AWM, the cost of capital channel is also the most important domestic channel in the first three years but unlike NiGEM it is more important than the exchange rate channel for the whole of the reporting period. This reflects the fact that the elasticity of the user cost of capital in investment is quite high in the AWM model. As indicated in Fagan et al (2001) a 100 basis point rise in the real interest rate will lower investment by around 10% after 10 years. The impacts of a 100 basis point rise in the user cost of capital on investment in NiGEM vary between countries, but are generally well below 10% after 10 years.

contribution of each channel to the change in GDP or prices with respect to the baseline. From the second year onwards, such an approach could potentially lead to a different assessment of the relative contribution and ranking of each channel.

Table 6: Decomposition of Channels for the GDP Response

Case 1: Common Monetary Policy

	Total	Income Effect	Wealth	Consumption Effect	Cost of capital	Exchange Rate Channel
NiGEM						
1	-0.24	-0.02	-0.02	-0.01	-0.06	**-0.15**
2	-0.31	-0.05	-0.04	-0.03	**-0.10**	-0.07
3	-0.19	**-0.06**	-0.02	-0.03	-0.03	0.03
5	-0.09	-0.05	0.03	0.00	**0.07**	-0.02
AWM						
1	-0.41	-0.05	0.00	-0.06	**-0.21**	-0.08
2	-0.86	-0.16	-0.01	-0.04	**-0.57**	-0.06
3	-0.83	-0.25	-0.02	0.06	**-0.60**	0.02
5	-0.61	**-0.29**	-0.06	0.05	-0.12	-0.06

Case 2: Channel-Dependent Monetary Policy

	Total	Income Effect	Wealth	Consumption Effect	Cost of capital	Exchange Rate Channel
NiGEM						
1	-0.24	0.00	-0.01	-0.01	-0.07	**-0.19**
2	-0.31	-0.03	-0.04	-0.02	**-0.16**	-0.13
3	-0.19	-0.05	-0.03	-0.02	**-0.12**	-0.01
5	-0.09	**-0.05**	-0.01	0.01	-0.04	-0.01
AWM						
1	-0.41	0.03	0.00	-0.06	**-0.21**	-0.14
2	-0.86	0.05	-0.01	-0.04	**-0.57**	-0.17
3	-0.83	0.04	-0.02	0.03	**-0.62**	-0.11
5	-0.61	0.00	-0.08	0.02	**-0.35**	-0.05

One interesting contrast is the magnitude of the income effects in the two models as the effects are much larger in the AWM. Both models take into account the effects of changes in interest rates on government interest payments. This should have a broadly neutral long-run effect in that it boosts interest payments received by the personal sector but also induces a fiscal reaction as the government seeks to adjust taxes in response to the change in interest costs. However, as already discussed, in the AWM the initial impact of the fall in long-term interest rates induced under simulation 4 is strongly negative, which is a somewhat counter-intuitive result. The reason is that the income loss is experienced immediately whilst it takes time for the fiscal rule to react and reduce taxation to restore the government budget balance to its baseline level. Nevertheless, the magnitude of this negative income effect from falling long-rates appears large in the AWM and is much larger than NiGEM would generate for a similar path of long-term interest rates. However, in this case, the negative income effect in NiGEM is not from this source as long-term interest rates do not fall in the NiGEM simulation. In NiGEM the negative income effect principally stems from the fact that this model takes into account that the domestic interest payments to foreigners increase following the rise in short-rates which leads to a worsening in the current account and net wealth.

To some extent, the relative importance of the channels alters when the decomposition is undertaken with a channel-dependent monetary policy. In NiGEM the exchange rate channel remains dominant in year 1 to be superseded by the cost of capital channel in year 2. However the relative importance of the other channels declines, notably the income effect which was previously dominant in year 3. A similar pattern also exists in the AWM results but the change is more striking, with the important income effect discussed above disappearing. This is because long-rates do not fall significantly with the channel dependent monetary policy. Since the dominant channels are closed there is no significant fall in output and hence no need for the Taylor Rule to lower short-term interest rates.

In terms of the impact on prices, the exchange rate channel tends to dominate initially with both models, as the change in exchange rate has a direct and rapid impact on import prices. Thereafter the exchange rate channel remains dominant for the NiGEM results, reflecting the fact that there is a permanent nominal appreciation, accompanied by a permanent fall in prices whilst most variables which have the potential to impact on prices have returned to their baseline levels. In the case of the AWM the cost of capital channel takes over in the case of the AWM in year 2, reflecting the larger and more persistent output gap that emerges in this case.

Table 7: Decomposition of Channels for the Response of Prices

Case 1: Common Monetary Policy						
	Total	Income Effect	Wealth	Consumption Effect	Cost of capital	Exchange Rate Channel
NiGEM						
1	-0.05	0.00	0.00	0.00	0.02	**-0.08**
2	-0.08	-0.01	-0.01	-0.01	0.03	**-0.12**
3	-0.15	-0.02	-0.03	-0.02	-0.02	**-0.12**
5	-0.31	-0.05	-0.03	-0.03	-0.08	**-0.13**
AWM						
1	-0.10	-0.01	0.00	-0.01	-0.02	**-0.07**
2	-0.24	-0.03	0.00	-0.02	**-0.12**	-0.07
3	-0.39	-0.09	0.00	-0.02	**-0.26**	-0.01
5	-1.02	-0.30	-0.03	0.01	**-0.55**	-0.11

Case 2: Channel-Dependent Monetary Policy						
	Total	Income Effect	Wealth	Consumption Effect	Cost of capital	Exchange Rate Channel
NiGEM						
1	-0.05	0.01	0.00	0.00	0.04	**-0.11**
2	-0.08	0.01	0.00	-0.01	0.06	**-0.18**
3	-0.15	0.00	-0.02	-0.02	0.02	**-0.21**
5	-0.31	-0.03	-0.04	-0.03	-0.06	**-0.25**
AWM						
1	-0.10	0.00	0.00	-0.01	-0.02	**-0.12**
2	-0.24	0.01	0.00	-0.02	-0.12	**-0.17**
3	-0.39	0.03	0.00	-0.02	**-0.26**	-0.14
5	-1.02	0.06	-0.03	-0.02	**-0.61**	-0.20

VI. Conclusions

In this paper we have examined some of the issues faced by macroeconomic model builders in analysing the monetary transmission mechanism using the AWM and NiGEM models. Our results have highlighted the importance of various aspects of model and simulation design in affecting the results from such monetary policy exercises. From this exercise we draw the following conclusions**:**

- The NiGEM and AWM models yield broadly similar results for the effect of monetary policy on output for the first 2-3 years when the forward-looking elements of the model are not used. Both the maximum and the cumulative loss of output over the first three years are quite similar, but there are differences in the timing of the output loss. This holds true when monetary and fiscal policy rules are introduced into the simulations.
- Allowing forward-looking behaviour in the models tends to increase the initial impact of the monetary policy exercise but also hastens the return to baseline values. Once the forward-looking elements of the model are allowed to operate the impact in the AWM is clearly stronger than in the NiGEM model. The output losses in the AWM are approximately twice as large in each of the first three years. A major factor behind this is the particularly large adverse income effects stemming from the fall in long-term interest rates generated by the forward-looking simulation.
- The models also have quite different properties in the longer term and after 5 years there has been a clear divergence in the results. This reflects a faster adjustment speed in the NiGEM model, which has largely returned to its baseline values by year 5. The considerably faster reaction of the NiGEM model reflects relatively stronger feedbacks and error correction mechanisms leading to a faster speed of adjustment and the larger number of forward-looking elements within the NiGEM model.
- The paper has highlighted the effects of using monetary policy rules following the initial interest rate shock. From the third year, a Taylor Rule will tend to lower interest rates in an attempt to return output and prices towards their baseline values. The initial response of the Taylor Rule was broadly similar across both models, although given the slower adjustment in the AWM, interest rates need to remain below their baseline levels for longer. The initial impact of the Taylor Rule on output and prices is not that large, but it does serve to expedite the return to baseline values. One important consequence of using such rules is that a decision has to be taken on how to treat them in the channel decomposition.
- If a fiscal policy rule is used – which seeks to maintain a target level of the government deficit or debt stock – this will tend to exacerbate the initial fall in output

due to the monetary policy shock. The initial impact of the fiscal rule is not that large as it acts with some delay, but it does increase in importance in the second and third years of the simulations

- In both models, the user cost of capital tends to be the dominant channel of transmission in terms of its impact on GDP when a common monetary policy is implemented across all channels. The main exceptions are that in the first year in the NiGEM model, the exchange rate channel is dominant whilst the income channel grows in importance in later years in both models. The user cost of capital and income effects tend to be larger in the AWM than in the NiGEM model. In the former case this is due to a higher sensitivity in the AWM to changes in the user cost of capital. In the latter case it is due to a particularly marked income effect from the impact of changes in long-term interest rates on government interest payments. The general pattern of results is not significantly altered when using a channel-specific monetary policy, although the income channel significantly diminishes in importance in the AWM. In terms of the impact on prices, the exchange rate channel plays an important role in both models given the direct impact on import prices stemming from changes in the exchange rate.

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Appendix 1 : Maquette Notation

Π : Inflation Rate
B: Stock OF Government Debt
C : Real Consumption
CA: Current Account
DEFICIT: Government Deficit Level
ER : Nominal Exchange Rate
G: Government Expenditure
I : Real Investment
IM: Import Volumes
K: Capital Stock
L: Employment
L: Labour
M: Money
MPK: Marginal Product Of Capital
MPL: Marginal Product Of Labour
NFA: Stock Of Net Foreign Assets
P: Output Price
PK: Investment Deflator
PROD: Labour Productivity =(Y/L)
PY: Value-Added Deflator
R : Nominal Short Interest Rate
RL : Nominal Long Interest Rate
RLR : Real Long Interest Rate
TX: Tax Rate
UCOC: Nominal User Cost Of Capital
Wages: Wage Level
X: Export Volumes
Y : Real Income

$c_i, z \ , m, a_i, b_i, z, j, n, e_i, f_i$: Coefficients
d: Depreciation rate.
Δ: First difference.

Appendix 2: Model Descriptions

AWM

The AWM is a single country model of the euro area. Its structure is fairly standard having a long-run classical equilibrium with a vertical Phillips curve with some short-run Keynesian features in price/wage setting and factor demands. As a result, activity is determined in the short run by demand, given incomplete prices and wages adjustment. In the longer run, output is supply determined, employment having converged to a level consistent with the exogenously given level of equilibrium unemployment. In addition, stock-flow adjustments are accounted for, e.g. by the inclusion of a wealth / cumulated saving term in consumption. At present the treatment of expectations in the model is limited; with the exception of the exchange rate (modelled by UIP) the model embodies backward looking expectations – although in this paper we have incorporated a forward-looking term structure. The model can in fact be adapted in a straightforward manner to incorporate forward-looking expectations in other key equations. Full model listing and simulation evidence can be found in Fagan et al (2001).

NiGEM

NiGEM is a 2500 equation quarterly global macro economic model with a specific focus on major industrial countries. It has been used in comparative exercises organised by the Macro Modelling Bureau at Warwick University, the OECD, the US Federal Reserve and the Brookings Institute in Washington and in the EC financed SPES model. It has also been widely used in academic studies of international policy co-operation as well as in published forecasts and policy analyses, notably those published in the National Institute Economic Review.

The model comprises the 18 detailed country sectors for the US, Canada, Japan, the EU economies and Mexico (full details are given in NIESR (2001). Each of these contains up to 110 variables covering individual components of demand, price indices, exchange rates and interest rates, trade, the public sector and the current account. Smaller models exist for Norway, Switzerland, the Visigrad countries, South Korea and Australia/New Zealand. The remaining sectors cover OPEC, East Asia, Latin America, Africa, China, developing Europe and miscellaneous developing countries.

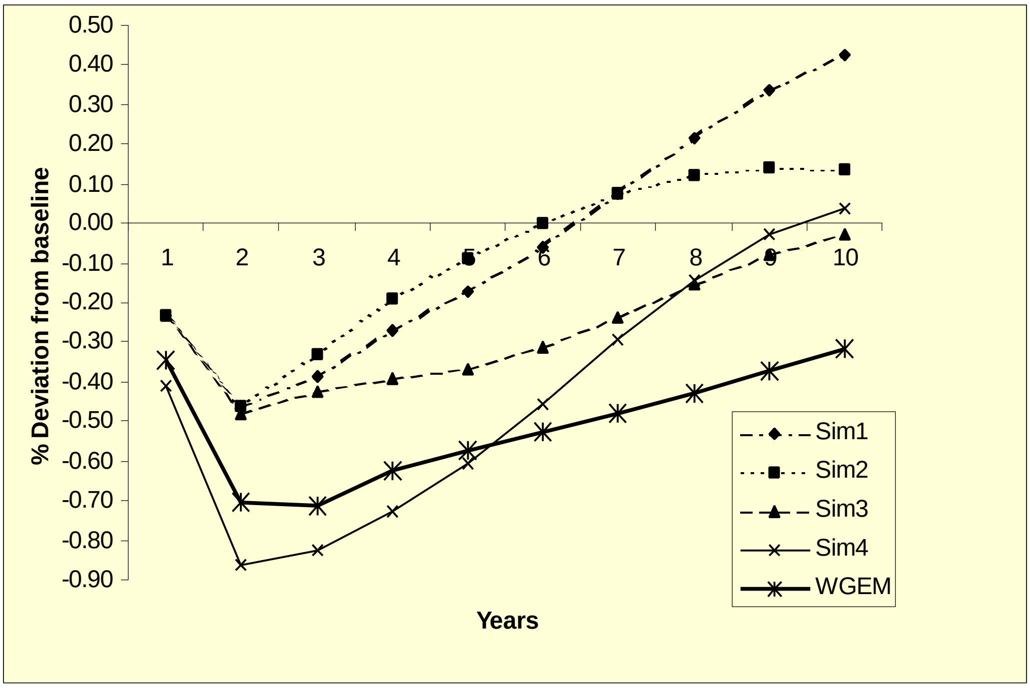
Behavioural equations in NiGEM are estimated not calibrated. The model incorporates rational expectations in financial, foreign exchange and labour markets, and a large number of options are available for setting fiscal policy and interest rates. The model is essentially New Keynesian in its approach. Agents are assumed to be forward looking, but nominal rigidities slow the adjustment to external events. Various mechanisms are in place in the model to ensure that world trade adds up.

Appendix 3: Comparison with the WGEM Experiment

For comparative purposes we also compare the results of the four simulations reported in this paper with another set of results. These have been generated using the AWM and NiGEM models but following the specification of a monetary policy experiment undertaken by the Working Group of Econometric Modelling (WGEM) using national central banks models and the AWM. This work is reported in Van Els et al (2001).

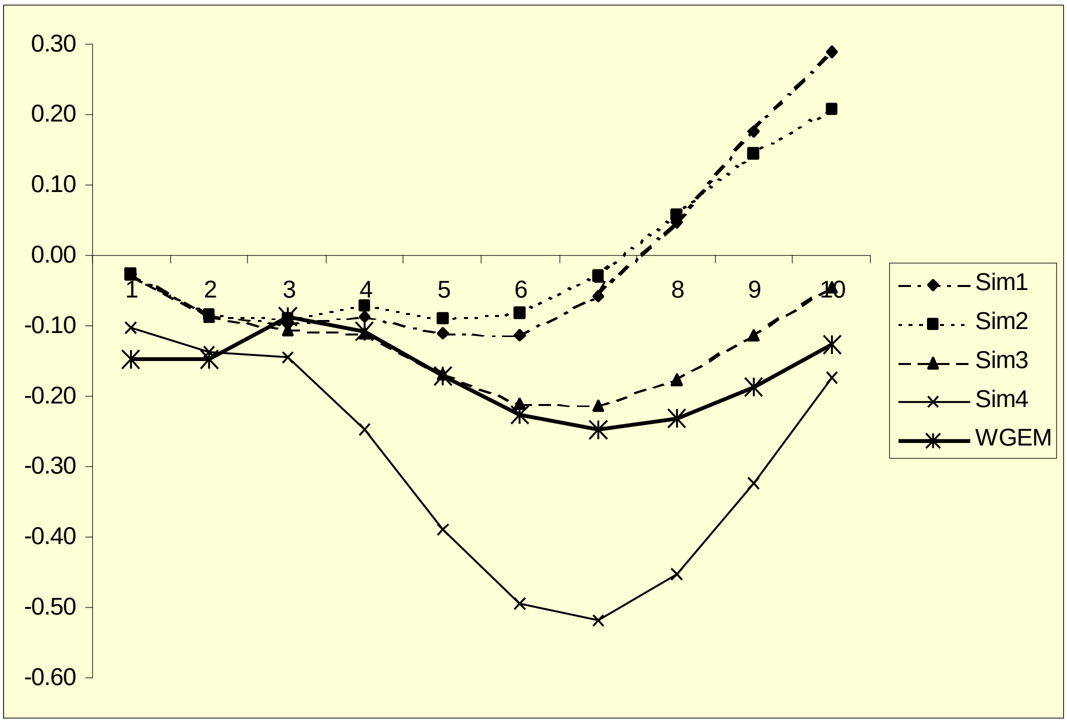
The details of the experiment are as follows. Following BIS (1995), the monetary policy shock was a two-year increase of the short-term policy interest rates by 1 percentage point from 2001Q1-2002Q4. From and including 2003Q1 a return to baseline values was assumed. No monetary or fiscal policy rules were implemented. The term structure was modelled using the expectations hypothesis, while exchange rates were determined by a simple uncovered interest parity condition. In both cases, risk premia were held constant at baseline values and there was no change in inflation expectations. This resulted in an appreciation of the euro nominal exchange rate of 1.63% in the first year and 0.62% in the second, and a rise in long-term interest rates of 16 basis points in the first year and 6 basis points in the second. Thereafter both the exchange rate and the long-term interest rates were exogenised at their baseline value. The motivation for the design of the experiment is outlined in Van Els et al (2001).

Figure 4a: GDP Response in AWM to the 5 Monetary Policy Experiments



The impact of this experiment on GDP using the AWM is given in Figure 4a with the line marked 'WGEM'. The closest comparison is with simulation 4, where there is also an initial appreciation and forward-looking long rate condition. The initial impact of the WGEM experiment is somewhat smaller than under simulation 4 but the subsequent return to baseline is markedly more protracted. Whilst the initial appreciation is larger in the WGEM case (1.6% as against 0.88%), which should lead to a larger initial loss in output, this is more than offset by the differing path of long term interest rates. In the WGEM scenario long-rate rise slightly above base whilst in simulation 4 they fall well below base reflecting the future decline in short-term interest rates when the Taylor Rule operates. As has already been discussed a fall in long-term interest rates has a significant negative effect on output as lower government income payments cut personal income. Without the fall long-term interest rates the WGEM experiment generates much reduced negative income effects.

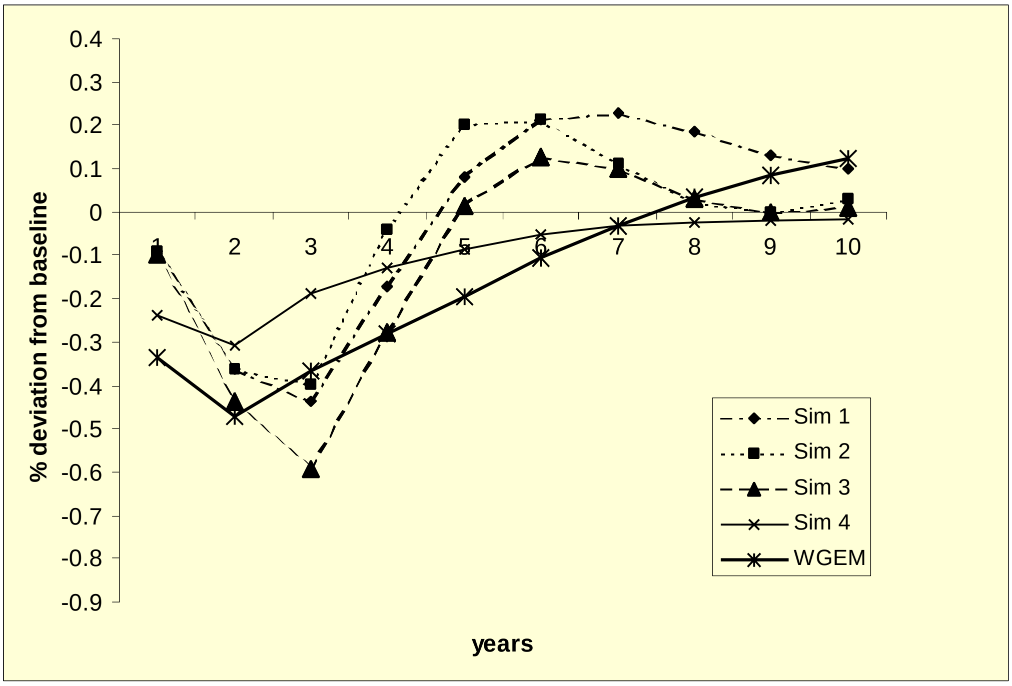
Figure 4b: Inflation Response in AWM to the 5 Monetary Policy Experiments



The subsequent return towards the baseline is much more protracted in the case of the WGEM scenario. This reflects the fact that the Taylor Rule is acting to reduce short-term interest rates and thereby aiming to close the output gap and return inflation to its baseline level. Figure 4b compares the deviation of inflation from its baseline level. The fall of inflation below baseline is initially stronger in the WGEM experiment - reflecting the sharper appreciation in the exchange rate. However, by year 3, the exchange rate is back to baseline in the WGEM experiment and the larger output loss in simulation 4 means that the fall in inflation is larger in magnitude. This remains the case for a number of years but subsequently the fall in inflation becomes broadly similar in both simulations.

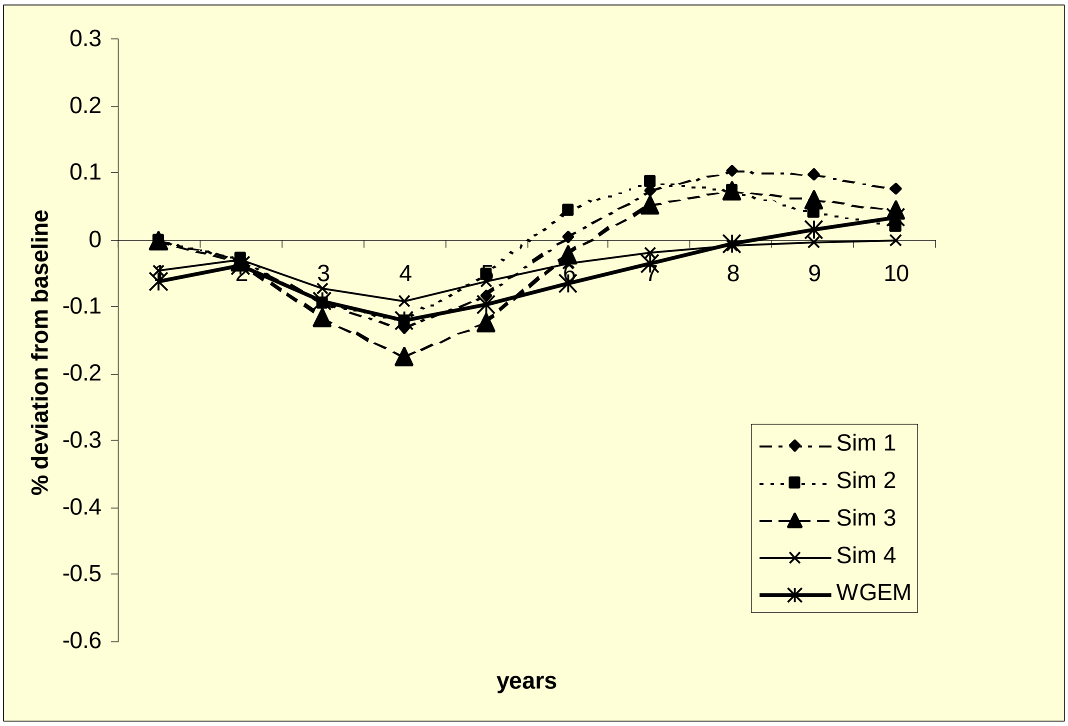
Figures 5a and 5b compare the same simulations using the NiGEM model (using the same scale as for the AWM figures to ensure comparability). In the NiGEM case the initial impact of the larger appreciation is a larger fall in output than in simulation 4 as the compensating long-rates income effect generated by the AWM in simulation 4 was not relevant for simulation 4 in NiGEM. Thereafter the absence of a monetary policy rule in the WGEM simulation means that it does not stabilise back at the baseline as quickly as in simulation 4.

Figure 5a: GDP Response in NiGEM to the 5 Monetary Policy Experiments



The impact on inflation in the NiGEM model is much less pronounced than in the AWM case as shown in Figure 5b. Nevertheless, inflation falls further below baseline in the WGEM experiment than in simulation 4, reflecting the larger output gap that emerges in this simulation. The WGEM simulation also requires a period of above baseline inflation to return the price level to its baseline level as the nominal exchange rate is also fixed at its baseline values. This is not required in simulation 4 where there is a permanent nominal appreciation and a permanent fall in prices and hence no need for a period of above baseline inflation.

Figure 5b: Inflation Response in NiGEM to the 5 Monetary Policy Experiments



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