An Encompassing Framework for Evaluating Simple Monetary Policy Rules:

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Abstract

Taylor and others have argued that model stability requires interest rate policy rules have an inflation feedback parameter greater than one. In this paper we build an encompassing framework to analyse the stability conditions of various policy rules on Taylor's model and in a world where there are nominal rigidities in the short-term evolution of demand. We conclude that with a combined nominal GDP and inflation targeting rule, this stability condition is not necessary. We use stochastic simulations on NiGEM to evaluate different parameterisations of the rules. We discuss the resulting covariance structures and discuss their implications for the ECB.

Key Words: Taylor rules, Inflation targeting, Monetary policy, feedback rules,

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Note: The results presented in this paper are provisional and due to the computational burden of stochastic simulations a wider set of results are being constructed for the final version of the paper.

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1. Introduction

The Purpose of this paper is to examine the merits of different monetary policy rules by using stochastic simulation techniques on the National Institutes Global Econometric model, NiGEM. More precisely, the paper investigates the stabilisation properties of these rules in terms of reduced variability in certain main economic time series, such as output and inflation. We are not only concerned with looking at different types of policy rules but also varying the parameters within a rule itself to contribute to the debate that has built up in the academic literature on the most appropriate size of feedback coefficients in the rules. Other issues are covered in the paper, such as the implications different policy rules may have for the European Central Bank and the implications of including exchange rate uncertainty into the analysis.

In this paper we start by looking at a simple description of the policy environment as given in Taylor (1998a) and at the stability of a small model under a set policy rules that are nested within a general framework. We look at targeting a nominal aggregate, a mixed nominal aggregate and inflation targeting regime, pure inflation targets and a Taylor rule.[2] We the go on to examine if the small model findings hold when applied to a large-scale macro economic model.

Large scale macro-models of the economy need monetary closure rules even more than they need fiscal closure, as many analyses cannot be sensibly undertaken without some knowledge of the response of the monetary authorities. There are two classes of monetary policy rule that can be used in large models and by policy makers, and they have slightly different implications for the price level and for the model. There are those that tie a nominal aggregate or variable down in the long run, including fixed exchange rate rules, money stock guidelines and nominal GDP targeting[3]. There are others that feed back on the inflation rate, and stabilise it in the long run, but whose impact on the level of prices depends on the nature of the shocks and the feedback in the policy rule. The distinction between these two classes of rules is brought out in an annex.

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[2] In Barrell Dury and Hurst (1999a) we look more directly at commonly used Taylor Rules in the context of international policy co-ordination, although these rules also fit within our framework., and in Barrell, Dury and Hurst (1999b) we investigate out-turns for monetary and fiscal policy in Europe, and discuss the targeting strategies available to the ECB.

[3]The class also includes using the change in the interest rate to target the level of inflation.

Since Taylor's paper (1993), there has been much interest in the evaluation of different monetary policy rules. A substantial part of this literature concentrates on the use of simple policy rules on small stylised models many of which are backward looking closed economy models (see Rudebusch and Svensson (1998), Svensson (1997) and Ball (1997)). They argue, for example, that the optimal policy is some form of inflation targeting through a Taylor type rule, in which interest rates are adjusted in response to the deviation of output and inflation from their desired path. Indeed many have advocated that interest feedback rules that respond to increases in inflation with more than one for one increase in the nominal interest rate, are stabilising[4]. Taylor (1998b) finds that there is historical evidence in the US that shows there is an unambiguous correlation between monetary policy rule and macroeconomic stability. Three eras of US monetary history were analysed; first 1879-1914, where rates were unresponsive to fluctuations in output and inflation: second, 1960-1979, where short term interest rates were more responsive but the response on interest rates to changes in inflation were less than 1; third 1986-1997 where the interest rate response was greater than 1. The latter period proved to be the most economically stable period.

Taylor (1998a) suggests that the ECB should follow such a rule where the response coefficient on the inflation target is greater than one. However a recent paper by Benhabib, Schmitt-Grohé and Uribe (1998) has argued that such an 'active' policy rule can lead to instability. They show in an optimisation framework that even if there exists a unique steady state equilibrium for this rule, there will exist an infinite number of equilibrium trajectories lying near the active steady state. They advocate that using local techniques to analyse the stability of the system may lead to inappropriate policy regimes.

Chappell and Turner (1998) demonstrate that the Taylor rule can induce instability into a small macroeconomic model with Rational Expectations because it effectively removes the real balance effect from the output equation making excess demand a function of only inflation. In addition it may be the case that in large models, small model results may not hold. As Chappell and Turner point out, in more complex models the Taylor rule may not produce instability as other factors will make output a

[4] See Clarida and Gertler (1997), Christiano and Gust (1998)

function of the price level, for instance the effects of the real exchange rate on competitiveness, and so stabilise the model.

Monetary policy also affects the economy through exchange rate channels as well as through the interest rate effects on domestic demand. Therefore the choice of a ‘best’ monetary policy rule may change when working in an open economy framework. Svensson (1998) extends the analysis of inflation targeting to a small open economy model where the exchange rate plays a prominent role in the transmission mechanism of monetary policy and shows that by targeting variables other than just inflation, the variability of other economic variables is reduced. In order to take account of the variability of these other variables it is necessary that small models are expanded to include them, and that we work in an open economy framework, and hence there is a strong case for analysing the ECB’s problems using a large open macro-economic model. Taylor does use stochastic simulations on a seven country macro-economic model to calculate the variability of certain economic variables under a Taylor rule. However, he does not analyse how the economic stability is affected by changing the parameters of the rule. We aim to build on this work by taking a class of monetary policy rules considered in the general framework we have developed and apply different parameterisations of the rules to ascertain whether these small model findings hold on a large open-economy macro-econometric model.

Our aim in this paper is to build an encompassing framework so that we can analyse the stability properties of a class of simple monetary policy feedback rules where both the Taylor rule and his description of the world is nested within the general framework. We start with the Taylor rule and show the theoretical basis for Taylor’s result. We then consider some alternative policy rules that are nested within the general framework of the model and examine the conditions necessary for stability. Within the framework we can then extend the simple Taylor world and examine the stabilisation properties of the class of rules when wealth effects are included in the aggregate demand schedule.

Following Taylor we will then go on to apply the theoretical calculations based on the small model results to a large global econometric rational expectations model. We will use stochastic simulation techniques on the National Instititutes Global Econometric Model, NiGEM, to evaluate the performance of the policy rules. The best way to evaluate the stabilisation properties of the rules is to apply a sequence of random shocks to the model. Analysing policy rules using deterministic shocks is useful as it can give a clear comparison of the effects under a very specific shock to the economy (Barrell, Dury and Pain (1998). However, the overall performance of a policy rule will depend on its ability to stabilise economic variables given a variety of shocks. To conclude that one rule is superior to another, we must apply a number of random shocks to the model and measure its overall performance, and hence the most effective way to evaluate rules is to use stochastic simulation techniques.

In section 2 we develop the theoretical framework for analysing a class of monetary policy rules. We discuss 5 types of rules that are nested within the general framework. Within the framework we can then extend the Taylor model to examine how real wealth effects alter the small model results. Section 3 gives a summary of the techniques used to undertake stochastic simulations on NiGEM and discusses the issue of including shocks to the exchange rate. Section 4 provides a brief overview of NiGEM and Section 5 reports the results of the simulations on the variability of certain economic variables. Section 6 examines results when exchange rates are excluded from the analysis and Section 7 concludes.

2. An Encompassing Framework

In this section we provide a general framework for evaluating different policy rules. Let us expand the simple Taylor model described in Taylor (1998a) to include real wealth effects and a wider class of monetary feedback rules. This simple analytical framework is sufficient to cover the class of models we wish to investigate, although the richness of expectational elements is not fully brought out. In particular, we do not feel that it is possible to undertake policy analysis without the assumption of rational expectations at least being considered, but Taylor's simple framework excludes these elements, and in this section we therefore do the same.

Consider the model, defined in terms of deviations from baseline:

$$y_t = -\beta_1(i_t - \pi_t) + \theta(w_t - p_t) + u_t \quad (1)$$

$$\pi_t = \pi_{t-1} + \beta_2 y_{t-1} + e_t \quad (2)$$

$$i_t = \gamma_1 \pi_t + \gamma_2 (p_t y_t) \quad (3)$$

where y_t is the percent deviation of real GDP from potential, π_t is the inflation rate, p_t is the price level, w_t is nominal wealth and i_t is the nominal short-term interest rate. e_t and u_t are serially uncorrelated stochastic shocks with a zero mean. Lower case denotes logarithms. Equation (1) is a conventional IS curve which relates output to the real interest rate and includes the possibility of wealth (or real balance) effects on demand. The parameters of the model are β_1, β_2 and θ and are assumed to be positive. Equation (2) can be interpreted as a conventional Phillips curve and equation (3) is the monetary policy rule used to close the model. In the more general model, the nominal interest rate is assumed to respond to deviations of inflation, price level and real GDP from their desired target paths. We shall first consider the various types of rules that this framework encompasses and then take each rule in turn and examine their stabilisation properties. Our objective is to include rules that can be described as targeting a nominal aggregate such as the money stock or nominal GDP[5]

We can expand equation (3) to give:

$$i_t = \gamma_1 \pi_t + \gamma_{21} p_t + \gamma_{22} y_t \tag{4}$$

Various types of rules are nested within this general framework.

Parameter values	**Type of rule**
$\gamma_1 = 0$, $(\gamma_{21}=\gamma_{22})$	Money or Nominal GDP targeting rule
$\gamma_1, \gamma_{21}, \gamma_{22} > 0$, $(\gamma_{21}=\gamma_{22})$	Combined money or nominal GDP and inflation targeting rule
$\gamma_{21} = \gamma_{22} = 0$; $\gamma_1 > 0$	Pure direct proportional rule on the inflation rate
$\gamma_{21} = 0$; $\gamma_{22}, \gamma_1 > 0$	Taylor rule

To examine the properties of the various rules let us first substitute equation 4 into equation 1 to get an aggregate demand relationship between inflation, π, and output y. This gives:

$$y_t = -\frac{\beta_1}{(1+\beta_1\gamma_{22})}\left[(\gamma_1 - 1)\pi_t + \gamma_{21} p_t\right] + \frac{\theta}{(1+\beta_1\gamma_{22})}(w_t - p_t) + \frac{e_t}{(1+\beta_1\gamma_{22})} \tag{5}$$

Note that $p_t = p_{t-1} + \pi_t$

[5] We use these terms as substitutes for each other, as a velocity de-trended monetary aggregate will move in line with nominal GDP in the medium term, and as we are not assuming that the authorities wish to hit their target period by period, responses will be similar with either target.

Substituting this into 5 and differentiating with respect to π gives:

$$\frac{dy_t}{d\pi} = -\frac{\beta_1}{(1+\beta_1\gamma_{22})}\left[(\gamma_1 - 1) + \gamma_{21}\right] - \frac{\theta}{(1+\beta_1\gamma_{22})}$$

The slope of the aggregate demand curve therefore becomes a function of the parameters of the policy rule. Stability would require the slope of the AD curve to be negative, i.e. $dy/d\pi < 0$. This would imply that a positive inflationary shock will result in a fall in *y* below zero (i.e. real output will be below potential output) and this will tend to reduce inflation and stabilise the model. After simplifying, the stability condition becomes:

$$-\beta\left[(\gamma_1 - 1) + \gamma_{21}\right] - \theta < 0 \qquad (6)$$

This condition shows that the stronger the wealth effects the less important is the feedback coefficient on inflation. In the simple Taylor model there are no wealth effects and no direct feedback on prices, so we have $\gamma_{21} = \theta = 0$. Therefore stability requires that:

$$-\beta\left[\gamma_1 - 1\right] < 0$$

As Taylor points out, γ_1 must be greater than 1 for the stability condition to be satisfied. However it is interesting to look at the stability of the model under different policy rule assumptions and to examine how targeting nominal aggregates and including wealth effects change the results. First we will consider some alternative policy rules that are nested in this general framework and then look at how wealth, or real balance, effects change the results.

2.1 Alternative policy rules on the simple model.

A A pure inflation targeting rule

Let us assume that a policy rule where short-term interest rates respond directly to the deviation of inflation from its desired path, i.e. $\gamma_{21} = \gamma_{22} = 0$. Therefore we have a simple proportional rule on inflation given by:

$$i_t = \gamma_1 \pi_t$$

We are also assuming no wealth effects at this point (θ=0). Using the stability condition (6), we find that the same parameter restrictions apply as in the Taylor rule, i.e.γ_1 >1. Therefore in this model a pure inflation targeting regime requires a more than a one to one response of interest rates to an inflationary shock in order that the model is stable in response to shocks.

B. Nominal GDP targeting rule

With a nominal GDP targeting or money stock rule, the parameters γ_{21} and γ_{22} are equal and γ_1 = 0, (θ=0). The stability condition requires:

$$\gamma_{21} > 1$$

Therefore for stability with this rule, the coefficient on the nominal aggregate, hence on both the price level and real GDP, is greater than one.

C. A combined rule—A nominal GDP and inflation targeting rule

We then consider a combined policy rule of nominal GDP targeting (or money stock rule) and a direct inflation target. It appears from Duisenberg (1998) that the ECB has adopted this combination and we discuss is further in Barrell, Dury and Hurst (1999b). With a nominal GDP targeting rule, the parameters γ_{21} and γ_{22} are equal. The inflation targeting component of the rule requires that γ_1 >0. With the combined rule the stability condition is given by:

$$-\beta[(\gamma_1 - 1) + \gamma_{21}] < 0$$

which reduces to $\gamma_1 + \gamma_{21} > 1$, ($\theta$=0). It is interesting that with the combined rule the stability condition does not require the parameter on the inflation target, γ_1 , to be greater than 1, nor the feedback on the nominal aggregate to exceed 1. The stability condition requires that the sum of the coefficient on direct inflation and the coefficient on the price level be greater than one.

2.2. The inclusion of wealth effects

Restating the stability condition (6) derived from our general model with wealth effects, we have.

$$-\beta[(\gamma_1 - 1) + \gamma_{21}] - \theta < 0 \qquad (6)$$

Taylor has shown, and we have re-stated, that his simple rule in a world where there are no wealth or price level effects will be stabilising as long as the inflation feedback parameter is greater than one. We have so far assumed that $\theta = 0$ and so there are no financial wealth effects included in the aggregate demand schedule. This is the assumption that Taylor uses to derive his stability conditions. However, the body of empirical evidence suggests that it is likely that there will be other variables in the aggregate demand schedule that are affected by the price level. In our general framework it is easy to extend the Taylor model to include wealth effects by simply assuming that $\theta > 0$. The stability conditions for the different types of rules are now:

- Taylor Rule :

$$\gamma_1 > 1 - \frac{\theta}{\beta_1}$$

For stability the Taylor rule now implies that the response of output to real interest changes must be stronger than the real wealth effect in the aggregate demand schedule. Hence, it is not necessary for γ_1 to be greater than one for the model to display stable responses to shocks. We would in general assume that real wealth effects were weaker than real interest rate effects, and hence the feedback needs to remain positive. This caveat holds for all rules that include this term.

- Pure Inflation Target

The same condition as the Taylor Rule applies: $\gamma_1 > 1 - \frac{\theta}{\beta_1}$ again implying that γ_1 does not have to be greater than one for stability. For the class of model we think represent the world and analyse in this paper, a feedback of one on inflation in an inflation targeting regime should be unambiguously stabilising.[6]

- Nominal GDP targeting

$$\gamma_{21} > 1 - \frac{\theta}{\beta_1}$$

implying the coefficient on the price level target and the real GDP target does not have to be greater than one when wealth effects are present.

[6] A feedback parameter of unity on inflation should not be confused with a rule that targets the real interest rate in the long run. If a shock requires that the real interest rate falls in the long run, then a feedback of one on inflation in the short run will be contractionary, and hence inflation will fall, and interest rates will follow. They will have to fall enough to stabilise inflation on the baseline. The argument is no different from that when the feedback coefficient exceeds one.

- The Combined Rule: Nominal GDP and Inflation Targeting

$$\gamma_1 + \gamma_{21} > 1 - \frac{\theta}{\beta_1}$$

implying the sum of the inflation feedback coefficient and the price level feedback coefficient does not have to be greater one. If for instance the effect of real interest rates on aggregate demand were four times the size of the real balance effect, then we could have nominal feedback effects of, say 0.4, and an inflation feedback of 0.5, and the model and economy would display stable responses to shocks, as their sum exceeds 0.75, which is all that is required for stability.

We would argue that there is a wide class of rules that can be considered as both usable and stabilising when considering how to set monetary policy. All must satisfy the condition that they stabilise the price level in the long run, and hence that inflation is stable. The choice of parametrisation depends upon the welfare effects of differing rules, and these can be judged by looking at the effects of rules on the variability of output and inflation, for instance.

3. Stochastic simulation techniques

The basic procedure

There are a number of ways to evaluate the properties of models and the role of policy rules. Policy rules are designed to deal with shocks to the economy. Different policy rules can be evaluated in the context of a specific shock, such as the change in structural capital flows to East Asia, which we discuss in Barrell, Dury and Pain (1998). However, their ability to deal with repeated shocks is the most important context in which they can be evaluated. Rules have to be designed for an uncertain world, and techniques, such as stochastic simulations, have to be utilised in order to analyse the effects of rules on the variability (and potentially also the level) of variables of interest to policy makers. Within the framework of stochastic simulations, a variety of shocks are imposed on the model. These shocks are taken at random from a particular distribution and are repeatedly applied to the model. Hence the moments of the solution of the endogenous variables can be calculated and uncertainty investigated. Stochastic simulation can be either in respect to the error terms, coefficient estimates or both. In this paper we assume that the coefficient estimates are known with certainty and the stochastic shocks to the model are only applied to the error terms, much as in the rest of the economic literature. [7]

We use the boot strap method where the shocks are generated by repeatedly drawing random errors for individual time periods for all equations of the model, NiGEM. The historical shocks to the estimated equations (and to calibrated ones) can be described as residuals in a regression equation, and they can be described by an n equation by t time periods matrix of single equation residuals (SER). If the equations are an adequate description of the structure of the economies we observe over the period we draw shock from, then we have constructed a set of random structural shocks to those economies. from the matrix of single equation residuals (SER). The shocks drawn will have the same contemporaneous distribution as the empirical distribution of the SER, which is assumed to be normally distributed, $N(0,\sigma^2)$. In this way the historical correlations of the error terms is maintained across variables, but not through time. If, for example, investment shocks across Europe are highly positively correlated, the error terms will tend to be high together for these countries. There are a number of other methods for drawing the shocks which rely on specifying the variance-covariance matrix or generating pseudo-random shocks which are consistent with the historical residuals (see Ireland and Westaway 1990 for a description).

One of the main techniques used for generating shocks is the McCarthy algorithm (See McCarthy 1972). This approach uses the formula to generate a vector of shocks, S:

$$S = T^{0.5}\, rU$$

where S is the vector of random shocks, r is the 1 x T vector of random numbers with distribution $N(0,1)$ and U is the T x M matrix of disturbances from T observations and M structural equations. The properties of S tend to the true structural errors as T tends to infinity, giving an asymptotic estimate of the true covariance matrix. The method we are using takes the actual historical residuals, picked at random from the SER matrix and then applied as shocks to the model. In this way computational requirements before the model is solved are reduced considerably.

[7] Chapter 5 of Clements and Hendry (1998) contains a clear description of the technique used in this paper.

There are around 800 stochastic equations in NIGEM, 500 post recursive and 500 identity equations. Not all stochastic equations have been estimated over the same period because of data limitations, However, the period 1993Q1 to 1997Q4 is common to all stochastic equations and so is taken as the estimation period from which to draw the shocks. In general all equations have been tested for structural stability, and the parameters for this period represent the set expected to hold over the future[8]. Using this period yields 20 vectors of quarterly error terms which can be drawn at random in order to undertake the stochastic simulations.

All stochastic equations in the model are shocked at the same time, although we draw a distinction between equations for exchange rates and for other variables, and we highlight the importance of shocks to the exchange rate in our analysis. Each stochastic equation is shocked in the first period using a random drawing from its errors over the historical period and the model is then solved in forward-looking mode to calculate the expectations that the shock would generate. This can be thought of as being equivalent to a single deterministic simulation where a number of different variables are shocked. A second random drawing of error terms is then made and applied to each stochastic equation in the following period of the simulation run, and again the model is solved forward. This is repeated for all time periods being stochastically simulated and is known as a 'trial'. Each trial will consist of T *(time period for which we are stochastically simulating)* draws of X *(number of stochastic equations)* values. This can be done as many times as desired and each trial will yield an estimate of the endogenous variables for each time period. It is important to solve the model far enough into the future so that the results in a trial solution period are not affected by the terminal date. In this paper we stochastically shock the model over the first 5 years of our forecast baseline but each time a shock is applied, the model is solved forward to 2017q1. For a 5 year solution period, each trial consists of 20 simulations, therefore the total number of simulations undertaken was 20 times the number of trials for each policy regime. It should be noted that we also apply the same shocks to each policy regime in order that a comparison between rules can be made with relatively small set of trials. Seeding the shocks in this way is useful as

[8] We have also de-meaned the shocks, as is common in this literature. A theoretical basis for this approach can be found in Clements and Hendry (1998), chapter 8, where they discuss a theory of intercept corrections.

differences in shocks will produce different results that cannot be ascribed to different policy regimes.

This paper is concerned with the variability of endogenous time series such as output and inflation and in order to present the results in a condensed form we concentrate on the Root Mean Squared Deviation (RMSD) of variables from their baseline path as in Bryant *et al* (1993). For level variables such as output and consumption the mean squared deviation for period *t* is calculated:

$$\tilde{\sigma}^2_{it} = \frac{1}{J}\sum_{j=1}^{J}\left[\frac{\left(y^j_{it} - y^B_{it}\right)}{y^B_{it}}\right]^2 \qquad (3)$$

Where $\tilde{\sigma}^2_{it}$ denotes the estimated variance of the variable *i* in period *t*, y^j_{it} is the value of the *jth* trial of variable *i* in period *t*, y^B_{it} is the value of variable *i* on the base in period *t*, and *J* is the number of trials taken. This will give a time series of estimated variances for each variable. We then take a simple average of this series over *N* time periods and take the square root to give a simple summary statistic to help assess the performance of the policy rules over the whole time period. The summary statistic given in the following tables are the *RMS*%*D*s, i.e.

$$RMS\%D(y_i) = \sqrt{\left(\frac{1}{N}\right)\sum_{t=1}^{N}\left\{\frac{1}{J}\sum_{j=1}^{J}\left[\frac{\left(y^j_{it} - y^B_{it}\right)}{y^B_{it}}\right]^2\right\}} \qquad (4)$$

For variables such as interest rates and the inflation rate, absolute deviations are measured in percentage points, i.e. the RMSD for the interest rate, *r*, would be:

$$RMSD(r) = \sqrt{\left(\frac{1}{N}\right)\sum_{t=1}^{N}\left\{\frac{1}{J}\sum_{j=1}^{J}\left(r^j_t - r^B_t\right)^2\right\}} \qquad (5)$$

where r^j_t is the value of the interest rate for trial *j* in period *t* and rB_t is the value of the interest rate on the base in period *t*.

Shocking the Exchange rate

In this paper we include shocks to exchange rates. This is not standard practice in these exercises (See Fair (1998)). These shocks have been excluded in the previous literature as exchange rates can be interpreted as policy reaction functions in the model. In our simulations we assume that exchange rate markets are forward looking and follow the arbitrage path with no risk premia and ‘jump’ when there is news. Hence they are calibrated, structural, not policy equations and have ‘errors’ on them, much as estimated equations do. An anticipated and sustained fall in interest rates in, say, Japan, will cause the Yen/dollar rate to jump in the first period[9]. The size of jumps depends on the effects on interest rates that are anticipated for the future, and hence policy rules affect financial markets. However, any exchange rate uncertainty must be taken account of in the model and we do this by including shocks to the exchange rate in the stochastic simulations.

The construction of historical shocks to sterling is clear, as the bilateral rate against the dollar existed in the past, as did the rates for Japan, Canada, Sweden and so on. However, we are simulating the model with an exchange rate equation for the Euro, a currency that did not exist in the past. Moving from the a regime where individual Euro area countries have their own exchange rates to one where there is single exchange rate for EMU members introduces some uncertainties as to what shocks to apply to the Euro. We could construct a set of shocks to the Euro that was the weighted average of shocks to the individual currencies over the past. However, this would not necessarily be the correct strategy, as EMU has been set up, and hence shocks across bilateral rates within the Union are no longer possible. A better strategy would be to apply the shocks that occurred to the core of EMU (Germany, Belgium, Netherlands, France (and Austria)) over the 1993 to 1997 period, and we adopt this for the Euro. However, this means that we are applying a subset of historical shocks, especially to the European Monetary Union and to the US, as in the latter case shocks to the exchange rate are the result of shocks to all US dollar bilateral rates.

Stochastic experiments on NiGEM

This paper seeks to use the method of stochastic simulations to evaluate the different types of monetary policy rules discussed in Section 1 on a large econometric open economy model. We focus on using the small model results by applying different parameterisations of the rules to the model to evaluate their performance and the implication of the results for interest rate determination at the ECB. The maintenance of medium term price stability in the euro area is of prime concern to the ECB, but we

[9] The forward solution utilises a solution algorithm based on and Hall (1985), and the terminal conditions on all forward looking variables involve a rate of growth condition.

will also look at the degree to which output, inflation and some other key economic variables fluctuate around the forecast baseline or target path. We will first look at the variability of individual time series across the different policy rules. A policy that reduces the variability of these economic series will be judged to be more effective.

The 5 policy rules considered can all be derived from the general policy rule, equation (3), restated here:

$$i_t = \gamma_1 \pi_t + \gamma_{21} p_t + \gamma_{22} y_t \qquad (3)$$

Rule 1: Nominal GDP targeting, or money targeting, where $\gamma_1 = 0$ and $\gamma_{21} = \gamma_{22} < 1$

Rule 2: A combined nominal GDP, or money stock, and inflation targeting rule where $\gamma_{21} = \gamma_{22} = 0.5$.

Rule 3: A pure inflation targeting rule where $\gamma_1 = 1$; $\gamma_{21} = \gamma_{22} = 0$

Rule 4: A Pure inflation targeting rule where $\gamma_1 = 1.5$; $\gamma_{21} = \gamma_{22} = 0$

Rule 5: A Taylor rule where $\gamma_1 = 1$; $\gamma_{21} = 0$, $\gamma_{22} = 0.5$

Rule		**Type of rule**	**Parameter values**		
			γ_1	γ_{21}	γ_{22}
1	**NOM**	Nominal GDP targeting rule	0	0.5	0.5
2	**CR**	Combined nominal GDP and inflation targeting rule	1	0.5	0.5
3	**INFT1**	Inflation targeting rule	1	0	0
4	**INFT1.5**	Inflation targeting rule	1.5	0	0
5	**TR**	Taylor rule	1	0	0.5

In each case we look at we are targeting the current rate of inflation and the current level of a nominal magnitude. Rules 1, 2, 3 and 5 are fully nested. Rule 2 adds an inflation target with a coefficient of 1, Rule 3 keeps the inflation target with the same coefficient but takes away the nominal aggregate and rule 5 keeps the same coefficient on real output but includes an inflation target with a coefficient of 1. Rule 3 and 4 are directly comparable in that the coefficient on the inflation target is increased from 1 to 1.5. Rule 3 and Rule 5 are nested together, as the same coefficient of 1 is used for the inflation target but Rule 5 adds a feedback on real GDP of 0.5.

The performance of the rules will give some insight into whether the small model properties hold on a large model. A single monetary policy is applied to the euro wide area in that interest rates do not react to individual country developments but to EMU wide aggregates. The United Kingdom is not in EMU and so follows its own interest rate reaction function and the results reported for the UK reflect the effect of changing coefficients in the UK monetary policy rule. Denmark is not in EMU but has declared that it will follow EMU monetary policy and so the results for Denmark come from the effects of changing the monetary policy rule in EMU. Denmark is also used in calculating the EMU aggregates. Sweden is also out of EMU and its policy rule is left unchanged across the stochastic simulations.

We first report the results of the stochastic simulations across the 5 classes of rules where we include shocks to the exchange rate. In Section 6 we then go on to present results for each rule where shocks to the exchange rate are excluded in the simulations.

4. The model

NiGEM is an estimated model which uses a 'New-Keynesian' framework in that agents are presumed to be forward-looking but nominal rigidities slow the process of adjustment to external events. The theoretical structure and the relevant simulation properties of NiGEM are described in Barell and Sefton (1997) and NIESR (1998). The model contains estimated structures for the whole world, with the major economies having 60-90 equation models with around 20 key behavioural equations. It has complete demand and supply sides, and there is an extensive monetary and financial sector. All countries in the OECD, including South Korea, are modelled separately, as is China. There are regional blocks for East Asia, Latin America, Africa, Miscellaneous Developing countries, and Developing Europe.

Short term interest rate changes should have an impact on long term interest rates, equity prices and exchange rates. NiGEM is most commonly used for scenario analysis under the assumption that expectations in financial markets are rational, in that they are fully consistent with the outcomes of an event given the reactions of policy makers. Hence financial variables can 'jump' in the first period of a scenario. These assumptions are adopted here. The size of the jump depends upon the interest differential that opens up. The anticipation of lower short-term rates will cause long-term rates to fall by the forward convolution of short term interest rate changes. Equity prices will rise when interest rates are anticipated to fall. Hence any shock that is expected to slow down activity will have its effects partly offset by the automatic shock absorbers in the monetary system. The size of the effect will depend upon the monetary rules used by the authorities.

Forward looking long rates have to look T periods forward

1) $(1+LR_t) = \Pi_{j=1,\,T}\,(1+SR_{t+j})^T$

We assume that exchange rate markets are forward looking, and exchange rates 'jump' when there is news. An anticipated and sustained fall in interest rates in Japan, say, will cause the Yen/dollar rate to jump in the first period[10]. The size of jumps depends on the effects on interest rates that are anticipated for the future, and hence policy rules affect financial markets.

Forward looking exchange rates have to look one period forward

2) $RX_t = RX_{t+1}\,(1+SRH_t)/(1+SRF_t)$

In our analyses labour markets are assumed to embody rational expectations, at least where we have evidence that bargainers use forward expectations, much as in Anderton and Barrell (1995). Contracts are overlapping, and there are forward and backward elements in the wage equations, and they display dynamic homogeneity in (almost) all cases. The speed of adjustment of wages and prices is estimated to vary between countries, and depends upon institutions in the labour and product markets. In general the US and the UK react more quickly to excess capacity than do the more regulated continental European markets, and our results reflect these differences, as well as differences in the underlying structure of wealth and consumption. Further details of the model are available on request.

Wage equations can be written as

3) $\Delta W/P = \lambda[(W/P)_{t-1} - PROD] + \beta\, U_t + \delta\,\Delta P^e + (1-\delta)\Delta P_{t-1}$ etc

Where W is the nominal wage, P is the price level, PROD is a long term measure of productivity and U is unemployment.

However consumers are not assumed to look forward when making their decisions today, but rather they react to current and past incomes and net financial wealth. This does not mean that future events do not affect their behaviour, as forward looking long rates and equity prices affect debt interest payments and asset values now.

[10] The forward solution utilises a solution algorithm based on and Hall (1985), and the terminal conditions on all forward looking variables involve a rate of growth condition.

Hence financial markets bring forward the consequences of future events, acting as 'agents' for more passive households. Changing to forward looking household behaviour does not affect our results in any significant way. The model is large, but with a common (estimated and calibrated) underlying structure across all economies. The whole model is solved simultaneously in forward mode.

The forward-looking nature of these markets is central to model properties, and especially in shocks such as that in East Asia and Latin America. The model is solved in a sequence of loops, utilising the sparse structure of forward links in time. A shock is applied, and the model is run over the full time period, and interest rates are allowed to be endogenous. A fall in demand will, for instance, cut interest rates. Forward looking agents know this, and we emulate this knowledge by running the model a second time, but calculating the long rate as the forward convolution of short rates in the previous run. The model is continually run forward and starts again, and this is repeated until a solution is found where rates of growth of expected variables are constant at the terminal date, and all equations are converged. In particular, long-term interest rates are forward convolutions, and this period's exchange rate depends on that next period adjusted through the arbitrage condition but short term interest rate differentials.

Policy rules are important in 'closing the model' and we have them for fiscal and monetary policy. We assume budget deficits are kept within bounds in the longer term, and taxes rise to do this. Governments are assumed to slowly adjust tax rates to offset any changes in their deficit from its target trajectory, and hence they remain solvent in the simulation (See Barrell and Sefton (1997)). This simple feedback rule is important in ensuring the long run stability of the model. Indeed, as Blanchard, 1986, shows, without a solvency rule (or a no Ponzi games assumption) there is no solution to a forward-looking model. We can describe the simple fiscal rule as

$$Tax_t = Tax_{t-1} + \phi \, [GBRT - GBR]$$

Where Tax is the direct tax rate, GBR and GBRT are the government surplus target and actual surplus, and ϕ is the feedback parameter designed to remove an excess deficit in less that five years.

5 Results

There are a number of potential patterns of results that we might observe. In this section we show that when we include a direct inflation target into the policy rule we find that output variability is increased and inflation variability is reduced compared to a simple nominal targeting rule for the UK. For the US and Euroland both output and inflation variability are reduced under the combined rule compared to the nominla aggregate rule. Indeed, the more flexible US economy prefers a pure inflation target, whereas for the Euro area including some nominal aggregate in the rule is preferred. Our results indicate that the inclusion of a real GDP target (with no direct price level target as in a nominal aggregate) into the policy rule rule for the ECB is unproductive as inflation variability increases substantially more than the fall in output variability. We also show, as one would expect that for the US, as the feedback coefficient on the pure inflation targeting rule is increased the variability of output and inflation falls[11].

The tables below give summary statistics from the stochastic simulations undertaken on NiGEM in terms of RMSD or RMS%D under the different policy rules and they also indicate the statistical significance between variances[12]. Tables 1,2 and 3 present the RMSDs for output, inflation and the price level respectively. Each table also contains an index value for Rule 2, 3, 4 and 5 (Rule 1 = 100). Individual country values are given as well as the EMU aggregates, the UK, and the US. Results are also available for Canada, Japan and individually for all other OECD members, and the non-OECD blocks on the model. They are omitted for reasons of space, and are discussed elsewhere, especially as the results for Japan throw significant light on the problems associated with operating an economy so near a potential liquidity trap on interest rates.

Our first set of results have been constructed under the assumption that exchange rates are shocked. This is uncommon in the literature as discussed earlier. However, in Section 6 we analyse the same set of rules but we remove exchange rate uncertainty.

[11] This maybe the point where inflation and output are both miniminsed and increasing the feedback coefficient further introduces instabilities. Further stochastic simulations will be presented in the final version of the paper to investigate this.

[12] The F-ratio to be tested is formed by taking the larger variance (not the RMSD as shown in the tables) divided by the smaller variance with the degrees of freedom associated with the number of sample points. This will give a value greater than unity. We may say that if variances differ by more than 6 to 7 percent then they are significantly different from each other. Only the significance of variances are shown for the UK, US and EL and only for output and inflation.

Table 1: Variability of Output; Index value for RMS%D of Rule 2 , Rule 3 and Rule 4 (Rule 1 = 100)[13]

	RULE 1	RULE 2	RULE 3	RULE 4	RULE 5		RULE 1 = 100			
							RULE 2	RULE 3	RULE 4	RULE 5
GE	3.17	3.10	3.29	3.28	3.12		98	104^{∇}	103^{∇}	98
FR	1.25	1.19	1.36	1.28	1.26		95*	109^{∇}	$103^{\oplus\nabla}$	101
SP	1.89	1.87	2.07	1.98	1.85		99	110^{∇}	$105^{\oplus\nabla}$	98
IT	1.12	1.11	1.20	1.18	1.13		99	107^{∇}	105^{∇}	101
NL	2.21	2.18	2.25	2.24	2.23		99	102^{∇}	101	101
BG	1.67	1.67	1.72	1.73	1.69		100	102	103	101
PT	2.35	2.33	2.41	2.39	2.36		99	102^{∇}	101	100
IR	3.06	3.07	3.13	3.14	3.04		100	102	103	99
FN	1.13	1.06	1.22	1.15	1.16		94*	108^{∇}	$102^{\oplus\nabla}$	102
OE	3.08	3.07	3.15	3.13	3.05		100	102	102	99
UK	0.63	0.67	0.70	0.76	0.64		105*	110^{∇}	$119^{\oplus}$	101
US	0.81	0.76	0.75	0.74	0.76		94*	92	91	93
EL	1.76	1.73	1.85	1.82	1.75		98	105^{∇}	103	99

Rule 1= NOM : **Rule 2** = CR : **Rule 3** = INFT1: **Rule 4** = INFT1.5: **Rule 5** = TR.

Output variability

Rule 1 → 2

- In general it is not clear what the effects of increasing the feedback on inflation should be on output. Introducing the inflation feedback into the nominal rule helps stabilise output for the US and Euroland. The fall is significant for the US with output volatility falling by 6%.
- The majority of EMU member states benefit from reduced output variability under the combined rule compared with a nominal targeting rule (although this is only significant for France and Finland). The variability for Euroland output falls although it is not significant. The UK sees a rise in output variability of 5%.

Rule 2 → 3

- The US experiences a further fall in output variability as the regime moves to inflation targeting alone, but the UK sees a rise in output variability.

[13] * indicates variance is significantly different to the variance under Rule 1
∇ indicates variance is significantly different to the variance under Rule2
⊕ indicates variance is significantly different to the variance under rule3 (only the comparison of Rule 4 to Rule 3 is shown)
indicates variance is significantly different to the variance under rule3 (only the comparison of Rule 5 to Rule 3 is shown)

- A pure inflation targeting rule increases output variability for all European countries compared to the combined rule. The increase is significant for all countries with the exception of Belgium, Ireland and Austria. Euroland output variability also increases significantly as the nominal aggregate is removed.

Rule 3 → 4

- All EMU member states experience a fall in output variability as the inflation coefficient is increased from 1 to 1.5, (except for Belgium and Ireland who experience a slight rise, although this is insignificant, and Austria who sees no change in output variability). However, output variability is higher than under either the nominal or the combined rule. The difference from the unit coefficient rule is only significant for France, Spain and Finland. The Euro area as a whole also sees a fall of 2% in output variability but this is not significant.
- The UK experiences a large increase in output variability and the US a slight fall.

Rule 3 → 5

- Including a target on real GDP helps to reduce output variability for a number of EMU member countries, significantly. For Euroland as a whole output variability is reduced by 6% which is significant. The UK sees a fall of around 9% and Euro area sees a fall of 6%.

Table 2: Variability of Inflation; Index value for RMSD of Rule 2, Rule 3 and Rule 4 (Rule 1 = 100)[14]

	RULE 1	RULE 2	RULE 3	RULE 4	RULE 5		RULE 1 = 100			
							RULE 2	RULE 3	RULE 4	RULE 5
GE	1.11	1.08	1.16	1.14	1.12		97	105$^{\nabla}$	103$^{\nabla}$	101
FR	0.59	0.56	0.66	0.64	0.65		95*	111$^{\nabla}$	108$^{\oplus\nabla}$	110
SP	0.97	0.95	1.04	1.00	0.97		97	108$^{\nabla}$	103$^{\oplus\nabla}$	100
IT	0.98	0.98	1.06	1.03	1.04		100	109$^{\nabla}$	105$^{\oplus\nabla}$	106
NL	0.97	0.95	1.00	0.99	1.00		98	104$^{\nabla}$	103$^{\nabla}$	104
BG	1.91	1.89	1.91	1.92	1.91		99	100	101	100
PT	1.61	1.64	1.61	1.62	1.61		102	100	101	100
IR	1.01	0.97	1.05	0.97	1.05		96*	104$^{\nabla}$	96$^{\oplus}$	103
FN	0.61	0.61	0.67	0.65	0.66		100	109$^{\nabla}$	106$^{\nabla}$	109
OE	1.73	1.72	1.77	1.74	1.76		100	102	101	102
UK	0.69	0.68	0.67	0.67	0.66		98	98	98	96
US	1.07	0.95	1.01	0.93	1.06		89*	94$^{\nabla}$	87$^{\oplus}$	99
EL	0.59	0.56	0.68	0.63	0.64		94*	115$^{\nabla}$	106$^{\oplus}$	108

Rule 1= NOM : **Rule 2** = CR : **Rule 3** = INFT1: **Rule 4** = INFT1.5: **Rule 5** = TR.

[14] see footnote 13

Inflation variability

Rule 1 → 2

- Most of EMU member countries see a fall in inflation variability under the combined rule compared to the nominal aggregate rule. Out of the 4 largest economies it is only Italian inflation variability that does not fall.
- The UK sees a fall of around 2% but the US inflation variability is reduced by around 11%. The Euro area as a whole sees a fall of 6%.

Rule 2 → 3

- Moving to a pure inflation targeting rule with a feedback coefficient of 1 raises inflation variability for all countries (with the exception of Portugal), and for virtually all countries this is significant. For EMU as a whole there is a rise in inflation variability of over 20% as compared to the combined rule[15].
- Moving to a pure inflation targeting rule leaves UK inflation variability the same but increases inflation variability for the US.

Rule 3 → 4

- All EMU countries see a fall in inflation variability when the feedback coefficient on inflation is increased in the pure inflation targeting case (with the exception of Belgium and Portugal). For EMU as a whole the fall in inflation variability between these two rules is significant.
- Increasing the inflation coefficient from 1 to 1.5 reduces the inflation variability for the US significantly but leaves it unchanged for the UK.

Rule 3 → 5

- Generally, the results for the member states show a fall in inflation variability when the real GDP target is introduced to a pure inflation targeting rule. The fall is only significant for Germany and Spain. For Euroland as a whole inflation variability falls by 7% which is significant.

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[15] It is interesting that for Euroland as a whole, inflation variability falls by more than in any individual country. This is due to the changes in the cross-country covariance structure of Euroland inflation. We discuss this issue in a related paper Barrell, Dury and Hurst (2000).

- The UK sees a fall in inflation variability as the real GDP target is included in the rule. However the US sees a rise of 5%.

Table 3: Variability of Price level; Index value for RMS%D of Rule 2, Rule 3 and Rule 4 (Rule 1 = 100)[16]

	RULE 1	**RULE 2**	**RULE 3**	**RULE 4**	**RULE 5**		**RULE 1 = 100**			
							RULE 2	**RULE 3**	**RULE 4**	**RULE 5**
GE	1.37	1.13	1.63	1.40	1.49		82*	119$^{\nabla}$	102$^{\oplus}$	109
FR	0.70	0.65	0.90	0.82	0.85		92*	129$^{\nabla}$	117$^{\oplus}$	122
SP	1.84	1.73	1.97	1.96	1.84		94*	107$^{\nabla}$	107	100
IT	0.93	0.79	1.30	1.17	1.16		85*	139$^{\nabla}$	125$^{\oplus}$	124
NL	1.16	1.01	1.30	1.23	1.30		87*	112$^{\nabla}$	106$^{\oplus}$	112
BG	0.83	0.74	0.98	0.91	0.94		90*	118$^{\nabla}$	110$^{\oplus}$	114
PT	0.96	0.89	1.02	1.04	1.03		93*	107$^{\nabla}$	109	108
IR	1.23	1.16	1.47	1.30	1.37		95*	120$^{\nabla}$	105$^{\oplus}$	111
FN	0.69	0.64	0.92	0.80	0.88		94*	134$^{\nabla}$	116$^{\oplus}$	128
OE	1.35	1.24	1.48	1.33	1.41		92*	109$^{\nabla}$	98$^{\oplus}$	104
UK	0.49	0.40	0.46	0.41	0.44		80*	93$^{\nabla}$	84$^{\oplus}$	88
US	1.28	1.05	1.39	1.28	1.56		82*	108$^{\nabla}$	99$^{\oplus}$	121
EL	0.97	0.79	1.26	1.11	1.15		82*	131$^{\nabla}$	115$^{\oplus}$	119

Rule 1= NOM : **Rule 2** = CR : **Rule 3** = INFT1: **Rule 4** = INFT1.5: **Rule 5** = TR.

Rule 1 $\rightarrow$ 2

- All countries experience a significant fall in the variability of the price level, particularly the UK which sees a fall of 20%. Price level variability in the US and Euorland falls by 18%.

Rule 2 $\rightarrow$ 3

- Moving to a pure inflation target results in a significant rise for all countries. Only in the UK does price level variability still remain below that under Rule 1(NOM). Euroland sees a very large rise of around 50%.

Rule 3 $\rightarrow$ 4

- As the inflation target coefficient is increased to 1.5 price level variability falls significantly for all countries except Spain and Portugal. For the US and the UK price level variability falls below that of Rule 1 (NOM).

Rule 3 $\rightarrow$ 5

[16] See footnote 13

- Under the Taylor rule the variability of the price level falls for virtually everyone except the US compared to a pure inflation targeting rule. The UK and Euroland see a fall of 5% and 12% respectively. However, the US sees a rise of 13%.

The combined rule is clearly the preferred rule for Euroland as output, inflation and price level variability are minimised under this rule. In terms of output and inflation, the US would prefer an inflation targeting rule with a coefficient of 1.5. The results for the UK are mixed. The preferred rule in terms of output stabilisation is the nominal aggregate targeting rule, whereas inflation variability is minimised under the Taylor rule with a feedback coefficient of 1 on inflation. However, if both output and inflation were of concern to the Bank of England, then the UK may prefer a Taylor rule with the same coefficient on inflation, although this would depend on the importance placed on output variability. If the concern of the central bank was to stabilise the price level then Euroland, UK and the US would all prefer a combined nominal aggregate and inflation targeting rule.

7 Shocking the exchange rate.

In this section we show that shocking the exchange rate can have important implications in terms of the choice of policy rule and that the arguments presented in the previous sections are strengthened. We present results for all rules when the exchange rates are not shocked and compare the results to the previous results under the same rule when exchange rates are shocked.

For the experiments undertaken above, the shocks drawn from the past include shocks for the exchange rates. The construction of historical shocks to sterling is clear, as the bilateral rate against the dollar existed in the past, as did the rates for Japan, Canada Sweden and so on. However, we are simulating the model with an exchange rate equation for the Euro, a currency that did not exist in the past. Moving from the a regime where individual Euro area countries have their own exchange rates to one where there is single exchange rate for EMU members, introduces some uncertainties as to what shocks to apply to the Euro and indeed whether they should be applied at all. This is the approach taken by Fair (1998).

Table 4 compares the results for output, inflation and the price level with that when exchange rates are shocked. An index value is given for results when exchange rates are shocked compared to when they are not shocked. Therefore a value greater than 100 indicates that shocking the exchange rate results in increased variability. Where shocking the exchange rate results in lower variability the box is shaded.

Table 4: Index for output variabilities when exchange rates are shocked. Not shocked = 100.

	RULE 1	RULE 2	RULE 3	RULE 4	RULE 5
Output					
UK	96	98	99	103	102
US	97	96	98	99	101
EL	101	99	102	101	102
Inflation					
UK	120	115	123	121	116
US	92	94	102	98	103
EL	99	97	102	98	103
Price level					
UK	91	86	96	94	95
US	95	91	98	105	102
EL	101	90	105	100	104

Rule 1= NOM : **Rule 2** = CR : **Rule 3** = INFT1: **Rule 4** = INFT1.5: **Rule 5** = TR.

Shocking the exchange rate results in a fall in output variability for the UK and the US over most of the rules, although Euroland experiences hardly any change. Exchange rate shocks have a pronounced effect on the variability of UK inflation, with the variability rising to over 20% under the inflation targeting rule. For the US and Euroland the difference in variability is very small compared to the results for the UK. This indicates that for the smaller more open economies it matters whether we shock the exchange rate or not but the large closed economies the differences are not as large. The UK benefits from a fall in the price level variability over every rule and the US benefits under all but the Taylor rule. Euroland only sees the benefit under the combined rule. To see if excluding exchange rate shocks changes the preferred country rules the following table presents the rule for each country which minimises some loss function both with and without exchange rate shocks.

It is likely that policy makers will not focus solely on the variability of one variable and will be concerned with the variability of both output and inflation rates and so both will appear in their loss functions. They may also believe that other non-price variables are an indication of economic welfare. Large frequent fluctuations in the interest rate may be regarded as imposing costs on the economy and so may be included in the loss function and this may change the conclusions about the relative performance of the policy rules. However, for illustration we concentrate on the output, inflation and the price level. The outcome of any loss function will depend on the relative weights on its arguments. Where the loss function has more than one argument, then equal weight is placed on each. We compare the results for when exchange rates are shocked and when they are not.

Table 5: Preferred rule for some illustrative welfare loss functions.

		Exchange rates shocked	Exchange rates NOT shocked
		Preferred Rule	
UK			
Output		1	5
Inflation		5	3
Price level		2	4
Output and inflation		5	5
Output, inflation and Price level		2	2
US			
Output		4	4
Inflation		4	4
Price level		2	2
Output and inflation		4	4
Output, inflation and Price level		2	4
Euroland			
Output		2	5
Inflation		2	2
Price level		2	2
Output and inflation		2	2
Output, inflation and Price level		2	2

The table shows that shocking the exchange rate has more of an impact on the preferred rule for the small open economy, the UK, than it does for the larger more closed economies, Euroland and the US, who keep maintain the same preferred rule except in one case each. The reason for the UK changing its preferred rule is that shocking the exchange rate doesn’t increase inflation variability to the same extent *across* the rules. Therefore we see a change in the relationship between the rules in terms of inflation variability whereas this is not true to such an extent for the US and Euroland. The table also shows that the

8 Conclusions

In this paper we have undertaken an analysis of different monetary policy regimes. We used the National Institutes Global Econometric Model, NiGEM to evaluate the performance of different rules in terms of stabilising economic variables. We did this by applying stochastic simulations techniques, that is repeatedly applying shocks to the model, and then calculating the subsequent variances of economic variables. This then allows a comparison to be made between the different rules and judgements to be made as to their performance in terms of economic stability. A rule is judged to be superior if it reduces the variability of certain economic variables.

The US favours a simple pure inflation targeting rule with a coefficient greater than 1 to minimise inflation and output variability whereas the Euro area as a whole would favour a combined nominal aggregate and inflation targeting rule. Also our results indicate that the inclusion of a real GDP target into the rule is unproductive for Euroland as a whole as inflation variability increases substantially more than the fall in output variability whereas for the UK a Taylor rule minimises both output and inflation variability.

We have also discussed problems in shocking the exchange rates on the model and have shown that shocking the exchange rates can matter for a small open economy such as the UK.

Our simulations suggest that some form of direct inflation target is beneficial in terms of reducing output and inflation variability. There are a number of avenues to move forward along in this area, including investigating inflation forecast targeting and extending the analysis of Taylor rules in Barrell Dury and Hurst (1999a). Clearly, different rules fit different economies, and the ‘best’ rule will depend upon the character of the economy in question and the objectives of the authorities.

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Annex

Price level determinancy

It is easy to show that the Taylor rule on the simple reduced model (i.e. no wealth effects) can leave the price level indeterminate in the sense that it depends upon the parameters of the model and not just on a target nominal variable.

Substituting (5) into (2) we get:

$$\pi_t = \left[1 - \beta_2 \frac{\alpha_2}{\alpha_1}\right]\pi_{t-1} - \beta_2\left[\frac{\beta_1\gamma_{21} + \vartheta}{\alpha_1}\right]p_{t-1} + \frac{\beta_2\theta}{\alpha_1}w_{t-1} + \frac{\beta_2}{\alpha_1}e_{1t-1} + e_{2t}$$

where $\alpha_1 = [1 + \gamma_{22}\beta_1]$ and $\alpha_2 = \beta_1[\gamma_1 - 1]$. Simplifying gives:

$$\pi_t = \lambda_1\pi_{t-1} - \lambda_2 p_{t-1} + \lambda_3 w_{t-1} + \lambda_4 e_{1t-1} + e_{2t} \qquad (7)$$

where:

$$\lambda_1 = \left[1 - \beta_2 \frac{\alpha_2}{\alpha_1}\right],\ \lambda_2 = \beta_2\left[\frac{\beta_1\gamma_2 + \theta}{\alpha_1}\right],\ \lambda_3 = \frac{\beta_1\theta}{\alpha_1},\ \lambda_4 = \frac{\beta_2}{\alpha_1}$$

In the Taylor model with no wealth effects the second and third term of (7) drop out and we can show that for inflation to be a stationary series (i.e. I(0)) $\lambda_1 < 1$), the parameter on the inflation target in the policy rule to be greater than one, i.e. $\gamma_1 > 1$. The is the same result as the earlier stability condition and also applies to the pure inflation targeting policy rule. We can use partial sums to show that the price level is a random walk that depends upon the parameters of the rule.

The price level at period *j* is the partial sum from *t*=0 to *t*=*j*. In the long run with $\theta = 0$ and $\gamma_2 = 0$ we have:

$$p_j = \sum_{t=o}^{j} \left[\frac{\beta_2 e_{1_{t-1}}}{\alpha_1 (1-\lambda_1)} + \frac{e_{2t}}{(1-\lambda_1)} \right] \tag{8}$$

With the Taylor rule (and the pure inflation targeting rule) the inflation rate is stable i.e converges onto its equilibrium or target level but the price level is a random walk where transitions depend upon the model coefficients and the parameters of the feedback rules. There is no force driving the price level back onto its baseline trajectory path after shocks and so the price level is therefore indeterminate with this policy rule. Including wealth and/or changing the policy rule to a combined nominal GDP and inflation targeting rule, we can see that nominal wealth and/or the price level will appear in the inflation and aggregate demand schedule and will remove the price level indeterminancy.