Choosing the Regime in an Uncertain World, The UK and Monetary Union[1]

Ray Barrell[2] Ian Hurst[3] and Tatiana Kirsanova[4]

NIESR

January 12th 2003

.

Abstract: The UK has to take a decision on EMU membership at some point, and the costs and benefits have to be evaluated. Different policy frameworks result in differing outcomes for the means and variances of economic variables such as inflation, output, and nominal and real exchange rates and interest rates. Changing the level of uncertainty in the economy may change the equilibrium level of output and investment. Hence membership of EMU has to be evaluated in the light of its impact on the volatility of target variables and on the impact of volatility on the level of output and welfare. In this paper we discuss a theoretical framework within which we can discuss these issues, and we undertake stochastic simulation on a large, New Keynesian model including all the European economies in order to evaluate the effects of membership on the level and volatility of output. Our experiments suggest that membership of EMU would reduce volatility and as a result raise the sustainable level of output and employment in the UK.

JEL Classification F3 and F4, E47

Keywords EMU, Exchange Rate Regimes, Uncertainty and Investment, UK membership.

Approximately 7800 words

Email : Rbarrell@niesr.ac.uk

---

[1] This research was financed by the ESRC, project L138250122.

[2] Corresponding author. Senior Research Fellow, NIESR,

[3] Research Fellow, NIESR

[4] Research Officer NIESR and Exeter University

Introduction

Macroeconomic policy has an impact on the economy both in the short term and over the longer horizon that allows us to study the determinants of sustainable output and the rate of growth. Levels of investment, the capital stock and of output depend on the volatility of output, inflation, interest rates and exchange rates, and it is important that we understand these links. In turn it is clear that the volatility of output, inflation and the exchange rate depend upon the choice of monetary and fiscal regimes and on the structure of feedback rules within the policy framework. In particular in this paper we consider the implications for output and growth of the UK being inside and outside EMU. Membership of EMU could create the conditions for a more stable economy with more investment, a larger capital stock and higher output and labour productivity. If this is the case then the loss of a degree of policy independence may be a price worth paying for membership.

The choice of policy framework, and hence of the exchange rate regime, can be analysed in a number of ways both with theoretical models and with applied analyses. Theoretical models can answer many questions, but some issues have to be addressed using a reasonable description of the economies of the European Union. We use NiGEM, a large rational expectations model of all the OECD economies to evaluate the effects of joining EMU on the UK. Stochastic trials are undertaken with the UK outside and inside EMU under different rules. We argue that the policy framework affects the degree of uncertainty in the economy, and hence changes equilibrium investment and output in the economy and hence in our model.

In this paper we first discuss the Chancellor’s Five Tests, and conclude that they require that it be clear that EMU membership will raise the level of output. We then discuss some theoretical work on uncertainty and the macro economy. In the third section we look at the model that we use, the policy frameworks implemented on the model and the techniques we use to evaluate policy rules. We also discuss the basis on which choices of policy regimes can be made, and in particular we address the effects of regime choice on volatility and on the level of output.

The Chancellor’s 5 tests

The UK government has made it clear that it thinks that membership of European Monetary Union (EMU) would probably be beneficial, but that an assessment of those benefits will be made before a decision is taken[5]. The evaluation of the case for membership will be taken in the light of the Chancellor’s Five Tests. Any assessment of the case for membership needs to look at the balance of advantages and disadvantages, both in the short term and over a longer horizon. The Five Economic Tests will define whether a clear and unambiguous case can be made. They are:

- sustainable convergence between Britain and the economies of a single currency;
- whether there is sufficient flexibility to cope with economic change;
- the effect on investment;
- the impact on our financial services industry;
- whether it is good for employment.

[5] The Government's policy on membership of the single currency was set out by the Chancellor of the Exchequer in October 1997, and restated by the Prime Minister in February 1999. In principle, the Government is in favour of UK membership; in practice, the economic conditions must be right.

The obvious gains from membership involve reductions in transactions costs and increases in competitiveness through greater price transparency. It is also likely that membership of EMU would lead to a significant improvement in macroeconomic stability, and greater stability in the Euro Area countries in the past has helped produce higher investment and a larger capital stock per head than in the UK. Increased stability would come in part from the reduction in uncertainty that would result from fixing the exchange rate against a major trading partner. Lower transactions costs and greater stability should have a significant effect on competition amongst producers and on long term investment decisions, and both should lead to higher output per head in the member countries.

The Importance of Uncertainty in the Macro Economy

It has long been clear that uncertainty affects the risk premia associated with the investment decision as well as with the valuation of equities. It has recently been possible to formalise some of these concepts, and we discuss the relevant literature. Recent literature involves the introduction of imperfect competition and nominal rigidities into dynamic stochastic Real Business Cycle general equilibrium models. The literature on the "new open economy macroeconomics" (Obstfeld and Rogoff (2000) and Lane (2001)) emphasises the role of nominal rigidities in the shock transmission mechanism under different exchange rate arrangements in two-country set-ups. This new generation of stochastic models provides useful insight into the welfare effects of the euro[6]. However, this literature only considers the transmission of exogenous monetary shocks, with monetary policy introduced by assuming that some monetary aggregate follows an exogenous stochastic process. The difference between floating and fixed regimes is then modelled as the difference in synchronisation of monetary policy shocks between countries.

So far, there are only few examples in the literature where monetary policy is endogenous in this New Keynesian setup. For example, Gali and Monaccelli (2002) present a small model with sticky prices to study the exchange rate volatility under several feedback rule based monetary regimes. They consider a small open economy in a large world economy and show that a Taylor rule generates excess nominal variability, and an exchange rate peg is an improvement. However, in the context of their model, monetary integration would be modelled as peg relative to the world currency, with no role for volatility as a result of pegging to one of two blocks.

The traditional approach in the modelling of the level effects of uncertainty comes from the stochastic growth model discussed by Merton (1975). Brock and Malliaris (1982) review many applications to finance and economics. This approach ignores short-run fluctuations but it is well suited to study properties of a stochastic equilibrium and it is especially relevant when we wish to address permanent structural changes due to the introduction of a single currency. We discuss a theoretical model with explicitly modelled corporate sector which would allow us to evaluate consumption/investment decisions in order to illustrate our modelling approach. As we can distinguish key first-order effects of uncertainty they can be introduced into NiGEM's long run relationships.

Turnovsky and Grinols (1993, 1994, 1996, 1998) analyse continuous time stochastic growth models with flexible wages and prices where monetary policy uncertainty operates almost exclusively through the allocation of wealth. Their approach is highly

[6] For examples see Devereux (1999), Devereux, Engel and Tille (2000), Obstfeld and Rogoff (2000)

transparent and provides substantial insight into the first-order effects of uncertainty on the equilibrium characteristics of key macroeconomic variables, consumption and investment. The detailed analytical model provides a guideline for introduction of uncertainty when dealing with large-scaled macroeconomic model such as NiGEM. It also helps us assess of the effects of uncertainty on welfare and the level of output.

The Model

Suppose there are four assets: money (M), domestic bonds (B), foreign bonds (F) and domestic equities (S). Prices evolve as

$$\frac{dP}{P} = p\,dt + du_p\,; \quad \frac{dP^*}{P^*} = p^*dt + du_{p^*}\,; \quad \frac{dE}{E} = edt + du_e$$

There are four exogenous sources of uncertainty: productivity shocks *dy,* uncertainty in foreign monetary policy du_{p^*} uncertainty in government spending *dz* and uncertainty in the conduct of the domestic monetary policy du_p . For the sake of concreteness we assume here that the monetary authorities target inflation and they are able to deliver the target with some degree of success. Variances of these variables will be important for the equilibrium levels of consumption and allocation of wealth. There is no income uncertainty in this model.

Household sector seeks to maximise consumption and the utility function depends on real money:

$$\max_{C,n_i} \int U(C, M/P)\exp(-\boldsymbol{r}t)dt$$

subject to the budget constraint where dR_i is return on asset *i* and *T* are taxes.

$$dW = W(n_M dR_M + n_B dR_B + n_F dR_F + n_S dR_S) - Cdt - dT$$

This optimisation problem leads to the money demand equation and arbitrage relationships for the financial assets. Firms are assumed to be maximising their value, with non-zero installation cost. The solution of their optimisation problem yields relationships for the rate of return on equities and variability of this rate. We also have equilibrium relationships for the product market and the balance of payment. Turnovsky (2000) writes the macroeconomic equilibrium conditions in the stochastic equilibrium in a form where volatilities affect the equilibrium level and growth of output. The exogenous factors include (i) the inflation rate ð delivered by the monetary policy, (ii) the mean rate of government expenditure g, (iii) debt policy ë, (iv) the mean foreign rate of inflation ð*, (v) the preference parameters ã,è (ã is parameter of risk aversion). There are four exogenous sources of uncertainty in the economy which are assumed to be mutually uncorrelated.

Turnovsky (2000) shows that the ratio of *C,* consumption to *W,* total financial wealth depends the preference parameters, and especially risk aversion, on β, the return on portfolio and on the volatility of productivity, of government spending and on foreign inflation shocks. The volatility of foreign inflation is a major determinant of the volatility of the real and nominal exchange rates in the models we discuss below. The consumption to wealth ratio is a major determinant of the equilibrium current account position in a small open economy, and also has an influence on the determinants of equilibrium output and growth in a world of capital mobility:

$$\frac{C}{W} = \frac{q}{1-gq}(r - bg - \frac{1}{2}g(g-1)s_w^2)$$

where s_w^2 the volatility of the portfolio is a weighted volatility of its components. The volatility of domestic part of the portfolio is determined by the ratio of average product of capital to Tobin's q and the volatility of government expenditure and technology shocks, whilst the foreign part depends on the volatility of foreign inflation

$$s_w^2 = w^2 (\frac{f(k)}{qk})^2 (s_y^2 + s_z^2) + (1-w)^2 s_{p^*}^2)$$

$$b = y + \frac{C}{W}$$

The return on portfolio, β, is partly determined by the equilibrium growth rate of the economy y, which depends in part on Tobin's q and this depends on *h*, a constant in adjustment cost function as well as the volatilities of productivity, government spending and foreign inflation. The equilibrium growth rate of the economy also depends directly on government spending g, the equilibrium capital stock k, foreign real interest rates ($i^* - p^*$) and the volatility of foreign inflation shocks.

$$q = yh + 1$$

$$y = w((1-g)\frac{f(k)}{qk} - \frac{1}{n_S}\frac{C}{W} + \frac{(q-1)^2}{2qh}) + (1-w)(i^* - p^* + s_{p^*}^2)$$

The equilibrium level of output is determined by a marginal productivity condition for the capital stock which depends on the volatility of output, the level of Tobin's q and volatilities of output and foreign inflation. The equilibrium level of output and the growth rate also depend upon ω, the share of capital in the traded portion of the consumer's portfolio, the quantity of the other factor, a, and n_S, the share of portfolio held in equities as well as ρ, the discount factor.

$$w = \frac{\frac{f(k)-a}{qk} + \frac{(q-1)^2}{2qh} - (i^* - p^* + s_{p^*}^2)}{(1-g)((\frac{f(k)}{qk})^2 s_y^2 + s_{p^*}^2)} + \frac{s_{p^*}^2}{((\frac{f(k)}{qk})^2 s_y^2 + s_{p^*}^2)}$$

$$a = (1-(1-g)w\frac{f(k)}{qk}s_y^2 + \frac{(q-1)^2}{2h})(f(k) - kf'(k))$$

$$n_S = w(1-(1+l)\frac{1}{i}\frac{1-q}{q}\frac{C}{W}$$

The volatility of domestic inflation enters this system only through its impact on the interest rate, which can be written as

$$i = \frac{f(k)}{qk} + p - s_p^2 - \frac{a}{qk} + \frac{(q-1)^2}{2qk} - (1-g)w(\frac{f(k)}{qk})^2 s_y^2$$

The effect of the interest rate on the economy works through the reallocation of wealth held in domestic equities, and hence affects the equilibrium level of output. Although this model is a highly stylised analysis of equilibrium conditions, it is a useful guide to the role of uncertainty in the determination of macroeconomic equilibrium.

The Structure of the NiGEM Model

In our strategy for modelling the economy we have to ensure that we have a sound theoretical structure with a good empirical basis. Over the last 15 years NIESR has developed the global macro model NiGEM for use in policy analysis. It is a new-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. All countries in the OECD are modelled separately, as is China and there are six other regional blocks. All economies are linked through the effects of trade and competitivenes. There are also links between countries in their financial markets as we model the structure and composition of wealth, emphasising the role and origin of foreign assets and liabilities. We have forward-looking wages, forward looking consumption, forward-looking exchange rates and long-term interest rates are the forward convolution of short-term interest rates. The model has complete demand and supply sides and there is an extensive monetary and financial sector. NiGEM contains expectations and we use the Extended Path Method to obtain values for the future and current expectations and iterate along solution paths

The Structure of Nigem

Trade. These equations depend upon demand and relative competitiveness effects, and the latter are defined in similar ways across countries. We assume that exporters compete against other people who export to the same market (RPX), and demand is given by the imports in the markets to which the country has previously exported (S)

$$\Delta X = \lambda[X(-1) - S(-1) + b*RPX] + c1*\Delta X(-1) + c2*\Delta S + \quad + error$$

and imports depend upon import prices relative to domestic prices (RPM) and on demand (TFE)

$$\Delta M = \lambda[M(-1) - b1*TFE(-1) + b2*RPM] + c1*\Delta M(-1) + c2*\Delta TFE + \quad + error$$

As exports depend on imports, they will rise together in the model.

Government. We consider the financing of the government deficit (BUD), and we allow either money (M) or bond finance (DEBT).

$$BUD = \Delta M + \Delta DEBT$$

Current fiscal revenues are disaggregated into personal taxes (TAX) which includes both personal income tax and social security contributions, corporate taxes (CTAX) and indirect taxes (MTAX). We also have real government consumption and investment (GC and GI), interest payments (GIP) and transfers (TRAN). As GC and GI are in constant prices, we convert them to nominal terms using the private consumption deflator CED and the GDP deflator P. The budget balance which reads:

$$BUD = TAX + MTAX + CTAX - TRAN - GIP - GC*CED - GI*P$$

Government interest payments are modelled as the income on a perpetual inventory, the change in the debt stock each period paying the long interest rate in the issue period until it is replaced.

Consumption and Personal Income. We assume that consumers consider their current income (RPDI income including non-labour income net of taxes) and their real financial wealth (RNW) and that they adjust toward a long run relationship involving these variables. Adjustment costs are assumed to be quadratic, and behaviour is forward looking. The resulting equation is;

$$\Delta C = \lambda[C(-1) - a*RPDI(-1) - (1-a)*RNW(-1)] + \delta\Delta C(+1) + error$$

The coefficient on the forward change in consumption is the rate of time preference. We assume that wealth is affected by financial markets through equity and bond prices, and hence if these markets ‘expect’ something in the future then it will be reflected in prices. News that changes expectations will cause wealth to be revalued, and hence will affect behaviour now.

Production and price setting. For each country we have an underlying CES production function which constitutes the theoretical background for the specification of the factor demand equations, forms the basis for unit total costs and the measure of capacity utilisation which then feed into the price system. A CES production function that embodies labour augmenting technological progress (denoted λ) with constant returns to scale, can be written as:

$$Q = g\left[s(K)^{-r} + (1-s)(Le^{lt})^{-r}\right]^{-1/r}$$

g and s are production function scale parameters, and the elasticity of substitution, s, is given by $1/(1+r)$. Variables K and L denote the net capital stock and labour input measured in terms of employee hours. The parameters of the production function vary across countries and w, c and p denote respectively labour costs per head, nominal user costs of capital and the price of value added (at factor cost) and b denotes the mark-up. With long-run constant returns to scale we obtain log-linear factor demand equations of the form:

$$Ln(L) = \left[s \ln\{b(1-s)\} - (1-s)\ln(g)\right] + \ln(Q) - (1-s)\,lt - s\ln(w/p)$$

$$Ln(K) = \left[s \ln(bs) - (1-s)\ln(g)\right] + \ln(Q) - s\ln(c/p)$$

The parameters are used in the construction of an indicator of capacity utilisation which affects the mark-up of prices over unit total costs. The capital stock adjustment equation depends upon the long run equilibrium, and the user cost of capital is influenced by the forward looking real rate, as well as by taxes and by depreciation. The speed of adjustment to equilibrium in the investment/capital stock adjustment equations also depends upon the short term real interest rate, with the effects being similar across countries.

Our core price equations relate the producer price to the cost function implied by our production function. Producer prices are driven by import prices and by the total cost of production, where the latter is constructed from the wage per person hour and the nominal user cost of capital per unit of capital. The producer price is a core variable in the determination of consumer prices and hence of the rate of inflation. The price equations are all statically homogenous[7].

Labour markets We assume that employers have a right to manage, and hence the bargain in the labour market is over the real wage. In the long run wages rise in line with productivity all else equal. Given the determinants of the trajectory for real wages, if unemployment rises then real wages fall relative to trend, and conversely.

[7] Dynamic homogeneity is present in the UK, but is absent in at lest one price equation in some Euro Area countries. None of the experiments reported here should change the trend rate of inflation and hence the absence of dynamic homogeneity does not influence our conclusions

There is continual structural change in labour markets and sustainable unemployment changes when policies change. Both the determinants of equilibrium and the dynamics of adjustment can changeover time and adjustment, especially in Europe is slow. We assume that labour markets embody rational expectations and we assume that wage bargainers use model consistent expectations, either for the immediate period ahead or over a longer term horizon. All wage equations are statically and dynamically homogenous.

Financial markets Forward looking long rates LR (and long real rates) have to look T periods forward

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

Forward looking exchange rates RX have to look one period forward along the arbitrage relation involving domestic and foreign interest rates (SRH and SRF)

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

Forward looking equity prices are solved out from the infinite forward recursion and depend only on the expected equity price next period

$EQP_t = Profits_t + EQP_{t+1}$ discounted

We also adjust for the expected real growth of the capital stock and its implications for profits per unit of equity.

Policy rules

Fiscal and monetary policy rules are important in 'closing the model' and our rules are discussed at greater length in Barrell and Dury (2000)

Fiscal Policy rules We assume budget deficits are kept within bounds in the longer term, and taxes rise to do this. This simple feedback rule is important in ensuring the long run stability of the model. Without a solvency rule (or a no Ponzi games assumption) there is no necessary solution to a forward-looking model. We can describe the simple fiscal rule as

$$Tax_t = Tax_{t-1} + \phi\ [GBRT - GBR] + \delta\ [GDRT\text{-}GDR]$$

Where Tax is the direct tax rate, GBR and GBRT are the government surplus target and actual surplus, GDR and GDRT are the stock of debt to GDP and the target for the stock, ϕ and δ are the feedback parameters. The former is designed to remove an excess deficit in less that five years, whilst the latter is set to zero in this exercise.

Monetary Policy Rules We assume that the monetary authorities adopt simple targeting rules that stabilise the price level or the inflation rate in the long term. The European Central Bank (ECB) has been set the objective of maintaining price stability in the medium term. It has set itself a target of 0 to 2 percent for inflation within the constraints of a nominal target for the stock of money, and it describes this as the two-pillar strategy[8]. A combined policy of nominal aggregate and inflation rate targeting would give:

$$r_t = g_1(P_tY_t - P*_t\ Y_t*) + g_2(\Delta P_{t+j} - \Delta P_{t+j}*)$$

The policy rules on the model use the Consumer Price Index (CPI) inflation rate. We choose the combined rule as our default monetary policy rule because it represents the

[8] European Central Bank (2001). We do not target money, as this is a poor indicator of the underlying target, which we take to be nominal GDP.

mixed framework that is used in Europe by the European Central Bank (ECB). In this paper we also use an industry standard Taylor rule. We may write the rule as

$$r_t = \gamma_1 (Y_t - Y_t *) + \gamma_2 (\Delta P_{t+j} - \Delta P_{t+j} *) + \gamma_0$$

where we have set γ_1=0.50 (50.0), γ_2=1.500 in the Taylor rule and 1.0 in the combined rule, and γ_0 is the steady state rate of interest. We target the expected inflation rate.

Stochastic simulations

We use a version of the residual based (RB) approach to stochastic simulations introduced by Brown and Mariano (1984). They take *T* sets of historical residuals and run *T* simulations, one for each vector of residuals, whereas we resample from the residuals as in 'bootstrapping' procedures (Efron, 1979). A matrix of single equation residuals (SER) is calculated, with *n* rows (corresponding to the *n* equations whose residuals we consider) and *t* columns (corresponding to *t* time periods). We then randomly draw vectors (i.e., columns) of shocks from that matrix, and apply them to the model[9]. The generated error distribution will be the same as that of the SER.

Shocking the equations on NiGEM. Behavioural equations have residuals associated with them that represent the unexplained part of the equation and we treat these as unexplained shocks. We draw historical shocks from these equations for the period 1991q1 to 1999q4, and we check them for serial correlation. Shocks are applied with the relevant lagged shock where this is present. Policy variables are treated as deterministic equations and therefore have no random error and so are not shocked. In our stochastic simulations all equations that have random errors are shocked and are shocked at the same time. This includes equations with expectations of the dependent variable and those with expectations of other variables in the system.

A typical (simplified) equation on the model, which may contain an expectations term, can be given by:

$$y_{it} = \alpha + \beta E_t z_{t+1} + \lambda x_t + \theta y_{jt} + u_t$$

where $y_{i,jt}$ are endogenous variables, x_t and z_t are both predetermined variables, E_t is the expectations operator and u_t is an error term with mean zero and constant variance. In some equations, such as the open arbitrage condition for the exchange rate, we may include forward values of the endogenous variable. The residuals used to shock these equations are calculated using the value of the variable in the next period as the data for the expectation term.

The method of construction of historical shocks to most exchange rates is clear, as the bilateral rate against the dollar existed in the past, for instance in the case of the UK, 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 a regime where individual Euro Area countries have their own exchange rates to one where there is a 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. We assume that the ECB would have the same credibility as the Bundesbank and hence apply the shocks that occurred to the core of EMU (Germany, Belgium, Netherlands, France (and Austria)) over the 1991 to 1999 period.

[9] Of course, nothing prevents that a given column is drawn more than once.

Stochastic trials. Once we have estimated our vector of random errors from the matrix of single equation residuals as described above we apply them to the model. We start in period *t* and apply shocks to this period. Agents know this set of shocks but set all future shocks equal to their expected value of zero (i.e. values for error terms are set to zero for periods *t+1* and beyond). The model is then solved forward in the way described above. The results for period *t* are recorded so that the solution values can be used to compute the variances for that period.

The solution obtained for all time periods from this first vector of shocks to the model provides us with a new current and future world outcome, including new values for agent's expectations. In period *t+1*, an agent's expectation of a variable in *t+2* is different from viewpoint *t+1* than it was in period *t*. We then apply another set of shocks randomly drawn from the SER matrix, to period *t+1*. Again we set all future error terms to zero and take as our starting point this new world outcome. We repeat this process until we have shocked all relevant time periods and this gives us one stochastic *trial.* In this paper we stochastically shock the model over the first 5 years of our baseline (2001q1 to 2005q4) and undertake 150 stochastic trials for each policy regime[10].

The Experimental Framework and the Results

We set up four differential future histories for 2001 to 2005 using stochastic simulations with the policy authorities responding in different ways. The UK can be outside or inside EMU, and if it is outside EMU it can use a Taylor Rule or a combined rule (Two Pillar) nominal aggregate plus inflation target. The ECB is assumed to adopt a combined (Two Pillar) nominal aggregate and inflation targeting rule if the UK is in. If it is outside then the ECB can either adopt a Two Pillar strategy or it can adopt an industry standard Taylor Rule.

We would not expect our stochastic simulations to exactly replicate the structure of past volatilities even with the same shocks, as we have different monetary and fiscal policies in place. The choice of rule must have a noticeable impact on the stochastic structure, with rules with integral controllers in the price level or nominal output (including the combined rule) giving lower variances for inflation than rules without the integral control component, all else equal.

The choice of regime depends in part on the weights on uncertainty in the policy welfare function and also on the effects of uncertainty on the level of output. We measure volatility using the RMSD following Bryant et al. (1993), our volatility statistic is of the form[11]

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

The results of our trials are reported in Tables 1 and 2 below. We can compare experimental RMSD outturns to the RMSD of deviations from a 13 period moving average trend from the period from which we draw residuals, following Barrell and Weale (2003)[12]. Output volatility in the Euro Area in our draw period was 1.30 as compared to 1.46 to 1.57 in our experiments, whilst inflation volatility was 0.80 as

[10] Barrell Dury and Hurst (2002) demonstrate that this is sufficient for results to have stabilised
[11] Where we report results on interest rates, inflation rates etc. we use the RMS absolute D.
[12] They investigate volatilities over this period for both the UK and the Euro Area, and suggest that the UK framework introduced in 1997 has already helped stabilise the macroeconomic environment

compared to our 0.25 to 0.31 in our experiments. For the UK output volatility on this basis was 1.07 in the draw period as compared to 1.77 to 2.20 in our experiments, whilst inflation volatility was 1.80 in the draw period and 0.66 to 0.71 in the experiment. In both cases the framework we have designed produces noticeably more stable inflation than in the past, as we would expect, but at the expense of higher output volatility. Hence we may conclude that our experiment is a reasonable restructuring of the past, but does (and was not intended to) replicate it.

It is common to assume that policy makers may wish to weight together uncertainty over variables such as output, inflation, prices and exchange rates. Barrell and Dury (2003) discuss the impact of varying the welfare function in assessing policy rules using stochastic simulations. We do not extend that discussion here, but we report our results in a way that allows the reader to construct a welfare function and evaluate regime choices with weighted RMSDs. The results from our stochastic trials are given in the tables below. Differences that are significant at the 95% level on a two tailed test based on 3000 observations (simulations) are indicated[13]. In Table 1 and 2 we use a Taylor rule for the UK and a Two Pillar Strategy for the Euro Area as our baseline.

Table 1 Euro Area Outcomes under Different Policy Rules

Root Mean Squared Percent (absolute) Deviations as compared to baseline

Euro Area	**UK in EMU** **ECB Two Pillar Strategy**	**UK out** **UK uses Two Pillar Strategy** **ECB uses Two Pillar Strategy**	**UK out** **UK uses Taylor Rule (Industry Standard)** **ECB uses Two Pillar Strategy**	**UK out** **UK uses Taylor Rule (Industry Standard)** **ECB uses Taylor Rule (Industry Standard)**
Price Levels				
Consumer	1.04*	1.24*	1.13	1.32*
GDP Deflator	1.27*	1.27*	1.18	1.38*
Exchange Rates				
Dollar	2.50	2.59	2.53	4.07*
Real Effective	1.70*	3.49	3.46	3.25*
Interest Rates				
3 Month	1.04	1.08*	1.04	1.61*
10 year bond	0.41	0.38	0.39	0.53*
Long real rate	0.24	0.23	0.23	0.20*
Targets				
Output level	1.46*	1.49*	1.64	1.57*
CPI Inflation	0.25*	0.31	0.31	0.30

A *indicates the difference from column 3 is significant at the 95% level

If we were to assess the ECB's choice of framework using output and inflation volatility alone, then if the UK adopts a Taylor rule it might be better for the ECB to do so as well. As Barrell and Dury (2000) stress, the ECB may also be concerned about the stability of the price level, and if it is then its choice would shift in favour of a combined strategy. This choice would be strengthened if the ECB was also concerned about the impact of exchange rate volatility and interest rate volatility on the economy, as theoretical discussion suggests they should be. If the UK joins EMU then output and inflation variability in the Euro Area will be reduced because some

[13] The ratio of two RMSD's is distributed as F(N*T,N*T) where N is the number of trials and T the number of time periods per trial.

exchange rate related shocks will be removed, and the variability of the real exchange rate will be reduced in the Euro Area as well as in the UK.

Our major focus in this paper is on the choice of regime for the UK and not on whether we would be welcome as members of EMU, although our results suggest that we would be. If the UK stays out then it will face a different set of shocks to the exchange rate, and if the 1991 to 1999 period is repeated then the volatility of shocks to the sterling dollar rate would be 65 percent larger than the shocks to the euro dollar rate.[14] In our experiments the volatility of the nominal dollar exchange rate for the UK is noticeably larger than for the Euro Area, in part because of the larger shocks, but also because an independent monetary policy in general requires noticeably more interest rate volatility in the small, open UK economy than it does in the large, relatively closed Euro Area, where the size of the economy helps pool the shocks driving interest rate reactions. The greater volatility in the policy response (even with the same targets and feedbacks) in the UK probably helps to double the volatility of nominal exchange rate in the trial period, unless the UK were in EMU. In our experiments short term interest rate volatility in the Euro Area is only marginally above the historical experience (0.89), whilst in the UK it is noticeably lager than both the Euro Area value and that from the draw period (1.06).

Table 2 UK Outcomes under Different Policy Rules

Root Mean Squared Percent (absolute) Deviations as compared to baseline

UK	UK in EMU ECB Two Pillar Strategy	UK out UK Two Pillar Strategy ECB uses Two Pillar Strategy	UK out UK uses Taylor Rule (Industry Standard) ECB uses Two Pillar Strategy	UK out UK uses Taylor Rule (Industry Standard) ECB uses Taylor Rule (Industry Standard)
Price Levels				
Consumer	3.19*+	2.56*	3.46	3.48
GDP Deflator	3.96*+	4.58	4.76	4.77
Exchange Rates				
Dollar	2.50*+	10.78*	11.39	11.64
Real Effective	3.48*+	10.89	10.48	10.27
Interest Rates				
3 Month	1.04*+	1.76*	3.07	3.12
10 year bond	0.41*+	0.39*	1.08	1.05
Long real rate	0.24+	0.25	0.25	0.21*
Targets				
Output level	1.90*+	2.20*	1.77	1.82
CPI Inflation	0.68*+	0.66*	0.71	0.71

A *indicates the difference from column 3 is significant at the 95% level
A +indicates the difference column 1 and 2 is significant at the 95% level

A Taylor Rule would give the UK lower output variability but higher inflation variability than if it adopted a Two Pillar strategy but remained outside EMU. If the UK joined EMU output variability would be higher than with an independent Taylor Rule but inflation variability would be lower, partly because EMU involves adopting a Two Pillar strategy with a nominal target integral controller. However, moving to

[14] This is calculated from forward arbitrage conditions for the UK and the Euro Area in the 1990s using outcomes for the exchange rate as the expectation of the exchange rate, with constant risk premia

such a strategy without joining EMU would raise output volatility but lower inflation volatility as compared to using a Taylor rule because the feedback on real output is weakened whilst that on the price level is increased, but the gains from exchange rate stability are not fully achieved. An independent two pillar strategy would increase the stability of the price level and the real exchange rate significantly when compared to a Taylor rule, and if these are important determinants of the long run level of output then such a strategy would be possibly be preferred.

There would be very significant gains to be made by joining EMU if price level stability and real exchange rate uncertainty were important determinants or the level of equilibrium output as our theoretical discussion suggests. Membership of EMU would enhance macroeconomic stability on all indicators except marginally on inflation as compared to an independent Two Pillar strategy and on output as compared to an independent Taylor rule. The consumer price level would be less variable than under a Taylor Rule, and interest rates and exchange rates would be noticeably less volatile in EMU than under any of the independent frameworks that we are considering. Hence the level of uncertainty in the economy would almost beyond doubt be lower in EMU than outside it, and it is important to assess the impact of this on the economy of the UK.

Effects of Uncertainty on the Level of Output

Uncertainty comes from many sources, and some forms matter more than others. If interest rates and inflation rates become more uncertain then risk premia develop in financial market decision making, and outturns in the future are more heavily discounted in evaluating multi-period projects. If the price level becomes more uncertain long term contracting becomes more difficult, as bankruptcy risk on the part of one partner or the other rises.

Kneller and Young (2001) survey the mixed literature on uncertainty and output and also use a panel of OECD countries to look for the effects of uncertainty on growth. They find that the volatility of inflation has a negative impact on growth, as do other financial factors such as real share prices. There is no significant impact of the volatility of output once these other factors are taken account of. These results suggest that a regime, such as EMU, that might reduce the volatility of inflation in the UK at the cost of some increased output volatility should raise the overall level of output.

The empirical literature in investment and uncertainty for the UK surveyed Pain (2002) does suggest that measures of uncertainty have a negative long-run effect on investment. Darby, Hughes Hallett, Ireland and Piscatelli (1999) find that there is systematic evidence that exchange rate uncertainty reduces the level of investment and hence the capital stock. Byrne and Davis (2002) extend their analysis to a panel of G7 countries and show that GARCH based indicators of exchange rate uncertainty have systematic effects, reducing the level of investment in all countries. Using Pooled Mean Group estimators they look at the role indicators of uncertainty, regressing the level of investment on output, Tobin’s q and on uncertainty. They demonstrate that uncertainty over the real exchange rate is an important determinant of investment. No other indicators are uniformly significant in a G7 panel, although long term interest rate uncertainty does seem to play a role on some EU countries.

We can calibrate the impact of the changes in real exchange rate uncertainty that result from joining EMU in our stochastic simulations using Byrne and Davis (2002) Their equation is of the form.

lnK = C + f(Y, …) + RP(Real Exchange Rate Uncertainty).

Their GARCH estimators for uncertainty decompose into total minus anticipated variance $\nu = \varepsilon^2 - \sigma^2$. The expected variance from the past can be lined up with our baseline, and the unexpected variance lines up with indicators of uncertainty in our stochastics. The NiGEM equation for investment is an adjustment to the equilibrium capital stock which depends upon a risk premium[15].

$$\ln(K) = C + \ln(Y) + \beta \ln(\text{User Cost} + RP(\sigma(RX)))$$

Byrne and Davis estimate the coefficient on the real exchange rate to be -0.094. Reducing real exchange rate uncertainty by the amount indicated in our stochastic simulations above by joining EMU would reduce the risk premium on investment in the UK by a quarter. Investment would rise, and the capital stock in the UK would increase by 9 percent in the steady state. Output in the UK would be 3 to 4 percent higher in the steady state. However, it is clear that the impact of reduced uncertainty could be noticeably higher than this, and Byrne and Davis (2002) produce results from other uncertainty indicators that in combination with our stochastic simulation results could mean that the effects of reduced volatility could be almost 3 times as big.

Conclusions

Both the theoretical analyses and the empirical work surveyed in this paper suggest that uncertainty over the economic environment reduces the level of investment and the equilibrium capital stock as well as the sustainable level of output. The work of Grinols and Turnovsky discussed above places stress on the importance of the variance of external monetary shocks for the level of output small open economies such as the UK. The external monetary shock will in general be reflected through the volatility of the real exchange rate. Byrne and Davis (2002) amongst other conclude that the variability of the real exchange rate has a significant impact on the level of investment. Our stochastic simulations on NiGEM suggest that joining EMU would reduce the variability of the UK's real effective exchange rate by a significant amount. In turn this leads us to the conclusion that membership of EMU would raise the sustainable level of output by 3 percent or more in the UK.

[15] The risk premium is related to the real exchange rate term in Byrne and Davis

References

Barrell, R., (2002) 'The UK and EMU: Choosing the Regime' *National Institute Economic Review No. 180* April 2002

Barrell, R., and Dury, K., (2000) 'An Evaluation of Monetary Targeting Regimes' *National Institute Economic Review No. 174 October* 2000

Barrell R. and Karen Dury (2000a) 'Choosing the Regime: Macroeconomic effects of UK entry into EMU' *Journal of Common Market Studies*, Vol. 30 (4)

Barrell, R., and Dury, K., (2003) 'Asymmetric Labour Markets in a Converging Europe: *National Institute Economic Review* No 183 January 2003

Barrell, R., Dury, K. and Hurst, I. (2002), 'International monetary policy co-ordination: An evaluation using a large Econometric model', *Economic Modelling*

Barrell, R., and Weale, M., (2003) 'Designing and Choosing Macroeconomic Frameworks: the \position of the UK after 4 years of the euro' Forthcoming in *Oxford Review of Economic Policy*

Benavie, A., Grinols, E. & Turnovsky, S. (1996), 'Adjustment costs and investment in a stochastic endogenous growth model', Journal of Monetary Economics 38, 77—100.

Blake A. and Weale, M. (2002) Policy Rules and economic Uncertainty, Mimeo, National Institute of Economic and Social Research

Bryant, R.C., Hooper, P. and Mann, C.L. (1993), Evaluating Policy Regimes: New Research in Empirical Macroeconomics, Washington, Brookings.

Byrne, J.P., and Davis, E.P. (2002) Investment and Uncertainty in the G7, National Institute Discussion Paper No. 198

Darby, J., Hughes Hallett, A., Ireland, J., and Piscatelli, L., (1999) 'The impact of exchange rate uncertainty on the level of investment' *Economic Journal* 109 C55-C67

Devereux, M. (1999), A Simple Dynamic General Equilibrium Analysis of the Trade-off. Between Fixed and Floating Exchange rates, Mimeo, University of British Columbia.

Devereux, M., Engel, C. & Tille, C. (2000), Exchange Rate Pass-Through and the Welfare Effects of the Euro, Working paper 7382, NBER.

European Central Bank (2001) 'Framework and Tools of Monetary Analysis' ECB Monthly Bulletin May 2002

Fair, R. (1998), "Estimated stabilisation costs of the EMU", *National Institute Economic Review*, No. 164, pp. 90-99.

Gali, J. & Monacelli, T. (2002), Optimal Monetary Policy and Exchange Rate Volatility in a Small Open Economy, NBER WP.

Grinols, E. & Turnovsky, S. (1993), 'Risk, the financial market, and macroeconomic equilibrium', Journal of Economic Dynamics and Control 17, 1—36.

Grinols, E. & Turnovsky, S. (1994), 'Exchange rate determination and asset prices in a stochastic small open economy', Journal of International Economics 36, 75—97.

Grinols, E. & Turnovsky, S. (1998), 'Risk, Optimal Government Finance and Monetary Policies in a Growing Economy', Economica 65, 401—27.

HM Treasury (1997) UK membership of the Single Currency: An Assessment of the Five Economic Tests (October 1997) PDF available at http://www.hm-Treasury.gov.uk/documents/the_euro/euro_index_index.cfm

HM Treasury (2001) Preliminary and Technical Work to Prepare for the Assessment of the Five Tests for UK Membership of the Single Currency (November 2001) PDF available at http://www.hm-treasury.gov.uk/documents/the_euro/euro_index_index.cfm

Kneller, R., and Young, G., (2001) ' Business Cycle Volatility, Uncertainty and Long Run Growth' *The Manchester School* 69 534-552

Lane, P. (2001), 'The New Open Economy Macroeconomics: A Survey', Journal of International Economics 54(2), 235—266.

Obstfeld, M. & Rogoff, K. (2000), 'New directions for stochastic open economy models', Journal of International Economics 50, 117—153.

Pain N., (2002) 'EMU, Investment and Growth: Some Unresolved Issues.' *National Institute Economic Review* No. 180 April 2002

Merton Robert C. 'An Asymptotic Theory of Growth Under Uncertainty' *The Review of Economic Studies*, Vol. 42, No. 3. (Jul., 1975), pp. 375-393

Turnovsky, S. (2000), Methods of Macroeconomic Dynamics, The MIT Press. 2nd edition