CIM

Centre for International Macroeconomics

Discussion Paper No. 2000.03

Modelling policy rules: Direct versus model-based approaches;

Comments and Illustrations

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ESRC Award "EMU and Financial Markets, Grant No. R000237486 is gratefully acknowledged. Thanks are due to Cecilie Lindh for help in preparing this paper.

ABSTRACT

We introduce a new procedure for deriving optimal simple policy rules under uncertainty, allowing for strategic interdependencies between policy actions of different countries. This methodology is contrasted to previous work on policy rules both of the directly estimated and of the complete macro model variety. We argue and illustrate, that directly estimated versions are likely to be unstable. Next, we comment that much existing work on policy rules applied to complete macro models are limited in their treatment of uncertainty. Following this a method of deriving optimal simple rules fully allowing for uncertainty and for strategic interactions between countries is defined. An empirical application for the case of a fiscal shock to the G-6 concludes the paper, which shows significant welfare benefits for coordination.

JEL Classification: E61, C70

Keywords: Policy coordination, uncertainty, strategic interdependence, optimal rules.

Contents

1. Introduction

Discussion of Macroeconomic policy is now most often done using the framework provided by policy rules. Following, primarily the work of Taylor, these rules are most often used to analyse monetary policy, and usually portray monetary policy as a linear function between interest rates and the deviations of expected inflation from target. thus

$$r_t = r_t^* + \beta(\pi_t - \pi^*) + \gamma(y_t - y^*)$$

Where r is the nominal interest rate, r* its long term equilibrium value, π the inflation rate, and * refers to a target or long run equilibrium value.

In the wake of the widespread adoption of inflation targeting in the 1990s, the applicability of rules like these is clear. But a caveat is in order. Svensson (1998) describes the characteristic feature of inflation targeting as the central bank's conditional inflation forecast being used as an intermediate target variable, and the bank's task is to select a path for the policy instrument to equate the inflation forecast with the its target. As Svensson emphasises, the resulting rule is thus much wider than the simple Taylor-type rule given above. In principle all variables affecting the bank's conditional forecast could enter the reaction function - except in the special case where output and inflation are sufficient statistics for the evolution of the economy. As examples he derives examples of alternative forms of reaction function depending on the objectives of policy and the openness of the economy. (We will comment further on his approach below so postpone that for the present).

Given their centrality to the policy debate, it is not surprising that analysing policy rules themselves has become a research area of great importance during the last decade. In this research two strands of work are discernable; one concerned with directly estimated policy rules, and the other concerned with policy rules applied to complete macro models – econometric or otherwise. We will later criticise directly estimated rules on the grounds that they are prone to a fundamental identification problem, which is not overcome by merely using simultaneous estimation methods to obtain them. The other strand of research applies policy rules to complete macro models, and there are examples of such applications to both empirical (econometric), and theoretical macro models. As the intention of applying policy rules is not to identify what policy makers have done but rather to explore the consequences which particular rules may have on economic performance, this application avoids the identification problem alluded to earlier. Other problems remain in such applications, especially where these use econometric models, largely due to the widespread practice of using ad-hoc forms for such policy rules. We provide illustrations later, and couple these with recommendations for overcoming some of the more important shortcomings in previous applications of policy rules to empirical models. In a further example of policy rules used in conjunction with macro models, simplified theoretical macro models are used to derive policy rules based on optimising behaviour (see Currie and Levine ( ), Blake and Westerway (1995), Blake and Weale ( ), Demerzis, Hughes-Hallett and Viegi(1999) and Svensson(1998) for examples). While these have a number of important advantages, including the possibility of directly linking the policy rule to underlying model and objective function parameters, they are limited by their simplicity, which makes them somewhat unrealistic. Svensson (op.cit.) for example derives optimal simple rules based on alternative assumptions about the economy, including its openness, and the objectives of economic policy. He derives policy rules –including rules which resemble those popularised by Taylor - using the familiar linear regulator optimisation problem assuming a quadratic loss function. The connection of the parameters of the policy rule, the model parameters and the optimisation problem are thus clear in this case, and here the identification issue mentioned earlier does not arise. But such applications are limited to the sort of simplified and calibrated macro structure Svensson employs. With a reasonably sized econometric model with data accepted complex dynamics and non-linearities, such a linking of the rule with the model and objective function parameters is not feasible. As our concerns are with empirical applications, in what follows we will ignore these more theoretical examples.

Apart from providing a constructive critique of research on empirical policy rules, of both types, the plan of this paper is to extend the application of policy rules applied to macro models in significant new directions. We will be arguing that - as well as being ad-hoc – these rules in practice are too limited. Specifically they usually do not properly allow for uncertainty, or for strategic policy behaviour on the part of different national authorities or, where it is a question of domestic policy setting, they do not allow for rivalries between different agencies in the country (the central bank and the finance ministry for example). Important exceptions to this generalisation are found in Demerzis, Hughes-Hallett and Viegi (1999). We claim that the methods described later encompass all existing approaches, and are sufficiently efficient computationally that they can be applied to large scale macro econometric models. For illustrations of the issues in strategic behaviour, the empirical examples we use in Section 4 and 5 below, concentrate on questions of international policy co-ordination, although they apply equally well to questions of policy co-ordination within a single country. Examples of strategic behaviour between different authorities in a single country are found in Hall, Henry and Nixon (1999, 2000) and Hall and Henry (2000), and are not discussed further here.

A major reason for our interest in strategic behaviour at the international level is our desire to give a reassessment of the finding of there being only small rewards to international policy co-ordination. Revisiting this question now seems to us to be necessary. One reason for this finding is that the empirical evaluation of the gains to co ordination has, until now, often been too limited, and has not explicitly allowed for strategic policy makers pursuing rival policies. Another is that it is possible that while in previous decades policy interactions internationally actually had small effects, since the late 1980s, with increasing capital mobility and closer financial links between national equity markets, these effects has grown substantially. Finally, in the present international conjucture there are at least two areas where the nature of international policy setting are now of paramount concern. One concerns the global economy, where the continuance of rapid US growth underpinning growth in the developed world is increasingly questioned. US growth in the last few years has depended on a low savings propensity, fuelled by increases in personal sector wealth, especially in stock market holdings. The disconnection of stock market values from fundamentals appears to some to be evident. (see Godley and Martin (1999)). Issues in the international policy agenda that have been raised by this concern include the extent to which US policy can continue to play the role of a "locomotive" for growth in other countries; more specifically, whether the effects on growth in other countries will play a part in US policy setting or not. Such international considerations appeared to be involved when the US lowered interest rates in the immediate aftermath of the Brazilian Crisis in 1998. The other area where increasing concerns are expressed is about monetary and fiscal policy in the EURO area. The continuing evidence of diverse growth in the member countries, the inappropriateness of "one glove fits all" monetary policy, coupled with the recent concessions to Italy on deficit reduction each raise issues of the appropriateness of both monetary and fiscal policy setting in the Union.

Here, we concentrate on international co-ordination in the developed world focussing on the G6. In section 5, we contrast the effects of national policy setting where other countries are to some extent or other passive, with the case where what other countries do plays an important part in the domestic policy setting in each country. The US example, particularly, brings home the possible importance of analysing national policy setting fully in an international setting so the international repercussions is an integral part of the analysis. There are two factors in this. The first is the analysis of domestic policy in a given country allowing for possible spillovers on other countries. But this is not sufficient. The possible policy reactions of other countries to policy initiatives in the first country matter as well. So a fully strategic analysis of policy choices by countries where they take other country's decisions into account is clearly necessary. Even this is not sufficient, however, since we will be arguing that policy itself needs to be designed in an optimal way. Examples abound where policy mistakes have compounded the effects of adverse exogenous shocks. The monetary policy easing following the stock market collapse in 1987, which led directly to the resurgence of inflation in the OECD is one recent example. The failure of the German government to curtail demand through a fiscal correction on unification, which led to an unbalanced policy mix, with consequent increases in real interest rates leading to the break up of the EMS in 1992 is another. Nor are examples all recent. The tight monetary policy in the early 1980s in the US following the Regan fiscal expansion, "exported" inflation to other countries, which led to monetary tightening and a slowdown in growth in Europe, is an important example from the 1980s.

In order to properly analyse such questions we propose a more general methodology to the application of policy rules in macro models, which brings together four separate strands from the literature – simple rules, optimising, strategic policy (game-theoretic policy), and uncertainty. As is well known, each of these elements have figured in a significant way in the international policy literature. The novelty in the present paper is that it brings them all together in a consistent way. As the analysis is empirical, an estimated model of the G6 is used with a coherent theoretical structure and with long run properties based on cointegration methods (see Hall and Henry (2000) for a description and listing of the model). The policy rules are of the so-called simple form, (p.i.d) rules for both monetary and fiscal policy, but their weights are obtained optimally. Moreover, this derivation is based on a fully dynamic and stochastic optimal control problem, so that uncertainty is fully incorporated. Lastly, policy rules are obtained for multi-country cases, where the extension allows for policy interactions between countries.

It is important to explain why such an elaboration is called for. Essentially, the argument for analysing international policy setting using stochastic dynamic, optimal and strategic methods, is that it overcomes important deficiencies in methods presently used. We take it as virtually self evident that the analysis should be an empirical (econometric) one, since the derivation of policy rules is complex and depends on the underlying economic model in complicated ways. There seems little value therefore in deriving rules from "calibrated" or illustrative models as e.g. in Svensson (1998), or Blake and Weale (1998), apart from the purely pedagogic value of such exercises. In addition, we argue there are other serious limitations in many recent applications. Taylor rules be they derived in an explicit optimising framework as in Svensson (op.cit) or directly estimated, as in Clarida, Gali and Gertler (1998), do not extend properly to the international case by fully allowing for strategic interactions between countries. This is evident even where the rules are explicitly altered to allow for the open economy case – e.g. the UK model used by Svensson invokes the small country assumptions with an important transmission mechanism of exchange rate changes onto domestic inflation so his Taylor rules have an important role for foreign disturbances, and Clarida et al test for the presence of the bilaterial $/DM rate in their estimates of the Bundesbank's monetary reaction function. But, nothwithstanding these extensions, such policy rules fall into the category of single country rules as they treat policy in each country as only indirectly affected by policy elsewhere(through exchange rate effects for example) This is true for the optimal, deterministic rules obtained by Svensson, and the descriptive rules estimated by Clarida et al. These assertions are fleshed out in the next two sections. A full econometric international modelling of policy which comes nearest to our own is given in Barrell and Pain (1998) but this uses ad-hoc changes to policy rules to investigate the effects of policy responses in the aftermath of the SE Asian financial crisis. And the important papers by Bryant and his co authors (1993), and by Taylor (1993) each share a common but unduly restrictive approach to the analysis of uncertainty. That is they evaluate the stochastic properties of models operating with policy rules the parameters of which are chosen in a arbitrary way. (See Section 2).

The paper is structured as follows. The next section provides an overview of recent approaches to the analysis of policy rules, contrasting the analysis of policy rules using a full macro econometric model analysis (e.g. such as Taylor (1993)) and the direct estimation of policy rules of the Taylor form (Clarida, Gali and Gertler (1998)). It will also give an outline of the methods we follow, and this serves as a more informal account of our methods which are given a more rigorous treatment in section 3. Section 4 outlines the model of the G-6 and section 5 provides an application of our approach, using this model. The final section offers conclusions and proposals for future work.

2. Policy rules in practice

In surveying the application of policy rules in empirical models (quantitative, be they econometric or calibrated), the major distinction is between directly estimated rules versus rules which are applied to a quantitative model. We start with the directly estimated versions, setting out some of the problems inherent in these, which a full model approach tries to overcome. .

(A) Directly estimated rules

In work of this sort, what might be termed <u>descriptive</u> methods are used to identify policy rules. The question thus posed is whether over the past the policy actions of the central bank (or the fiscal authority) can be represented by an estimated rule linking instruments to targets. Examples include Clarida et al (op.cit) applied to G6 and E3 (UK, France and Italy), and Walton and Massone (1999), for the UK. Clarida et al provide the most fully worked out version, and we use this as representative. Their monetary reaction function starts from the form used by Taylor linking interest rates to discrepancies between inflation and its target, and the output gap,

$$r_t^* = \alpha + \beta[\Pi_{t+n}] + \delta E x_t \qquad (1)$$

where r is the nominal short rate, (r* its target), Π the rate of inflation and x the output gap (y-y*; where y is real output). Assuming interest rate smoothing and rational expectations gives the equation in a form suitable for estimation, i.e.

$$r_t = (1-\rho)\alpha + (1-\rho)\beta\Pi_{t+n} + (1-\rho)\delta x_t + \rho r_{t-1} + \varepsilon_t \qquad (2)$$

where the interest rate smoothing is given by the equation

$$r_t = (1-\rho) r_t^* + \rho r_{t-1} + v_t$$

with v_t white noise, and the error term ε_t in the estimated equation above is a combination of "rational" forecast and equation error,

$$\varepsilon_t = -(1-\rho)[\beta(\Pi_{t-n} - \mathrm{E}(\Pi_{t+n}) + \delta(x_t - \mathrm{E}(x_t)] + v_t$$

Estimated by GMM for the G3, and for what the authors describe as the E3 (namely the UK, France and Italy) using monthly data for the sample 1979M4-1993M12, the equations generally fit well. For our purpose the empirical results for the G3 are all that is needed since our comments apply equally well to those of the E3 also.

We argue that there are two fundamental problems with this approach, the first is the problem of the econometric identification of the reaction function, the second is the economic interpretation of this function once it is derived. We will discuss these two in turn.

The econometric problems of identifying a reaction function where none of the variables are weakly exogenous are profound. The authors themselves interpret their equations as characterising monetary policy over the period, showing that there was a concerted move towards inflation targeting, albeit what the authors call "soft-hearted" targeting, i.e inflation targets with some stabilisation element in policy too (Svensson (1998) refers to this as "flexible" inflation targeting). That is, the response to a rise in expected inflation is to push up nominal rates by a sufficient amount to increase real interest rates. In this case β >1 and the authorities move the real rate to stabilise inflation and output. Where $b<1$ then the authorities do not move nominal rates by enough to stop real rates from declining, so increases in both inflation and output are possible. The results for the G3 show that the baseline specification given by equation (2) above works best. In other words, the addition of additional variables like money aggregates or exchange rates does not add significantly to the explanatory power of the equation. Also adding lagged inflation does not significantly improve the equation, and the authors interpret this as confirming the forward looking specification used in the model. In sum, the estimated equations are advanced as a plausible description of how central banks have conducted policy. There is also the suggestion that the results may be interpreted as showing what policies were actually desirable.(see Clarida et.al (1998) p1037). We discuss such an optimal interpretation of these equations below. Even interpreting the results as a description of what determined policy actions of the authorities is highly problematic. Fitting econometric equations to instruments and objectives and interpreting the result as an actual reaction function is almost certainly inappropriate. This because there is a fundamental identification problem involved in exercises of this sort: there are at least two relations between these variables – the "true " policy reaction function (which we assert is not what the authors identify with their equations), and the relationships of the economy itself. The fitted equations combine these two in some unknown way. The authors argue that the benefit of their "weakly restricted" version of the reaction function is that it is sensible for a wide range of different macroeconomic frameworks (models). It is hard to know how we would establish this. Estimating by allowing for the regressor variables to be stochastic, as the authors do, does not deal with this issue. A Full Information method is required as a means of identifying both the responses of the economy to policy and other exogenous shocks on the one hand, and the policy responses to developments in the economy on the other. Furthermore, there is almost certainly structural change affecting both of these basic relations – the model and the policy reaction equations – in different ways. Thus we would strongly suspect that equations of this sort, although apparently well fitting, will exhibit structural instability. This suggests a simple way to test the validity of the Clarida et al approach, is to test its structural stability. Our argument suggests these estimates must be structurally or parameter unstable[1]. We report briefly on tests of this next.

The second problem we identify is that even assuming the estimation has correctly identified the authorities reaction function, the interpretation of this equation is profoundly difficult. The best that can be said is that it represents what the authorities were actually doing. But were they behaving correctly, or optimally, or were they in fact following a completely erroneous set of policies. Even if we can assert that the authorities have been operating a good set of policies are they based on a particular form of co-operative structure? How would the policy have changed if the form of co-operation changed? All these questions are completely unanswerable from the perspective of this methodology and hence represent a sever limitation on its use for policy analysis.

To illustrate the importance of our first, econometric, problem we reestimated equation (2) for the G3 using quarterly data, and obtained comparable results to the Clarida et al paper. For brevity we do not report these[2]. These results are used as a basis from which to test our conjecture that the reaction functions are likely to prove parameter unstable. Evidence on parameter instability in the functions is given by their one-step forecasting performance, which is shown for each of the G3 countries, taking the date from which to start the test as 1991Q4. (1994Q4 in the case of post unification Germany).

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[1] This could be due to changing forms of the policy reaction function as well of course.

[2] Full results available from the authors.

Figure 1: US

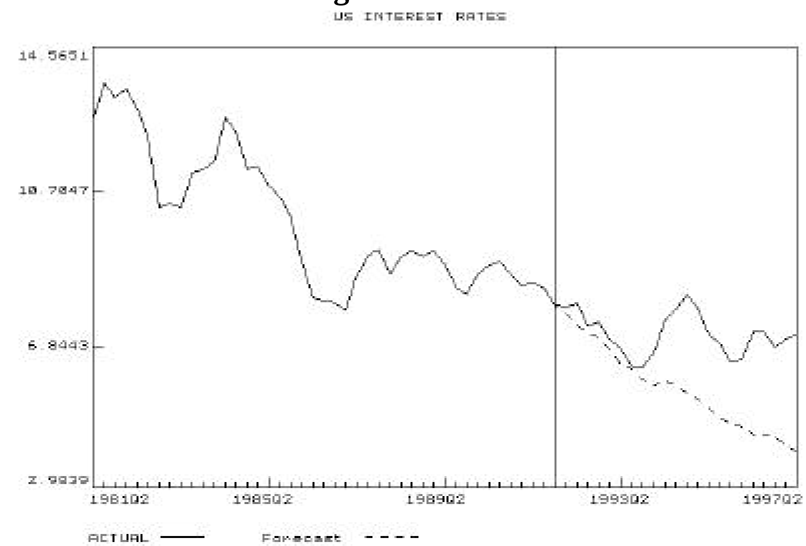


Figure 2: Japan

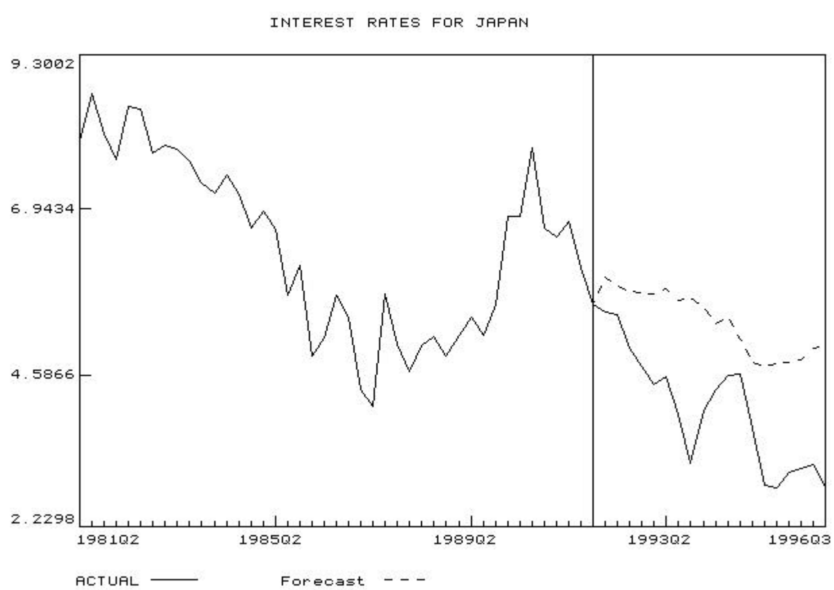
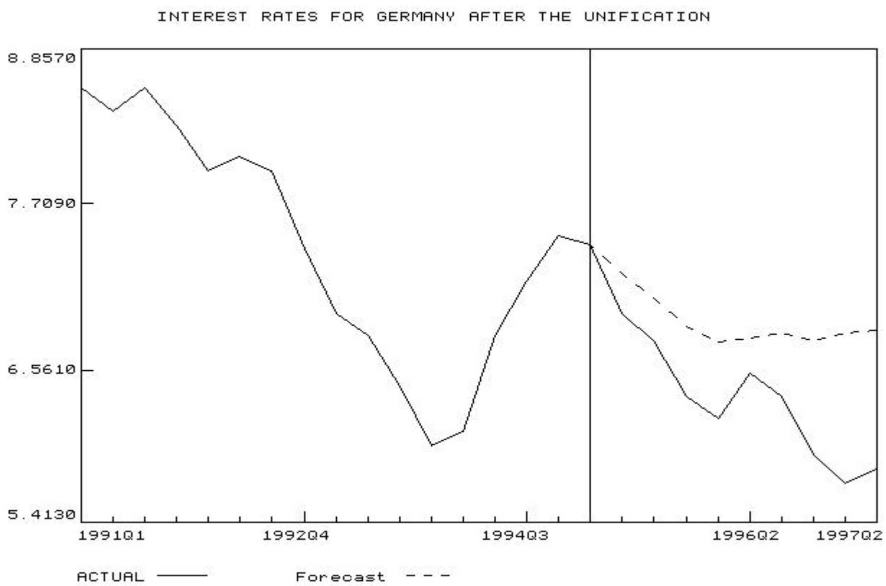


Figure 3: Germany after the unification



These show that the model is, as suspected, highly unstable. The one-step predictions from each country's reaction function move substantially away from the actual values in the post-fitting period. In the US there is a tendency for the model to underpredict, in the other two counties the tendency is the reverse, that of overprediction. Apart from these reported tests, other residual based tests we conducted, such as CUSUM, CUSUMSQ, and recursive least squares, confirmed this general finding of parameter instability.

So to conclude this section, we have argued that the practice of fitting econometric equations between policy instruments and objectives leads to misleading results. This is due to the acute problems in separately identifying policy responses to developments in the economy from the economy's response to changes in these instruments and other exogenous shocks in an empirical framework, and the fundamental problem with such directly estimated policy reaction functions is that they mix these elements together. Almost inevitably such econometric equations will prove to be structurally unstable. Hence, an alternative is needed and is found in the other widely used methodology of applying policy rules to complete macro models, evaluating their properties in the light of some performance criteria, such as the familiar quadratic loss function. We turn to these next.

(B) Policy rules in macro models

When using large macro econometric models there are two reasons for modelling the process of policy response to economic events. The first is the obvious importance of this topic to the policy formation process itself. The second is the need to provide a basic model closure so that the model is a sensible forecasting tool.

Thus, the use of models in policy formulation has always been one of the prime uses of macro econometric models. This use encompasses basic uses such as the traditional technique of exogenous fiscal and monetary policy and using the model to forecast conditional on these assumptions, to a complex range of optimal control techniques or endogenous feedback rules. Regardless of the degree of sophistication, the objective is the same; to help to specify a 'better' set of economic policies through the use of a fully specified model of the economy. In more complex modelling exercises, such as those using endogenous feedback rules for example, the analysis of policy formation is explicit and aims at specifying the ways the policy maker responds to economic events.

The model closure aspect of policy formulation is primarily a technical issue, and reflects the feature that policy formulation is so important to the behaviour of a model that it is unrealistic to attempt to evaluate model properties in isolation from assumptions made about policy formulation. Even where expectations are backward looking (such as adaptive expectations), the dynamics of the wage-price-exchange rate equations contains a unit root given the usual finding of long run derivative homogeneity, so the models may not be determinate unless a monetary rule is used in the model with the effect of stabilising inflation. Moreover as models have become more sophisticated the traditional treatment of economic policy as being an exogenous assumption has become increasingly untenable. For example where expectations formation follows rational expectations a model may not solve under the assumption of fixed policy settings, and indeed we know that often it should not. In comparative exercises, the specification of the policy response may have substantial effects on the response of a model to a shock and so any model comparison needs to be done on the basis of similar policy assumptions (e.g. Bryant et al 1988, 1993).

Hence, there has been a general move towards the use of explicit feedback rules in policy analysis using macro models. These have usually been a monetary rule using interest rates to target inflation and the output gap, and a fiscal rule relating fiscal instruments to deficit or debt ratios, effectively ruling out explosive paths for government borrowing.(the no-Ponzi game condition). A number of methods for representing these rules have been used however, even in econometric macro models. Often, though not always, in deterministic solutions rules are selected optimally (in the sense that their parameters are chosen to minimise some criteria). In stochastic analysis, rules are designed to minimise the variance of the key variables in the economy but invariably the rules are not optimal. This second feature is due to the numerical complexity of choosing optimal parameters in a stochastic model. We argue that these limitations are unnecessary. The essence of the approach set out later is contained in a simple technique which allows optimal parameter selection in a stochastic model and thus opens up the possibility of using full optimal feedback rules for policy analysis under uncertainty even in a multi player game setting. We proceed by building up the key ingredients in our approach to policy analysis: Optimal and optimal single rules, strategic policy setting, and finally allowing for stochastic effects.

(i) Optimal control

The basic underpinning of all policy analysis is an optimal control framework which specifies an objective function and an economic system and chooses the optimal setting for the policy instruments in the light of the these two elements. The basic idea takes a macromodel which, in its most general form, is a mapping from the known information set $X_t=x_0....x_T$, $Y_t=y_0....y_{t-1}$ onto the future endogenous variables $Y_{t+I,}$ i=0...T. An expression for such a general macromodel would be;

$$y(y_{t+i}, X, Y) = 0 \qquad (1)$$

This can also be written as a function of current information and - splitting the exogenous variables into *n* policy variables U, and the other exogenous variables X*:-

$$y_{t+i} = w(U, X^{*}, Y) \quad i = 1.....T \tag{2}$$

As is well known, a policy rule can then be obtained by minimising a cost function, such as the standard quadratic function given below:

$$MinC = \sum_{i=0}^{T} (Y_{t+i} - \overline{Y}_{t+i})^2 \tag{3}$$

where the optimal policy rule satisfies:

$$\sum_{i=0}^{T} 2(Y - \overline{Y}) w_{ujk} .(U, X^{*}, Y) = 0 \tag{4}$$

$$j = 1.....n$$

$$k = 1.....T$$

where

$$w_{ujk}(U, X^{*}, Y) = \frac{dw(X, U)}{duu_{jk}} \tag{5}$$

There are well established numerical techniques for solving such problems. An open loop solution does not take account of a change in the initial conditions or the exogenous variables except by recalculating the complete solution to (4). The alternative to this is to specify the solution to (4) in closed loop form which in general can be written as,

$$u_{jk} = \Phi(X, Y) \tag{6}$$

If the function Φ can be obtained then this gives a closed loop feedback, in that it is possible to calculate the appropriate change in u_j for any change in $X_{t..}$ This is often possible for linear models, but for the non-linear case one has to solve the optimisation problem numerically and hence derive open loop trajectories for the policy instruments, ie. a given value for each u_j in each t.

It is clear from equation (6) that the fully optimal rule makes use of the entire state vector of the model including all future values. This rule is therefore likely to be quite complex and, as already noted, it is not generally possible to solve this equation explicitly.

Arguments against using fully optimal rules are well known. Firstly they are based on the full information about the structure of the model. Optimal policy rules therefore tend to be highly model specific, as is demonstrated by Bray et al (1995). The rule will also be of limited value if there is uncertainty about either the underlying structure of the economy or at the very least the rate of dynamic adjustment in the economy. Secondly, the Lucas critique raises doubts about the usefulness of macroeconomic models for policy making when economic agents form expectations which are forward looking. The mere announcement of a future change in policy could alter agents behaviour, and with agents changing their expectations and hence their behaviour, the incentive to carry through the announced policy might evaporate. Put formally, in the presence of forward looking expectations in the model the derivative of the model solution to future policy changes is not zero, ie.

$$\frac{dY_t}{du_{jt+i}} \neq 0 \tag{7}$$

Thus a policy for period $t+i$ will be optimal for current period t, in which it is derived but may no longer be optimal when the future period $t+i$ actually arrives. Policy is thus time inconsistent.

To some extent developments in the literature have attempted to circumnavigate this problem. Barro and Gordon (1983), for example, examine whether reputational considerations can restore credibility for policy makers and hence avoid the inferior outcome of the time consistency constraint. They assume that policy makers suffer a loss of reputation if they renege on their earlier commitments. With this "punishment" mechanism in place, Barro and Gordon show that credible and sustainable policies, superior to the time consistent policy, can exist. This argument however seems to ignore the main message in Kydland and Prescott ( ), that *building* credibility will require monitoring the authorities actions, which will be very difficult if the optimal control rule is complex.

(ii) Simple Rules

The alternative to the full optimal feedback rule is rules which exploit only the information which is believed to be useful, de-emphasising the less reliable elements of the model's structure. Simple feedback rules are an example, and are generally a restricted form of the full optimal control solution which limit the amount of information drawn from the structure of the model to those areas which are of special relevance to the policy question at hand (see for example, Vines et. al. 1983; Currie and Levine, 1985; Taylor, 1985 and Edison et. al. 1988). By implicitly excluding much of the model, simple rules may be robust to uncertainty. Furthermore, if articulated publicly, they meet Kydland and Prescott's criteria of being simple and easy to interpret, and therefore useful when it comes to monitoring the authorities.

Simple feedback rules were developed in the engineering literature and later applied to economic systems by Phillips (1954) (1957). The full standard closed loop feedback rule includes elements of proportional, integral and derivative control;

$$\Delta u_t = b_1 \Delta^2 (Y_t - \overline{Y}_t) + b_2 \Delta (Y_t - \overline{Y}_t) + b_3 (Y_t - \overline{Y}_t) \tag{8}$$

Such a rule still only reflects a very small part of the optimal closed loop feedback rule given above, in particular only a very small part of the information set is utilised and only past or current values of the model variables affect the settings of the policy variables. This second point is particularly important as it means that the rule will normally only react to events sluggishly and this can give rise to slow and unstable policy responses. Obviously policy makers go to great lengths to anticipate future events in practice. It is however possible to go beyond the standard framework of (8) to incorporate this effect by adding a forward looking component to the feedback rule (see Hall and Nixon(1996)).

With simple rules there is an important distinction based on how the parameters of the rule are chosen. These may be chosen by trial and error, although later work parameterises simple rules more formally thus giving optimal simple rules. This is done quite simply be specifying an objective function such as (3) and then treating the parameters of the control rule (8) as the control variables which are to be determined so that (3) is minimised. This is the method used below.

(iii) Uncertainty

It is important to allow fully for a stochastic formulation because in non-linear models the expected value of the endogenous variables are not usually the same as the deterministic solution of the model. Moreover, we may actually be interested in designing policies which minimise the uncertainty around a particular outcome (i.e. we are interested in minimising the variance of the outcome). For any exercise where uncertainty figures, whether these involve optimality or not, then stochastic simulations are used (see Hall and Henry(1988) for a full survey). Previous research has considered the derivation of optimal policies where there is uncertainty. Hall and Stephenson (1990) for example, investigate the degree of bias in a model by using optimal stochastic control to evaluate the difference between the expected value and the deterministic value of a macro model. Their work was not directed at the variances of model outcomes. This, however, is considered by Rustem (1993) who proposed an approximation to the variance of a model when analysing it using optimal control, by adding an additional term to the objective function, depending on the way the function changes as the stochastic term changes.

A continuing theme in the present study, however, is to emphasise the limited nature of many previous analyses of policy rules where there is uncertainty. It is the case that there have been a number of studies evaluating policy rules or policy options using stochastic simulations to test whether the rule, for example, gave the smallest variance. (see Bryant et. al.(1989) and (1993), and Taylor(1993)). A common problem with these studies is that parameters of the rule are chosen in an arbitrary way. What we describe in section 3 aims to combine optimality with uncertainty (and game-theoretic ingredients). Before that, we outline the Taylor method, since it is close to ours, but it, like so much existing work, is based on ad-hoc paramerisation of its policy rules.

Essentially, Taylor (1993) posits a monetary feedback rule[3] for each country, using short term interest rates (RS)

$$RS - RS^* = P(+4) - P + g_1(P - P^*) + g_2(Y - Y^*) \tag{9}$$

where P is prices, and Y is detrended real output at time t. The (*) refers to target values for P and Y. Equation (9) is not derived as an optimal rule, unlike the rules we derive below. Instead, it is a plausible feedback rule allowing for responses to price and output shocks (i.e. countercyclically), with alternative degrees of accommodation being possible. In the case where $g_1 = g_2$, then (9) is a nominal income rule.

The issue of policy design - the setting of the g_i (i = 1, 2) parameters in the present context - then is paramount. Taylor approaches this problem by using stochastic simulations.

Thus for the structural macro economic model

$$A_0 Z_t = A(L) Z_{t-1} + b(L) u_t \tag{10}$$

where Z are endogenous, and u serially uncorrelated errors, we may write the reduced form

$$Z_t = \Sigma q_i(.) u_{t-i} \tag{11}$$

where q is a function of A_0, A(L) and B(L), and - crucially - depends on the parameters in the policy rule g_1 and g_2. Hence we may write, in general,

$$Y(g_1, g_2) = \sum_i q_i \Omega q_i' \tag{12}$$

[3]Fiscal policy rules are not considered in the Taylor analysis.

as the steady state variance - covariance matrix of the Z's, where Ω is the variance-covariance matrix of the Structural Model (10).

To search for appropriate settings of the policy parameter g_i, Taylor evaluates the historical performance of country empirical models, varying the g parameters in an ad-hoc way, and calibrating the consequent behaviour of the variability of the target variables prices and output. But, as is clear from (10) to (12), this problem can be set up as a dynamic stochastic optimal control problem. Taylor, for example, argues that the computation of such a general optimisation, with non linear rational expectations models coupled with stochastic shocks, is not feasible. Below, we show that with the efficiencies introduced by our method of conducting stochastic simulations such general optimisation solutions are achievable (see Hall (1997)), and are employed in the analysis we present here.

(iv) Policy Games

3. A new quantitative procedure for obtaining policy rules

(A) Summarising the background

As already described, existing work deriving policy rules is limited in several important ways. It may be helpful to summarise these limitations now.

- In traditional simulations, the "policy change" is arbitrary, and subject to the Sims critique – of an arbitrary distinction of endogenous and exogenous (including policy) variables;
- Where explicit endogenous policy rules are used, their parameterisation is arbitrary (i.e. is not typically a general optimisation procedure);
- There is often a limited treatment of uncertainty;
- Policy interactions between policy making institutions in different countries, and/or between such institutions in a single country, are implicit with little strategic analysis.

In what follows, we describe the methods we have adopted which aim to overcome most of these shortcomings

The present paper takes a different approach to policy analysis, and provides a *normative* analysis of the effects of shocks by optimising endogenous policy rules using an empirical model of the G6. In so doing, it overcomes some of the disadvantages of the earlier studies described above. As just noted, where these studies are of the traditional form of "policy analysis" which simulates the effects of an exogenous policy change, this is without an explicit policy framework including explicit policy objectives. It is often not explicitly stochastic. Notable exceptions to the latter are provided in Bryant (1993) and - in the case of monetary policy - by Taylor (1993).

(B) Optimal rules to minimise the variance of economic variables in a game context

Given the preceding discussion, the type of analysis we propose as an advance over current applications and their limitations is to choose the parameters of a set of rules so as to minimise the variance of selected variables in the economy when it is subject to a particular set of stochastic shocks. Moreover, this often needs to be done allowing for possible strategic interaction between different policy makers, so the analysis has to allow for game playing which will involve successive optimisations over a number of players to achieve a range of different forms of solution, eg Nash, stackelberg, co-operative etc.. We therefore specify the problem, in compact notation as,

$$\min \ \text{var} \ (C) = \text{var}(\sum_{t=1}^{T} \Phi_t \sum_{i=1}^{n} \Theta_i Y_{it})$$

(13)

$$Y_{it} = g(e,u)$$

where e is a matrix of k stochastic terms over the T periods of the model solution which have a given covariance matrix Ω_t, Y is the vector of endogenous variables in the model, Φ and Θ are weights in the cost function and u is a vector of control variables which in our case are the parameters of a control rule. In a policy game each player would have an objective function of this form.

The computational burden of this form of problem is considerable; to evaluate the variance alone needs a stochastic simulation involving thousands of conventional model solutions. This kind of solution would have to be calculated many hundreds of time during a conventional numerical optimisation. It seems that, for this reason alone, researchers have not pursued this approach to policy formulation. The innovation we propose is a simplification of the problem which will yield an identical solution for most forms of nonlinearity which are observed in the large macro models. The idea here is based on the notion that any monotonic transformation of the cost function will yield an identical solution for the control variables. So if we minimise the variance of the cost function (V(.)) with respect to a set of variables u then we will have exactly the same solution for u if we minimised a monotonic transformation of V (e.g. log (V) or V^2). We use these propositions to substantially reduce the computational problem in minimising V(.), using a special transformation based on two elements: the first is the technique of anti-thetic errors used in stochastic simulation, the second constructs a minimum set of replications which exactly reproduce the covariance matrix of the stochastic process.

Anti-thetic Errors

Anti-thetic errors simply mean that instead of drawing a sequence of completely random sets of shocks, the sets of shocks are chosen in symmetric pairs so that two replications from a stochastic simulation represent an exactly symmetric pair, in terms of the shocks being applied to the model. This technique increases the efficiency of stochastic simulations enormously but even one pair gives a lot of information. For example if the model is linear then the resulting average of the endogenous variables from the two solutions will be identical to the deterministic model solution, hence any divergence from the deterministic solution is an absolute sign of non-linearity

Minimum Set of Replications

For the moment lets assume that we are dealing with a single stochastic error term. In that case the following objective function would be our monotonic transformation of (13).

$$\min \ C^* = \sum_{t=1}^{t} \Phi_t \sum_{i=1}^{n} \Theta_i (\mid g(e,u) - g(0,u) \mid + \mid g(-e,u) - g(0,u) \mid)$$

(14)

This objective function minimises the absolute deviation from the no shock solution after applying an arbitrary size shock to the model. The antithetic errors are represented by the two terms with plus the shock and minus the shock. Our claim is that there is a monotonic transformation between this objective function and (13). Hence the resulting optimal u will also be the solution to (13).

If we were dealing with a single error this would obviously be sufficient to give the solution we require. However, there is a further complication when the vector of errors is larger than a single scalar. The problem is that any single draw of the error vector cannot be representative of the whole distribution of errors, so it cannot represent the covariance matrix. A scalar error can have a value equal to its standard error but a vector cannot have both variances and covariance's equal to the full covariance matrix. This point can be seen by considering the bivariate case. Let the covariance matrix be,

$$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \qquad (14)$$

Now any single pair of shocks cannot give both the variance and covariance's simultaneously. For example (1,1) has unit variances for both errors but a unit covariance, (1,0) would have a zero covariance but the variance on e_2 would also be zero. In fact, in this case it takes two sets of shocks to exactly replicate the covariance matrix. The required shocks are (1,-1), (1,1), which have unit variances for both errors and zero covariance. The anti-thetic pair corresponding to this would be (-1,1), (-1,-1). So if we were interested in solving the problem for a vector of two stochastic shocks we could do this by evaluating

$$\min \ C^* = \sum_{j=1}^{k} \ (\sum_{t=1}^{t} \Phi_t \sum_{i=1}^{n} \Theta_i (\, | \, g(e^j, u) - g(0,u) \, | + | \, g(-e^j, u) - g(0,u) \, | \,) \,) \qquad (15)$$

where k=2 and where the two vectors of shocks (e^j) are given as above. So in this case, instead of carrying out many thousand replications to estimate the variance of c, (VAR(C)) we can achieve the same object by calculating C* based on only four model solutions. This clearly brings the possibility of using optimal control within the bounds of computational feasibility, even in a game context.

The above case is an example of how the proposed procedure would work for a case of two shocks. In the general procedure we chose a set of k vectors of shocks such that

$$\Omega = \sum_{i=1}^{k} e_i e_i \qquad (16)$$

This will generally involve approximately n=k sets of shocks where n is the number of stochastic elements in the model being examined. The reason why this is only approximate is that the relationship is different for an even and odd number of shocks. The above formulae gives an exact determination of the shocks when n is odd but when it is even we need some extra conditions to uniquely determine the shocks. In the bivariate case above, for example, there are actually an infinite number of pairs which would give the required covariance matrix. This can be seen by writing out the problem in full.

$$\begin{aligned} \Omega_{11} &= e_{11}^2 + e_{21}^2 \\ \Omega_{12} &= e_{11}e_{12} + e_{21}e_{22} \\ \Omega_{22} &= e_{12}^2 + e_{22}^2 \end{aligned} \qquad (17)$$

this yields 3 equations in four unknowns and so we need to impose an extra condition to uniquely determine the shocks, we propose simply setting $e_{11}^2 = \Omega_{11}$ as the extra required restriction. For an odd number of shocks we exactly determine the k vectors of errors.

The following table gives the relationship between n, the dimension of the covariance matrix, k the minimum number of sets of shocks and r, the number of extra sets of restrictions required.

N	K	R
1	1	0
2	2	1
3	3	3
4	4	6
5	5	10
6	6	15
7	7	21

So in general, given the extra effect of the antithetic errors, we will need approximately twice number of replications as the dimension of the covariance matrix. If we wish to calculate an optimal policy rule for a countries monetary policy given shocks to both the exchange rate in that country and shocks to the exchange rate in two other country's we would therefore need six model solutions to evaluate the objective function we need to maximise.

The Monotonic Transformation

This proposed technique will not always give exactly the same answer as (13) above, it is possible that for a sufficiently non-linear model the mapping between (13) and (15) would cease to be monotonic and hence they would have different solutions. However our argument is that this would require and extremly perverse and unusual form of non-linearity to be present which is not typical of any macroeconomic model.

The essence of the monotonicity assumption is that if we have any two sets of control variables, u^1 and u^2, such that

$$C^*(u^1) > C^*(u^2) \qquad (18)$$

that is, a deviation in C from its deterministic value is larger for the set of control variables u^1 than u^2. Then monotonicity between the two objective functions means that

$$var(C(u^1)) > var(C(u^2)) \qquad (19)$$

This simply amounts to the assumption that if one set of control produces larger deviations in the model variables from their deterministic values then it will also lead to a larger variance. In our view it is almost inconceivable to think of an economic model where this would not be true.

4. The G-6 model

The G-6 model used here to illustrate the technique proposed above is a reasonably small world model, which is designed to focus on the interaction between the G6 economies. It was specifically designed with a view to analysing the policy co-ordination question amongst the major industrial countries. It comprises six country blocks, the USA, Japan, Germany, UK, France and Italy with the rest of the world as a residual group. Each country model is a small, econometric model with a clear analytical basis, comprising

- A transparent and theoretically consistent supply side, but one where insufficient capital may constrain employment in the medium term (see Henry and Rowthorn (1999) and Blanchard (1998)). To see this, only the wage and price equations are needed. In the standard model the wage equation is based on union-firm bargaining, and the price equation is typically taken to be of the mark-up form. Thus, suppose

$$w - p = \alpha\beta_2(k - l) + \alpha_2 U + \alpha_3 Z$$

$$p - w = \beta_0 + \beta_1(y - y^*) + \beta_2(y - k).$$

where w is earnings, p is prices, k the capital stock, l the labour force, U is unemployment, y is GDP (and y* its trend level), and Z a set of exogenous "push" variables. (see Layard, Nickell and Jackman(1991) on which this is based). Assuming a linear homogeneous CD technology, the last term in the price equation can be written as $\beta_2\alpha(l - k)$ where α is the output elasticity of employment. Hence the capital-labour ratio has an equal and offsetting effect in the wage-price system, and when these are solved for equilibrium unemployment (U*, the NAIRU) this too is independent of the capital-labour ratio.

We test, and readily reject this restriction in each of the countries. Hence, technology appears not to follow the linear homogeneous CD case, and, more significantly, U* is not independent of the capital-labour ratio. The importance of this finding is profound, since it implies that equilibrium unemployment is not independent of capital accumulation. As changes in monetary policy imply changes in real interest rates in the presence of nominal rigidities, this also leads to the implication that changes in monetary policy can affect the NAIRU.

- A simple, but complete model of the demand side, with a consistent bilateral trade model between all six country blocks. This is sufficiently standard not to warrant further comment here. (But see references for details)

- An important role for wealth in consumption spending, where national wealth accumulates via current account surpluses, and changes in national wealth occur due to revaluation effects in bond and equity markets. The strength of these financial spillovers depends – among other things – on how expectations of future earnings in financial markets are formed. Below we comment on a further important innovation in the present study concerning the methods we use for representing expectation formation.

- Medium term solvency ensured by simple fiscal rules depending upon debt/income ratios.

- Model closure is also ensured through the use of simple monetary rules depending upon inflation and deviation of output from trend. Both this and the forgoing fiscal rule are of the form given in equation ( ) and ( ) above.

- As already mentioned, expectations are an important feature in the models of financial markets behaviour, and in this model we use the assumption of boundedly rational learning. It is well known that rational expectations are a special case of the boundedly rational hypothesis, but in any event, the boundedly rational form is preferable in that it does not make the extreme informational assumptions that the pure rationality assumption does. Further details on the empirical techniques used to implement boundedly rational expectations in macro-econometric models are found in [ ].

The key equations in the G-6 model are estimated, allowing for non-stationarities in the data and the existence of cointegration between these non-stationary variables where it is present. Further details on the empirical results are presented in Hall and Henry(2000).

The next section provides an application of the techniques outlined in Section 3 to this model of the G-6. It is an illustrative exercise; undertaken to show the consequence of uncoordinated in contrast to coordinated policy between the six countries. For this illustration, we take an initial fiscal shock in the US as beginning a round of further policy responses – both in the US itself and in the other countries.

5. Policy exercises

In these exercises we derive the optimal feedback response of monetary policy in the face of a stochastic demand shock with a normal distribution and a standard error equivalent to 5% of US government expenditure, for the entire solution period 1986-1994. Four quite separate forms of solutions are then compared. In the first, the US reacts optimally under the assumption that monetary policy (interest rates) remains fixed in the other countries. The same exercise is repeated for each country, giving a "national" optimal rule for each. This exercise is the equivalent to what a modeller might carry out using only a single country model for policy analysis. In the second exercise, every country uses its "national" rule from the first case to optimise. The case illustrates that although each rule is optimal in isolation when combined they can perform in a very different way. The third case is where each country optimises in the light, and the knowledge of, optimal behaviour in each other country but without any attempt at co-operating or considering the implications of its actions on the other countries. This gives a Nash solution. In the last case we have a fully cooperative solution. In what follows we refer to the first as single country optimising, the second as multicountry I (where each of the country assumes no policy reaction from the other). The third is multicountry II (Nash) and the last is multicountry III which is a fully co-operative solution.

A final point to note is that the results of the exercise are difficult to illustrate. The model exercise performed is the full stochastic optimisation outlined in section 3. However the output of this exercise is just the computed values for the three feedback parameters in the monetary policy rule and the corresponding value for the objective function. These are not very informative about how different are the effects of the different rules. So rather than report these parameter values we illustrate the performance of the rules in each of the exercises by carrying out a full model simulation of a demand increase of 1 standard error of the shock using the optimal values of the policy rule already obtained. This then allows us to compare the performance of the rules under the various forms of co-operation.

(*a*) *Single country optimising*

In this case, each national authority optimises the weights of its PID monetary rule, in order to minimise the deviations of inflation from its base following the shock to the US demand. But in these exercises, in each country, policy actions are governed by the national monetary rule under the assumption that there is no policy reaction from the other countries. There are *consequences* for each country, which flow from the actions of the others nevertheless. Here these take the form of the spillover effects noted in our introductory section. That is, there are orthodox trade quantity and trade price effects affecting the other countries following the US demand shock, operating through net trade and the real exchange rate. But, for example when we carry out the US exercise, as monetary policy in the US is changed to counteract the inflationary effects of the demand shock, we assume that real interest rates do not rise elsewhere. Case (ii) introduces this further effect as explained in the introduction, and these interest rate changes will then exert additional effects upon wages, prices and employment in the medium term, and hence the inflation-unemployment choices for the authorities. How important are these latter interest rate effects? We can consider the evidence on this in comparison between single country optimising and multicountry I.

Figure 5: Single Country Optimising:
Inflation Effects based on US optimising only

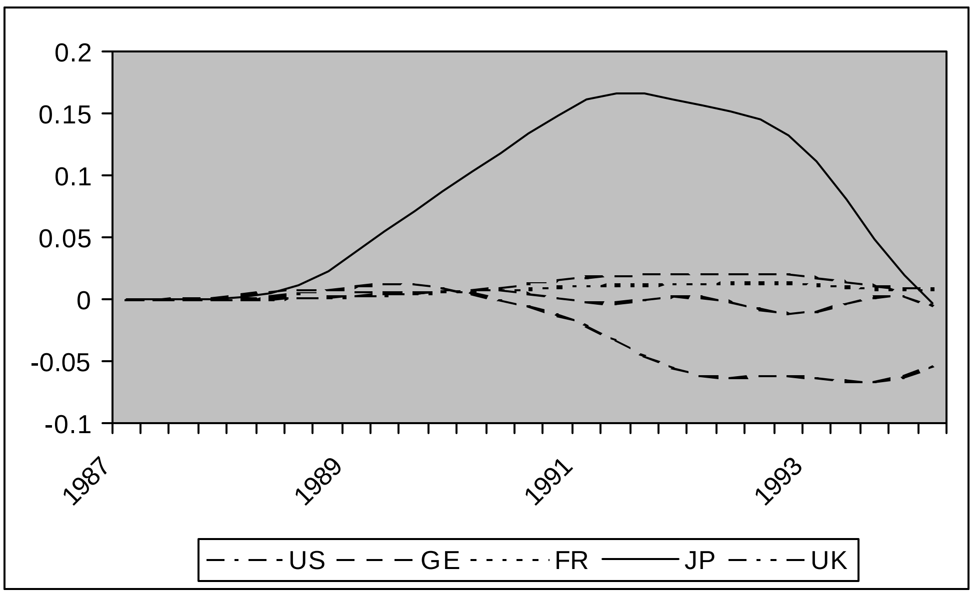


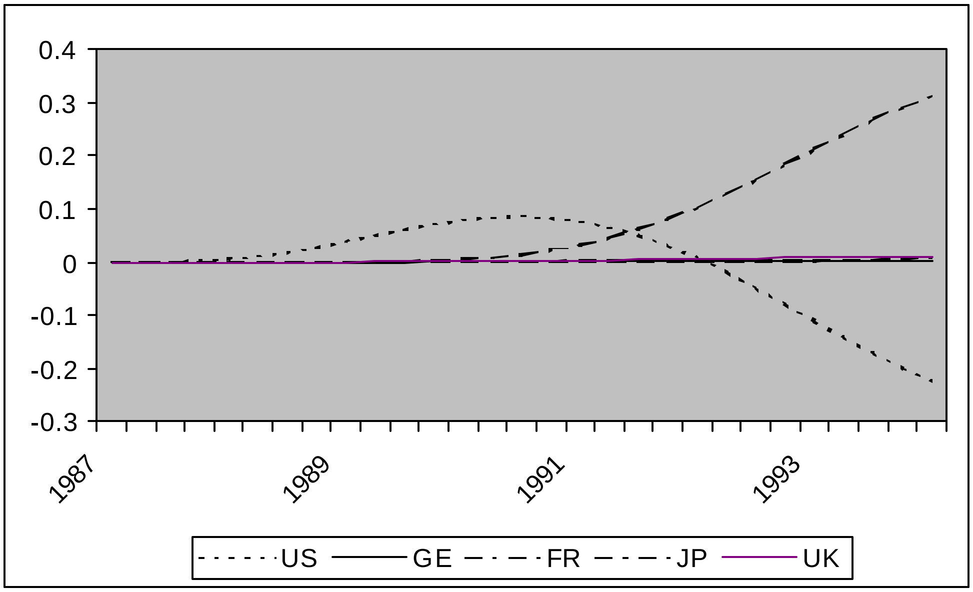
Figure 5 shows the inflation deviations due to a positive US demand shock accompanied by optimal US monetary response, assuming there is no policy response in the other countries.

What Figure 5 shows is that the US completely contains the inflationary stimulus due to the (optimal) way it sets its monetary policy. Inflation is contained in this case by effectively exporting the inflation overseas. That is, the UK, France and Japan all experience an increase in the rate of inflation as the US raises its interest rates and appreciates its currency to contain the inflationary shock there. Of course this policy works for the US primarily because there is no reaction from the other countries, which is obviously an unreasonable assumption. Overcoming this entails first deriving rules for each country, which are qualitatively the same as the one above for the US. That is, they are optimal rules for each country treated singly. In each case the country concerned can successfully control inflation domestically by appreciating the currency and exporting the inflation abroad. We do not show the results of all these exercises to conserve space. The next exercise however then investigates the effect of putting all these optimal single country policies together simultaneously to see how they interact. This is what we term Multicountry I.

(*b*) *Multicountry I*

Figure 6 demonstrates that the single country policy is not very effective when implemented by all countries at once. Inflation cycles through the system, first being forced out of the US but then coming back again as the other countries react defensively.

Figure 6 Single Country Optimising:
All countries reacting

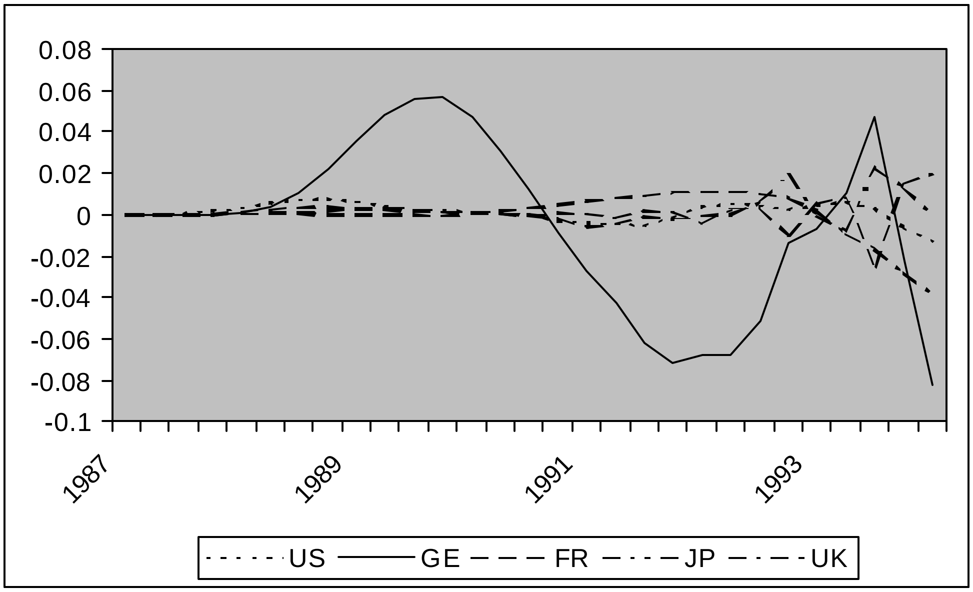


We are now in a position to analyse in a preliminary way the optimal responses to the US fiscal shock on a proper multicountry basis. In this next exercise, all countries respond together, each country according to its own optimal monetary policy rule derived from the simple country optimising exercise above. It is a limited form of multicountry response: although each country follows a (national) optimal rule, it assumes there will be no policy reaction in the other countries. This is an incorrect assumption to make, and we explore the effects of relaxing it in (*c*) below. However, the present exercise does introduce further forms of spillover compared with the traditional case (which came in (*a*) above). Firstly, there are effects between interest rates across countries due to the workings of interest arbitrage. Secondly, there are policy induced effects on interest rates, as each national authority seeks to offset the inflation consequences of the US fiscal expansion, using its own monetary policy rule. For both reasons, there will be inflation and unemployment effects due to the effects of changing interest rates on expenditures, including investment, and thence the capital stock.

Although this exercise is obviously limited - it assumes that each country assumes the others will not react to its own policy changes, incorrectly - it indicates that the spillover effects of unilateral fiscal expansion can be very substantial indeed. Why does this finding differ so much from the typical finding of limited spillovers? There are two parts to the answer to this. The first is that the transmission mechanisms included in our exercise are more elaborate than normally used. In particular the emphasis we place upon the medium term effects of interest rate changes, the capital stock and the supply side gives added potency to the international transmission of fiscal shocks which themselves impinge upon interest rates (via orthodox crowding out *and* because the fiscal shock stimulates monetary responses through the monetary rule). The second is that monetary policy is an optimal policy aimed to squeeze inflation shocks out. In practice monetary reactions to inflation changes have not proved so severe.

(*c*) *Multicountry II*

Figure 7. The full NASH game

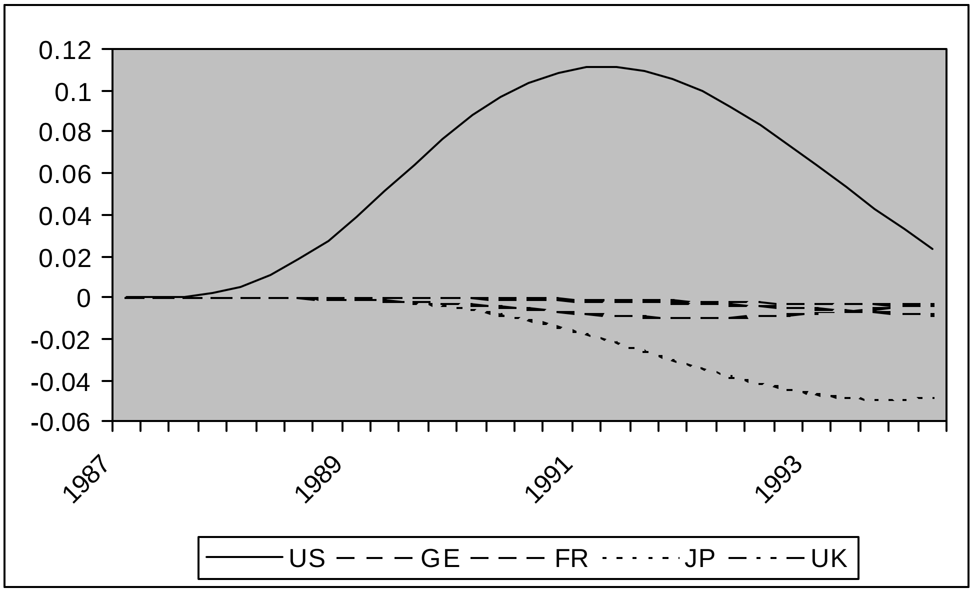


One of the limiting assumptions in the previous exercise is now dropped, and we proceed to implement a full Nash solution. Allowing for each country to optimise, given that it assumes (correctly) that each of the other does the same, has evident consequences for the outcomes following the US fiscal shock. Figure 7 shows that the system is now much more stable. The UK and France now experience very little inflation and the US and Japanese inflation rates cycle around zero in a more controlled fashion. Hence, this case may be characterised as showing that better inflation can be achieved with smaller output losses when adopting Nash-type optimal strategic policies compared with single country optimising.

(*d*) *Multicountry III*

Once a fully cooperative international policy regime is instituted the situation is further improved over the full Nash solution. Figure 8 gives the deviations in inflation from base for this case. Inflation is broadly full controlled in the all the countries except Japan which is still improved over the NASH solution.

Figure 8: The Co-operative solution



6. Conclusions

We review recent methods of policy analysis in this paper, arguing that these have important deficiencies. This is most clearly the case in applications using Taylor Rules of some form fitted to past data. Although these may be of possible use in predicting the short term movements in interest rates, they do not appear structurally stable according to our tests, and so are unlikely to represent what the authority's policy reaction function is. Turning to the model based applications; we have advocated a technique, which brings together all the previous elements – optimality, uncertainty, and strategic behaviour – as the basis for the analysis of issues of policy coordination. Although very preliminary, our applications show there is much that can be done using this new approach.

References

Barrel, R., and Pain, N., (1998), "Working Under Different Rules: An Analysis of the Effects of the Asian Crisis under Different Policy Feedback Rules", NIESR, mimeo.

Barro, R.J., and Gordon, (1983), "Rules, Discretion and Reputation in a Model of Monetary Policy", *Journal of Monetary Economics*, Vol. 22, pp. 101-21.

Blake, A., and Weale, M., (1998), "Costs of Separating Budgetary Policy from Control of Inflation, A Neglected Aspect of Central Bank Independence", NIESR, mimeo.

Blake, A.P. and Westerway, P.F (1996) "Credibility and the Effectiveness of Inflation Targeting Regimes", *The Manchester School Supplement.*

Blanchard, O., (1998), "Revisiting European Unemployment: Unemployment, Capital Accumulation and Factor Prices", NBER Working Paper No. 6566, Washington DC.

Bray, J., Hall, S.G., Kuleshov, A., Nixon, J., and Westaway, P., (1995), "The Interfaces Between Policy Markers, Markets and Modellers", *The Economic Journal*, Vol. 105, No. 431, pp. 989-1000.

Bryant, R.C., Henderson, D.W., Holtham, G., Hooper, P., and Symanski, S.,(eds.)`(1988), "Empirical Macroeconomics for Interdependent Economies" Washington DC, Brookings Institute.

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

Caporale, G., Chui, M., Hall, S.G., and Henry, S.G.B., (1997), "Empirical Models of the International Economy", CEF, mimeo.

Chow, G.C., (1975), *Analysis and Control of Dynamic Economic Systems*, Wiley, New York.

Clarida, R., Gali, J., and Gerlter, M., (1998), "Monetary Policy Rules in Practice: Some International Evidence", "European Economic Review, 42. p.1033-1067.

Currie, D.A., and Levine, P., (1985), "Simple Macroeconomic Policy Rules in an Open Economy", *The Economic Journal*, Vol.85, pp. 60-70.

Currie, D.A. and Levine, P ( )

Demerzis M., Hughes-Hallett A. And Viegi N. (1999) `Can the ECB be Truly Independent? Should it be?'Empirica, November.

Edison, H., Miller, M., and Williamson, J., (1988), "On Evaluating and Extending the Target Zone Proposal", *Journal of Policy Modelling*.

Fair, R.C., (1984), *Specification, Estimation and Analysis of Macroeconomic Models*, Harvard University Press, Cambridge, MA.

Godley, W and Martin, W. (1999), " America's New Era", LDS/OEF Economic Outlook, Vol 24, Number 1, October.

Hall, S.G., (1997), "Modelling Economic Policy Responses", Discussion Paper No. 08-97, Centre for Economic Forecasting, London Business School.

Hall, S.G., and Henry, S.G.B., (1988), *Macroeconomic Modelling*, North Holland, Amsterdam.

Hall, S.G., and Nixon, J., (1996), "Controlling Inflation: Modelling Monetary Policy in the 1990s" in Macroeconomic Modelling in a Changing World, ed Allen, C., and Hall, S., John Wiley and Sons.

Hall, S.G., and Stephenson, M.J., (1990), "Optimal Control of Stochastic Non-Linear Models", in Henry S G B and Patterson (eds), *Economic Modelling at the Bank of England*, Chapman and Hall, London.

Henry, SGB., Lindh, C., and Williams, G., (1998), "A Model of the Developed World Economy", Centre for Economic Forecasting, mimeo.

Henry, SGB., and Rowthorn, R., (1999), "Unemployment, Wages and Capital: An Analysis of the Short and Medium Run", Centre for Economic Forecasting, mimeo.

Hughes-Hallett ( )

Kydland, F.E., and Prescott, E.C., (1977), "Rules Rather than Discretion: The Inconsistency of Optimal Plans", *Journal of Political Economy*, pp. 473-92.

Lucas, R.E., (1976), "Econometric Policy Evaluation: A Critique", in *The Phillips Curve and Labour Markets*, K Brunner and A H Meltzer (eds), North Holland, Amsterdam, pp 19-46.

Nash, J.F., (1951), "Non-Co-operative Games" Annals of Mathematics, p286-95, 54.

Phillips, A.W., (1954), "Stabilisation Policy in a Closed Economy", *The Economic Journal*, Vol. 64, pp. 290-323.

Phillips, A.W., (1957), "Stabilisation Policy and the Time-form of Lagged Responses"; *Economic Journal*, Vol. 67, pp. 265-277.

Rustem, B., (1993), "Stochastic and Robust Control of Nonlinear Economic Systems", European Journal of Operations Research.

Svensson (1998), "Open Economy Inflation Targetting", NBER Working Paper No. 6545. Cambridge, Mass.

Taylor, J.B., (1985), "International Coordination in the Design of Macroeconomic Policy Rules", *European Economic Review*, Vol. 28, pp. 53-82.

Taylor, (1993), "Macroeconomic Policy in a World Economy", WW Norton & Co., New York.

Vines, D., Maciejowski, J.M., and Meade, J.E., (1983), *Stagflation, Vol 2: Demand Management*, George Allen and Unwin, London.

Walton and Massone (1999), "MPC Still Following Taylor Rule", Goldman Sachs UK Weekly Analyst, Issue No. 316, 5th February.