Base Money Rules in the United Kingdom

by

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Contents

Abstract

We conduct counterfactual stochastic simulation of McCallum's monetary policy rule for the United Kingdom. This rule targets nominal GDP using the monetary base as its instrument. It is able to secure a dramatic improvement in inflation performance compared with historical outturns, at the same time imposing few countervailing costs, measured in terms of output or instrument instability. An example is given of how the rule might be used at an operational level in the setting of United Kingdom monetary policy.

1 Introduction

Economists have long debated the merits - and demerits - of policy rules. Fischer (1990) observes that the rules versus discretion debate is already over 150 years old. Through history, the fortunes of this debate have pendulumed. In the monetary policy field, Friedman's (1959) *k%* growth rule was a guiding principle for a great many monetary policy-makers through the 1970s and 1980s. Its attraction was obvious. A monetary policy autopilot substituted hard policy choices with simple mechanistic actions. But academic trial - and no little practical error - have in time suggested that a *k%* rule may, for most policy purposes, be too restrictive. Instead there exists a range of *feedback* rules whose performance will typically dominate that of a fixed growth rule [see, eg, Friedman (1975), Buiter (1981) and Dotsey and King (1985)]. This much is a clear *a priori.*

Much less clear *a priori*, however, is the precise form such a policy feedback rule should take: which *instrument* should be controlled (money prices or quantities); which - if any - *intermediate variables* should be monitored; and which *final variables* should be targeted. Theory tells us that answers to these questions depend upon the economy's stochastic structure [Friedman (1990)]. So such questions can only be meaningfully tackled at an empirical level. As this has been recognised, there has been a groundswell of recent interest in stochastic simulations of alternative policy rules. The books by Bryant, Hooper and Mann (1993) and Taylor (1993) offer two recent examples.

This paper conducts similar counterfactual policy analysis for the United Kingdom. It considers the performance of a specific class of monetary policy feedback rules, advocated in a set of papers by one of the authors (McCallum 1988, 1990a, 1993). This rule - hereafter "McCallum's rule" - feeds back from the deviation of *nominal GDP* from a preset path, using the *monetary base* as its (implicit) instrument. McCallum (*ibid.*) and Judd and Motley (1991) present evidence to suggest that this rule would have performed favourably in stabilising prices and GDP in the United States and Japan in much of the period since the second world war;[1] while McCallum (1990b) suggests that such a rule could have helped significantly smooth aggregate fluctuations in the United States during the 1930s, thus possibly preventing the Great Depression.

(1) Friedman (1988) and Croushore and Stark (1995) offer some cautionary notes.

What relevance has such a rule to the United Kingdom? At first blush, very little it would seem. For the McCallum rule targets money GDP - while United Kingdom monetary policy's final objective is prices, as embodied in an inflation target of 2.5% or less. Further, the McCallum rule uses the monetary base as its instrument - whereas institutional practice points towards short-term interest rates as the monetary policy lever in the United Kingdom and elsewhere. So on both targets and instruments, it could be argued that the McCallum rule is some way wide of the institutional mark. In practice, however, these differences are more apparent than real.

On *targets*, it is clear that monetary policy actions - even under an inflation target - are not invariant to GDP outcomes. As a *practical* matter, too rapid disinflation could incur prohibitive real costs - costs which monetary policy might legitimately guard against. And, as Rogoff (1985) shows, as a *theoretical* matter it is very rarely optimal to place zero weight on output stabilisation when forming monetary policy choices: in general, this leads to an inefficient outcome. So for both practical and theoretical reasons, output outcomes are very much a valid - if sometimes implicit - consideration when forming monetary policy choices, even under an inflation target regime. Indeed, inflation targets condense to *de facto* nominal income targets in most states of the world. In the face of demand shocks, both targets imply the same monetary policy response. This is not the case in the face of supply shocks [see, for example, Bean (1983)]. But since most inflation-target countries specify exemptions or escape clashes from the target in the event of major supply shocks, the two targeting procedures still have a direct correspondence when operated in practice [see, for example, Mayes and Chapple (1995) for the New Zealand experience].

On *instruments,* Goodhart (1994) has recently criticised empirical studies which have used the monetary base as the implied instrument of monetary policy. The feasibility and desirability of money base control is a contentious issue in its own right. But this debate is, in the main, tangential to our exercise here. For us, it does not much matter whether the central bank's liabilities are controlled *directly*; or whether instead they serve a more *indirect* role as an intermediate *information variable*, with short-term interest rates as the policy instrument aiming at this intermediate variable.(2) McCallum (1995) provides an empirical example of the latter two-stage approach to monetary policy

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(2) Goodhart (1994) recognises such a potential role for the monetary base as an information variable when setting monetary policy.

formulation, whereby interest rates are adjusted to ensure that base money growth is consistent each quarter with the McCallum rule. This study shows that the implied path for interest rates does not become excessively volatile under such a rule - a potential criticism of this type of approach.

Indeed, as an information variable the monetary base has a number of attractions - both conceptual and empirical. Conceptually, some monetary theory would ascribe the central bank balance sheet a key role in pinning down the economy's equilibrium price level. This follows from base money's uniqueness as the ultimate means of payment for transactions [see, for example, Fama (1983)]. Empirically, too, base money's credentials - in the United Kingdom at least - are impressive. Since the Second World War, base money velocity trends in the United Kingdom have been by far the most predictable of any monetary aggregate. For example, over the last thirty years the variability of narrow money velocity in the United Kingdom has been around two thirds that of broad money (M4) velocity. Finding stable and well-defined structural demand for narrow money functions has thus proved reasonably straightforward [see, for example, Breedon and Fisher (1993) for M0]. And perhaps most importantly, as an empirical leading indicator of inflation narrow money has been found not only to be far superior to broader monetary aggregates [Astley and Haldane (1995)], but also as good as any real-side indicator too [Henry and Pesaran (1992)].

This is not to suggest that the monetary base is the only information variable which monetary policy might usefully feed back from. As is well known, the optimal feedback rule will in general comprise a wide range of information variables [Friedman (1990)]. A simple rule, such as McCallum's, will never substitute perfectly for the policy-makers' inflation projection, which combines information from a myriad of indicators - including, significantly, policy-makers' judgment. Nor will such a rule be capable of macro *fine-tuning*. But it should be able to isolate and correct "big" policy mistakes - it facilitates *coarse-tuning* - by providing reference paths for narrow money which are consistent with meeting policy objectives. Such reference paths might then prove a useful "add-on" to the existing policy formation process. They offer a compact and transparent means of synthesising the inflationary information content of narrow money. The rule can be thought of as offering a *dynamic* monitoring range for narrow money which, unlike the current static monitoring ranges in the United Kingdom, could serve as a cross-check on monetary conditions quarter-by-quarter. We provide an example of how this might work at the end of the paper.

The paper is planned as follows: the next Section discusses methodology; Sections 3 through 5 then consider a set of macro-models - of increasing sophistication - within which our monetary policy rule will be imbedded and its performance assessed; Section 6 provides an example of how such a rule could be used at a practical level, serving as a cross-check on monetary policy performance; Section 7 briefly summarises.

2 Methodology

In assessing the performance of the McCallum rule, we use counterfactual stochastic simulations. These have three basic ingredients: (a) a model (or set of models) describing how the economy functions; (b) a monetary policy rule (or set of rules) to allow a counterfactual comparison; and (c) a set of behavioural shocks to feed into the system, which the monetary policy rule is then asked to cope with. Consider each of these in turn.

(a) Choice of macro-model

The starting point here should be the recognition that there is no off-the-shelf macroeconomic paradigm upon which to draw. This uncertainty is particularly acute in - though not exclusive to - modelling the short-run aggregate supply curve. Moreover, the choice of an appropriate model is an issue of fundamental importance: first, because of the susceptibility of our counterfactual simulations to the Lucas critique; and second, because of the potential sensitivity of policy conclusions to misspecification of the underlying model.

McCallum's (op.cit.) approach to this problem is to experiment with a variety of macro systems, ranging from atheoretic single equations, through multivariate vector autoregressions (VARs), to small structural models. We follow this eclectic approach here too.[3] We use three types of basic model, described in sections 3 through 5. First, we consider a simple single equation, following McCallum (op.cit.). Second, we experiment with some VARs, as in McCallum (op.cit.), Judd and Motley (1991, 1992) and Feldstein and Stock (1994).[4] And finally we turn to some small, semi-structural, macro-models, the type of which McCallum (op.cit.) and Taylor (1993) have used for policy

(3) Judd and Motley (1991, 1992) also use a range of small macro-models in their simulations.
(4) Feldstein and Stock conduct structural stability tests of the coefficients in their VAR systems in an attempt to minimise Lucas critique problems.

analysis. Taken together, these set of models should offer some defense against Lucas critique and misspecification problems - though, clearly, as the models are neither truly structural nor fundamentally different in terms of their reduced-form responses they do not secure immunity from such problems.

(b) Choice of monetary policy rule

As discussed above, our primary interest is in McCallum's rule which can be written:

$$\Delta b_t = \alpha - (1/16)\,[x_{t-1} - b_{t-1} - x_{t-17} + b_{t-17}] + \lambda\,[x^* - x]_{t-1} \qquad (1)$$

where b denotes the log of the monetary base, x is the log of money GDP and a * denotes a target value. All data are quarterly. The growth in the base, Δb, can be interpreted here either as the policy instrument or as an information variable entering the authorities' decision set when setting interest rates. The rule then contains three terms.

The *constant term*, α, fixes the path for steady-state nominal income growth. For the United Kingdom, we set it to 0.01 (1%) in our simulations, which corresponds to 4% annual nominal GDP growth. This can be decomposed as 2.25/2.5% average real GDP growth - which is around the empirical average over the simulation period - and a 1.75/1.5% average inflation target. Slightly lower real GDP assumptions would give us a slightly higher target inflation rate.(5) α is the analogue of the "*k*" in Friedman's fixed money-growth rule.

The second term in **(1)** is an adjustment for secular base money *velocity trends*. Following McCallum (1988), it is modelled as a very simple backward-looking four-year moving average. The long averaging period is used because this term is intended to capture long-lasting institutional changes, not cyclical factors. We could clearly model this velocity adjustment in a more sophisticated behavioural manner. This would probably improve the rule's performance.

The third term reflects *policy feedback* responses related to cyclical conditions. It is this term that most clearly distinguishes **(1)** from a Friedmanite fixed money-growth rule. λ, here, is a feedback parameter, dictating the speed with which deviations of money GDP from its target path are offset through

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(5) McCallum (1988, 1993) uses slightly higher real growth assumptions for the United States and Japan, reflecting their superior average growth performance since the Second World War.

monetary policy actions. In the simulations below, we typically look at the performance of the rule over values of λ between zero and unity.[6] Issues of dynamic instability become relevant for values of λ much in excess of unity.

The *feedback variable* in (1) is nominal income. Nominal GDP targets have a corpus of theoretical and empirical support: see, for example, Bean (1983), Taylor (1993), Hall and Mankiw (1994), Feldstein and Stock (1994). They can be motivated in any number of ways. For example, in the face of supply shocks, money GDP targets provide exactly the right - automatically stabilising - monetary policy response, since they accommodate (rather than offset) the change in the equilibrium price level resulting from the shock. Alternatively, nominal income targets might be favoured because we were agnostic about the short-run real/nominal split of money GDP - perhaps because the slope of the short-run aggregate supply schedule remains an area of great contention among macroeconomists.

The choice of a target path for nominal GDP - x^* - also merits some discussion. As in McCallum (1993), we experiment (at least to begin with) with three specifications of x^*:

$$x_t^* = x_{t-1}^* + 0.01 \qquad \text{: TAR (Levels Target)} \qquad \textbf{(2a)}$$

$$x_t^* = x_{t-1} + 0.01 \qquad \text{: TARA (Growth Target)} \qquad \textbf{(2b)}$$

$$x_t^* = 0.2 * x_{t-1}^* + 0.8 * x_{t-1} + 0.01 \qquad \text{: TARM (Mixed Target)} \qquad \textbf{(2c)}$$

Using the *levels* target, TAR, induces trend-stationarity of nominal GDP. This might be thought desirable because many of the costs of price instability are believed to derive from trends in the price level (rather than its growth rate). The feedback term in (1) might then be likened to an error-correction mechanism. Or, to borrow Phillips' (1954) terminology, it secures *integral* control of the target variable.

Nevertheless, a levels target for nominal GDP may carry a cost. The argument that a nominal GDP target offers the optimal response to shocks is dependent upon the nature of the shocks and the nature of the target. If shocks to prices and output are only temporary, then a levels nominal GDP target will be

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(6) Feldstein and Stock (1994) conduct an optimal control exercise to discover the variance-minimising value of the feedback parameter within a particular model.

appropriate: in the short-run the interaction between prices and real activity should (approximately) offset each other so that the nominal GDP target will accommodate the shock; while in the long-run prices and output will return to equilibrium. However, if there are permanent shocks to output, real GDP will have a unit root. So, for a given target inflation rate, long-run equilibrium nominal GDP will change. In this case a *growth* rate target for nominal GDP - such on TARA - will be appropriate as it will adjust in response to shocks and treat past levels target misses as bygones. Or, put differently, the policy-maker should aim to secure *proportional* control in the face of permanent shocks. Feldstein and Stock (1994) favour a growth rate target for just these reasons.(7)

Reflecting these considerations, we experiment with both levels and growth rate targets here. We also consider a hybrid target (TARM) which mixes the two. This uses the (arbitrary) weights used in McCallum (1993, 1995) of 0.2 on the levels and 0.8 on the growth target. This hybrid target would be consistent with a world in which both temporary and permanent shocks to real GDP occur, with relative frequencies of 0.8 and 0.2 respectively. Alternatively, we might note that Phillips' (1954) *optimal* PID - proportional, integral, derivative - controller combined more than one type of feedback mechanism.(8)

(c) Simulation techniques

Stochastic simulations feed into the rule-augmented model measures of shocks, to assess how well the rule could have coped with smoothing out stochastic disturbances. There are basically two approaches to generating such shocks. One is to conduct counterfactual analysis, using as shocks the historically-estimated residuals backed out from a macro-model. This approach allows history to be re-run once, subject to the hypothesised policy rule having been in place. And, as in McCallum (op.cit.), it is the approach we adopt here. A second - more ambitious - approach would be to conduct Monte Carlo experiments, by artificially generating shocks whose moments conform to the set of shocks observed historically.(9) This has the advantage of allowing confidence intervals to be drawn around simulation paths, but will be left to a later paper.

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(7) And because it is likely to induce rather less instrument instability.
(8) Which further suggests that a *derivative* - acceleration in nominal GDP - target might also usefully be included in the rule. We do not attempt that here.
(9) See Judd and Motley (1991) and Haldane and Salmon (1995) for exercises of this sort.

Our policy simulations were then conducted as follows. Each simulation begins by taking the actual observations prevailing at 1959 Q1 as initial conditions. Thereafter the system is simulated using rule (1) together with each of the macro-models, feeding in each quarter the historically-observed shocks. This procedure yields simulated profiles for each of the endogenous variables in the system.

In assessing the performance of the rule, we use a variety of yardsticks. The most important is the Root Mean Squared Error (RMSE) of nominal GDP. This measures the deviation of nominal GDP from its target path: it penalises both *mean* deviations of nominal GDP from its target path, and any induced *variability* in money GDP.(10) We also look at the induced variability of the policy instrument as an arbiter of policy performance, as well as the mean and variance of real output and inflation where these measures are available. These are all terms one might also expect to enter the authorities' loss function.

3 The simplest model

Consider first the simplest possible reduced-form model of nominal GDP determination - an atheoretic single equation linked to past nominal GDP and base money growth rates.(11) We take only lagged values of the base as regressors to limit the possibility of simultaneous equation bias.(12) Estimating this single equation using quarterly, seasonally-adjusted, logarithmic first-differenced data between 1956 Q1 and 1994 Q1 gave:

$$\underset{}{\Delta x_t} = \underset{(3.09)}{0.0065} + \underset{(1.96)}{0.1540\Delta x_{t-3}} + \underset{(3.89)}{0.4941\Delta b_{t-1}} + \underset{(0.98)}{0.1181\Delta b_{t-2}} + \underset{(2.07)}{0.2542\Delta b_{t-3}} + \varepsilon_t \qquad (3)$$

$R^2 = 0.3670$; SEE = 0.0127; DW Statistic = 2.07

The dynamics of the equation are not straightforward. Particularly striking is the fact that lagged values of the base absorb the explanatory power of the first two lagged dependent variables. So the preferred equation is specified to include only the third lag of the dependent variable - which itself is only

(10) Arithmetically, the RMSE can be thought of as the sum of the (squared) mean and variance of the deviation of nominal GDP from its target path.
(11) Following McCallum (1988, 1990a, 1993) for the United States and Japan.
(12) Although our single equation is clearly not a structural relation, it needs at least to be consistently estimated and to reflect causality from base money to income, not the opposite.

marginally significant at 5% - together with three lags of the base.(13) The equation is reasonably well fitting, explaining around 37% of the variation in money GDP growth [similar to McCallum's (1988) analogous equation for the United States]. And the diagnostics do not suggest significant misspecification.

Using **(1)** and **(3)**, we can then simulate values for nominal GDP and base money under the counterfactual assumption that the policy rule, **(1)**, had been in place over the historical sample period. To do this, we first set initial values of these variables equal to their actual outcomes in 1959 Q1. We then feed into the system ε_t - estimates of the shocks that hit the system over the period 1959 Q2-1994 Q1 - and simulate new values for money GDP and the monetary base, conditional on these shocks having occurred. The resulting paths can be compared with a reference path for money GDP, either graphically or by considering summary statistics of performance such as the RMSE.

The *reference path* for nominal GDP which we use throughout when calculating the RMSEs is the fixed *levels* target TAR; this allows a simple and straightforward comparison across model specifications.(14) The *targets* we consider in our feedback rule include the pure levels target (TAR), the pure growth target (TARA) and the growth/levels hybrid (TARM). The resulting RMSE outcomes are summarised in Table A, for varying values of the feedback parameter, λ.

(a) Performance of the rule

Consider the first line of Table A, which gives the RMSE for the levels target (TAR). The actual performance of the rule is encouraging if we compare it with historical outturns. For example at $\lambda = 0.25$ or 0.5, the RMSE under the rule is around 0.03 (3%). By comparison, the historical RMSE of money GDP relative to the reference path is 1.19. Much of this historical error is accounted for by deviations of the *mean* value of money GDP growth from its (assumed) target path - average inflation in excess of the target - rather than variability around this path. But even so, the historical RMSE relative to a fitted time trend is still 0.139, which is comfortably in excess of all (non-explosive)

(13) An equation with the first three lagged dependent variables included yielded very similar results.

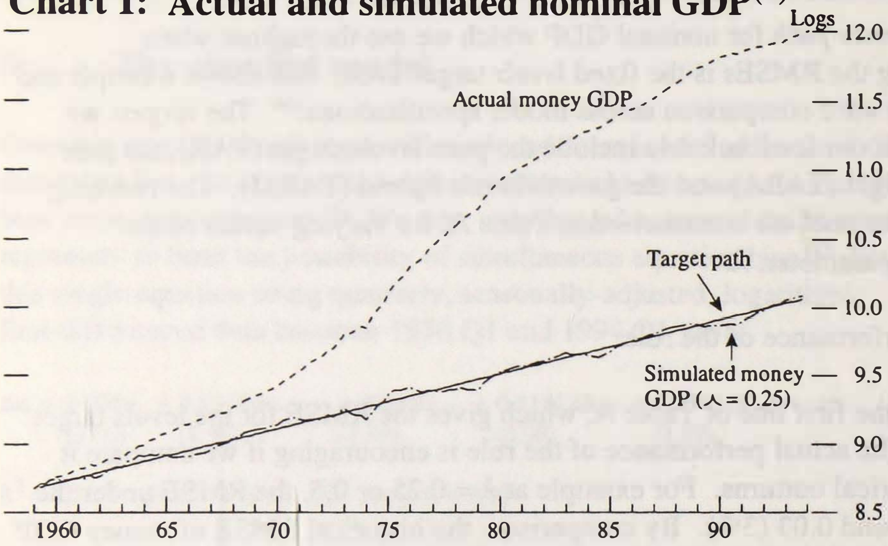
(14) McCallum (1988, 1993) also looks at the performance of the rule relative to the growth rate and mixed levels/growth reference paths.

simulations using the base money rule. So the base money rule's performance is unambiguously superior to historical outturns in smoothing GDP, using the single equation model. And, of course, at the same time the rule ensures average inflation of not greater than 2% over the period 1959-93, which compares favourably with historical inflation of around 6.8% on average. Chart 1 plots simulated nominal GDP (along with its target) and actual money GDP over the sample, by way of comparison.

Table A: RMSE values for single equation: 1959-94

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$
TAR	0.0539	0.0313	0.0287	0.1266	0.8290
TARA	0.0539	0.0440	0.0370	0.0330	0.0300
TARM	0.0539	0.0291	0.0247	0.0224	0.0210

Chart 1: Actual and simulated nominal GDP[(a)]



(a) Single equation model, using a levels target (2a) rule.

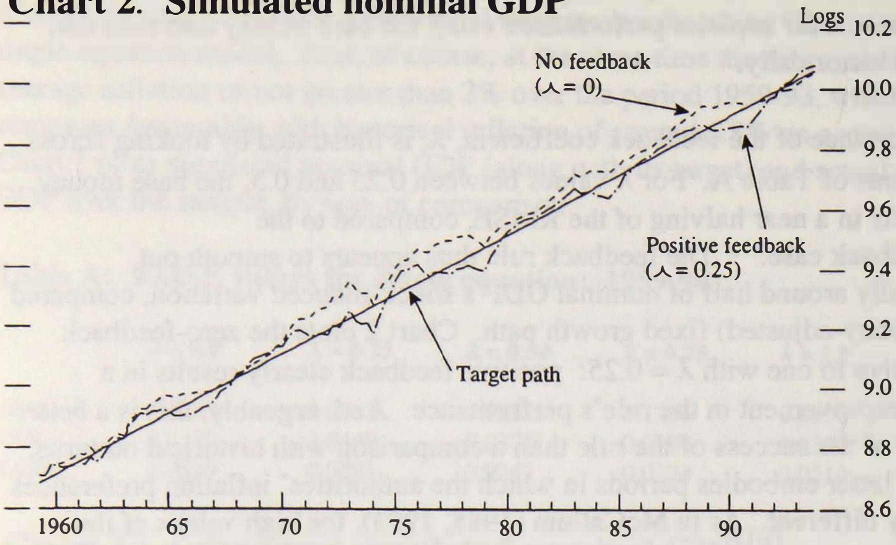
Comparing these results with those for the United States [McCallum (1988)] and Japan [McCallum (1993)], suggests that performance in the United Kingdom is about as good as in these countries. For a similar single-equation model and a levels target, the comparable RMSEs are 0.021 for the United States, 0.032 for Japan and 0.031 for the United Kingdom (with $\lambda = 0.25$). Of course, these results are not strictly comparable because of differences in the relative incidence and susceptibility of countries to shocks.[15] But in every case they point to a far superior performance using the base money rule than that observed historically.

The importance of the feedback coefficient, λ, is illustrated by looking across the columns of Table A. For λ values between 0.25 and 0.5, the base money rule results in a near halving of the RMSE, compared to the zero-feedback case.[16] The feedback rule thus appears to smooth out successfully around half of nominal GDP's shock-induced variation, compared to a (velocity-adjusted) fixed growth path. Chart 2 plots the zero-feedback path relative to one with $\lambda = 0.25$: positive feedback clearly results in a marked improvement in the rule's performance. And, arguably, this is a better indicator of the success of the rule than a comparison with historical outturns, since the latter embodies periods in which the authorities' inflation preferences were very different. As in McCallum (1988, 1993), for high values of the feedback parameter - values of 0.75 or greater here - the system becomes dynamically unstable, with explosive oscillations. Chart 3 illustrates this for $\lambda = 1$. The intuition here is that if monetary policy overreacts to shocks, it may exaggerate (to an ever-greater degree) nominal GDP deviations from the reference path.

(15) And, in the Japanese case, a shorter sample.

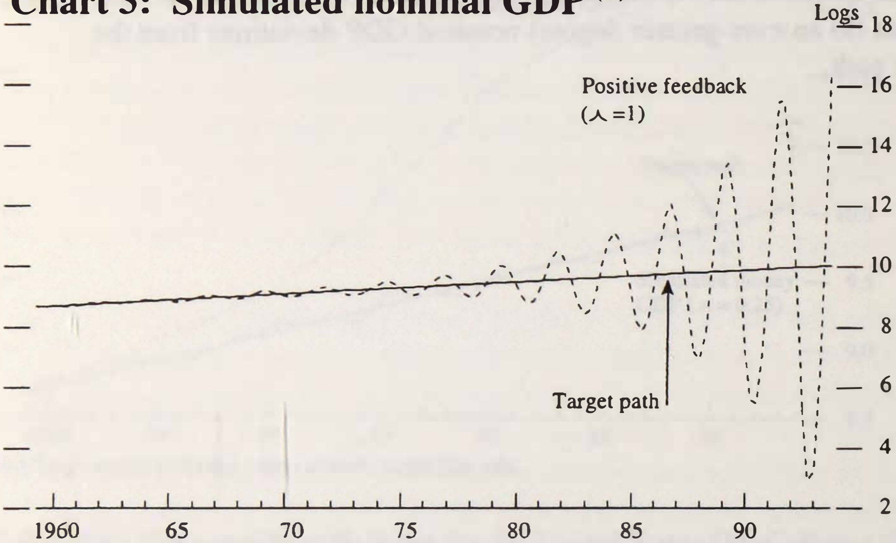
(16) In fact, even with $\lambda = 0$ there is still a feedback rule of sorts in operation, since the velocity adjustment is itself a feedback term.

Chart 2: Simulated nominal GDP[a]



(a) Single equation model, using a levels target (2a) rule.

Chart 3: Simulated nominal GDP[a]



(a) Single equation model, using a levels target (2a) rule.

(b) Alternative feedback targets

The second and third lines of Table A consider respectively the growth rate and the hybrid (levels/growth) targets. Consider first the growth target. At first glance, the results seem unambiguously poorer: at values of λ between 0.25-0.5, the RMSEs are always higher than in the levels target case. But we need to qualify this conclusion in three aspects. First, the reference path against which the growth rule is being judged is a *levels* one. If the growth rate rule is compared against a *growth* rate reference path, then the RMSE lies below that of the levels target.(17)

Second, the growth rate target prevents dynamic instability at high values of λ, unlike the levels target, and so is arguably more robust. Why? The growth target permits forgiveness of past (levels) target misses, thus preventing excessive feedback responses from the policy instrument - which brings us to the third point. Table B gives the standard deviation of quarterly base money growth under each of the feedback rules. The historical standard deviation of quarterly base money growth over the sample is 0.0107. The levels target results in instrument variability around as great as that observed historically, for $\lambda < 1$. But the growth target results in a far smoother path for base money growth: the standard deviation is around half that of the levels target. So one cost of the smoother GDP path induced by the levels target is heightened instrument variability. Again, this is an intuitively sensible result, as we would expect shooting for a levels target to induce sharper fluctuations in the instrument to reverse fully deviations from the target path.

Table B: Standard deviation of quarterly base money growth: 1959-94

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$
TAR	0.0033	0.0092	0.0156	0.0995	0.7701
TARA	0.0033	0.0047	0.0075	0.0110	0.0148
TARM	0.0033	0.0052	0.0079	0.0110	0.0146

It is probably a fact that variability of the policy instrument enters the authorities' loss function, as well as variability of the final target. The precise weights the authorities place on instrument and target variability in their objective function would then influence the choice of λ.(18) But as an illustrative example, with equal weight placed on target and instrument variability, a λ of between 0.25-0.5 would be desirable (for both the levels and growth rate targets). This accords with intuition.

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(17) For example, the RMSE is 0.019 for $\lambda = 0.25$ and 0.025 for $\lambda = 0.5$.

(18) One formal approach to this problem would be to specify up front an objective function for the authorities and then solve for the implied weights using optimal control techniques: again, we leave this to a later paper.

The third line of Tables A and B gives the results for the hybrid growth/levels target. These are striking. For reasonably low values of λ, the mixed target does better than either the growth or the levels target in stabilising money GDP. And at the same time the rule has few adverse implications for instrument variability: this is little different to the growth target (Table B). So a feedback rule comprising both integral (levels) and proportional (growth rate) control appears preferable from our simulations. This is in keeping with the findings of McCallum and Judd and Motley for the United States.[19] It is consistent with a world in which both demand and supply (or temporary as well as permanent) shocks occur, but where the latter-type shocks occur rather less frequently - hence the lower relative weight placed on the levels target. Given its superiority, we use the mixed target rule in the rest of the simulations reported below. It is clear, however, that - irrespective of which target path is assumed - McCallum's rule results in a distinctly superior performance than observed historically, and a considerably better performance than would obtain from a no-feedback rule.

4 Vector autoregressions

We now switch to a Vector AutoRegressive (VAR) framework, to examine the robustness of the monetary rule in a multivariate setting. Clearly, the focus is still upon atheoretic models of the macroeconomy. But VARs provide a useful means of characterising multivariate data relationships, and as such have often been used in policy simulation exercises of this sort [see, for example, McCallum (op.cit.), Feldstein and Stock (1994), Judd and Motley (1991, 1992)].

We consider four VAR systems, which can be considered ever more extended, unrestricted reduced-forms of a textbook macro-model. All of them make an attempt at a real/nominal split of money GDP, and therefore have an added advantage over earlier single-equation models. The first (model 1) comprises prices, real output and the monetary base. Models 2, 3 and 4 then add, incrementally, short-term interest rates, real government spending and the real exchange rate to this system. Because there was not an obvious cointegrating relationship among the variables, all the VARs were estimated in first differences (of logs), except short-term interest rates which were entered in

(19) And, more generally, Phillips (1954).

levels.[20] Four lags were included in all of the systems. Each of the models was then combined with (1) and simulated using the same procedure as earlier, only now feeding in a vector of shocks given by the VAR residuals.

The performance of the McCallum rule within these systems is summarised in Tables C-G. Looking first at the RMSE of money GDP (Table C), there is little difference in performance across any of the VAR models.[21] Nor is the performance of the rule much different than that observed from the single-equation systems. The RMSE is held at around 0.03 for λ between 0.25-0.5, and explodes for lambda greater than unity. As we discussed earlier, this is a substantial improvement over historical and no-feedback outcomes.

Table C: RMSE for VAR models: 1959-93

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$
Model 1	0.047	0.029	0.025	0.022	0.021
Model 2	0.042	0.028	0.024	0.022	0.021
Model 3	0.046	0.031	0.027	0.024	0.023
Model 4	0.045	0.035	0.030	0.026	0.025

Table D: Standard deviation of quarterly base money growth: 1959-93

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model 1	0.0033	0.0053	0.0077	0.0107	0.0146	80.5
Model 2	0.0032	0.0051	0.0076	0.0107	0.0150	2830.2
Model 3	0.0033	0.0052	0.0076	0.0107	0.0147	796.3
Model 4	0.0038	0.0059	0.0081	0.0110	0.0151	1366.6

Table E: Standard deviation of interest rates: 1959-93

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model 1	n/a	n/a	n/a	n/a	n/a	n/a
Model 2	0.0069	0.0072	0.0074	0.0075	0.0076	n/a
Model 3	0.0069	0.0072	0.0073	0.0074	0.0075	59.98
Model 4	0.0070	0.0070	0.0070	0.0071	0.0072	114.41

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(20) In fact, it made little difference to the simulations if the systems were estimated in levels.
(21) Stabilisation of nominal GDP is slightly poorer in the larger systems that incorporate real exchange rate effects.

Table F: Standard deviation of annual real output growth: 1959-93

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model 1	0.0195	0.0203	0.0216	0.0233	0.0253	47.99
Model 2	0.0202	0.0210	0.0221	0.0236	0.0254	1260.3
Model 3	0.0206	0.0213	0.0223	0.0237	0.0253	343.6
Model 4	0.0199	0.0209	0.0223	0.0238	0.0256	626.4

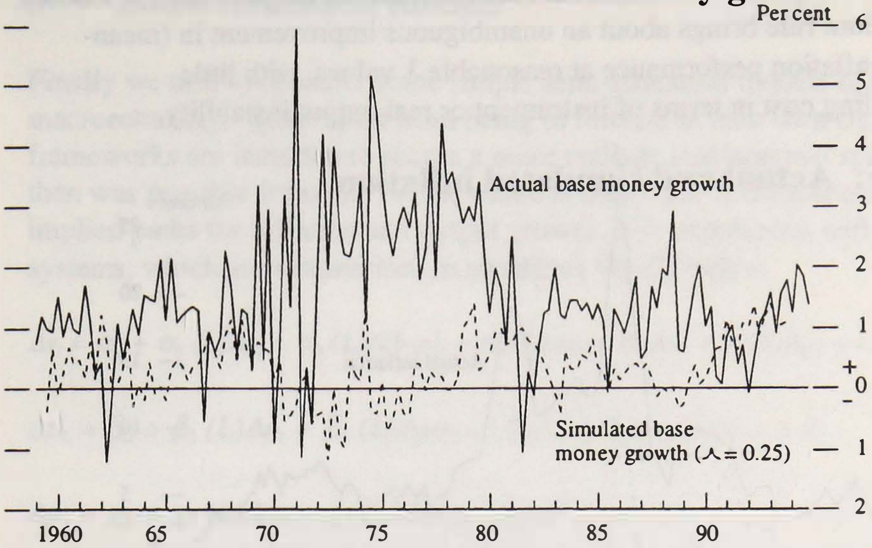
Table G: Standard deviation of annual inflation: 1959-93

	$\lambda = 0.0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model 1	0.0296	0.0325	0.0343	0.0352	0.0353	12.32
Model 2	0.031	0.0335	0.035	0.0356	0.0355	452.72
Model 3	0.031	0.0333	0.035	0.035	0.035	149.18
Model 4	0.031	0.035	0.037	0.037	0.037	03.5

For $\lambda > 0.5$, the improvement in RMSE is marginal and comes at the expense of heightened base instability (Table D).[22] Interestingly, the VAR models suggest that the McCallum rule imposes few costs in terms of heightened *interest rate* variability (Table E). Much of the debate on base money control rests on the belief that this heightens interest rate uncertainty, as volatility spills over from money into interest rates. The US experiment with non-borrowed reserves targeting between 1979-83 is typically held up as a counterfactual. The evidence here suggests few such disruptive volatility spillovers. To the contrary: in all cases interest rate variability at the quarterly frequency is lower than that observed historically (0.0086). Chart 4 plots actual and simulated values of base money growth (for $\lambda = 0.5$) over the sample.

(22) The standard deviation of base money growth is higher than observed historically for $\lambda > 0.5$.

Chart 4: Actual and simulated base money growth



The real/nominal split of money GDP given by the VARs is less convincing. Average real output growth is around 1% higher in the simulations than observed historically. Correspondingly, simulated average inflation - at around zero - is much lower than the targeted value implicit in McCallum's rule (of around 2%). Although such an outcome would clearly be desirable, over a long time period we would expect the rule to act only on nominal activity, with trends in real activity being determined by non-monetary factors: that is, the model seems to embody a (rather implausible) money non-neutrality. This is a legacy of having left unrestricted all dynamic real/nominal interactions in the VAR models - something we look to rectify when we turn to structural models in the next section.

But while average real growth rates are far from ideal, the VARs do give some flavour of the *dynamics* - that is, the variability of the growth rates - of output and inflation. Simulated output growth and inflation variability are shown in Tables F and G; while Charts 5 and 6 plot output growth and inflation, together with their actual values, over the sample (again for $\lambda = 0.5$). Looking at Table G and Chart 5, the McCallum rule brings about an unambiguous lowering of inflation variability - which in turn shows up in the lower RMSEs. And, perhaps most importantly, it achieves this at little cost in terms of output variability (Chart 6 and Table F). For λ less than 0.75, the rule results in lower real output variability than observed historically (0.0237). At higher values of λ this result is reversed - which further argues against too high a feedback parameter. In general, however, the results from the VAR systems tend to corroborate the positive conclusions reached from the single-equation models: the McCallum rule brings about an unambiguous improvement in (mean-variance) inflation performance at reasonable λ values, with little countervailing cost in terms of instrument or real output instability.

Chart 5: Actual and simulated inflation

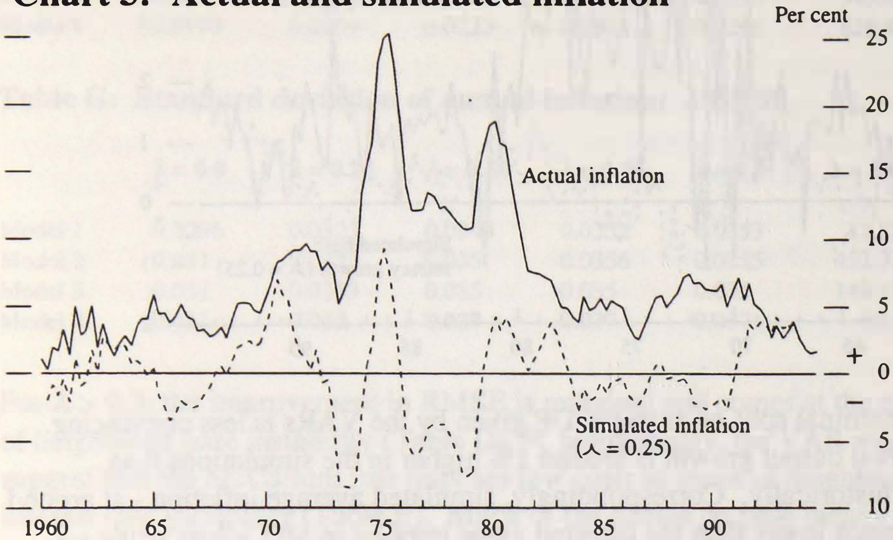
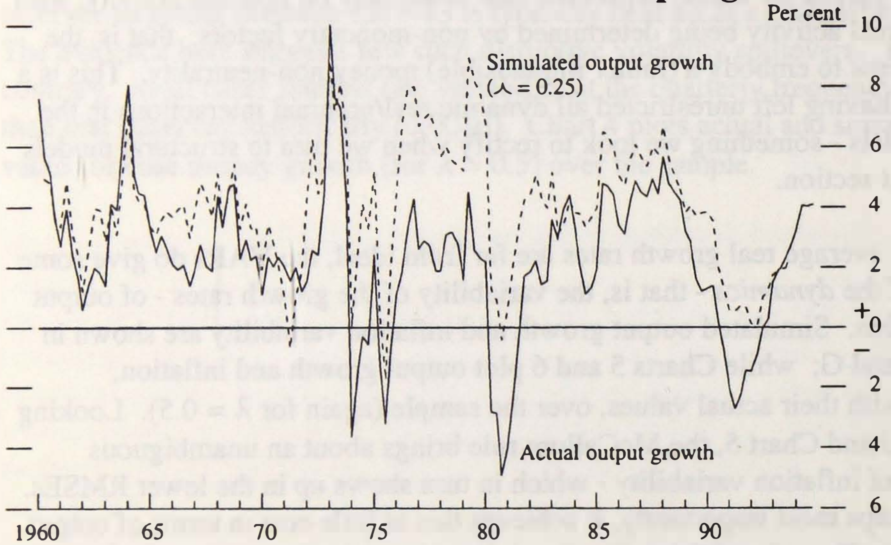


Chart 6: Actual and simulated real output growth



5 Some structural models

Finally we turn to consider some simple semi-structural models of the macroeconomy. Quite apart from being of interest in their own right, structural frameworks are intended to secure a more realistic real/nominal split of activity than was possible from the VARs, which is important when assessing the implied paths for inflation and output growth. We experiment with three systems, which are summarised in equations (4)-(7) below:

$$\Delta y_t = \alpha_0 + \alpha_1 (L)\Delta y_t + \alpha_2 (L)\Delta(b\text{-}p)_t + \alpha_3 (L)\Delta q_t + \alpha_4 \Delta y_t^* + \alpha_5(L)\Delta g_t + \varepsilon_1 \quad (4)$$

$$\Delta p_t = \beta_0 + \beta_1 (L)\Delta p_t + \beta_2 (L)\Delta pim_t + \beta_3 (y - \bar{y})_{t-1} + \beta_4 \Delta b_{t-1} + \varepsilon_2 \quad (5)$$

$$\Delta p_t = \chi_0 + \chi_1 (L)\Delta w_t + \chi_2 (L)\Delta pim_t + \chi_3 (L)\Delta p_t + \varepsilon_3 \quad \textbf{(5a)}$$

$$\Delta w_t - E_{t-1}(\Delta p_t) = \delta_0 + \delta_1 (L)(y - \bar{y})_t + \delta_2(L)w_t + \varepsilon_4 \quad \textbf{(5b)}$$

$$E_{t-1}(\Delta p_t) = \hat{\eta}_0 + \hat{\eta}_1(L)\Delta p_t + \hat{\eta}_2 \Delta b_{t-1} \quad \textbf{(5c)}$$

$$\Delta(b\text{-}p)_t = \theta_0 + \theta_1(L)\Delta(b\text{-}p)_t + \theta_2(L)\Delta p_t + \theta_3 i_t + \theta_4(b - p - \theta_5 y - \theta_6 \Sigma i)_{t-1} + \varepsilon_5 \quad (6)$$

$$\Delta y_t = k_0 + k_1 \Delta y_{t-1} + k_2(i_t - E_{t-1}(\Delta p_t)) + k_3 (L)\Delta q_t + k_4 \Delta y_t^* + k_5 \Delta g_t + \varepsilon_6 \quad (7)$$

Here E_t is the mathematical expectations operator conditional on data available at time t or earlier, L is a finite-order polynomial in the lag operator (L), and the other variables are as defined in the appendix. The equations (4)-(7) were estimated using quarterly data over the period 1955 Q1-1993 Q4,[23] the results of which are also kept to the appendix.

The first, and simplest, system (model A) comprises equations (4) and (5). These represent, respectively, aggregate demand and Phillips curve (aggregate supply) relations. (4) is a textbook open-economy aggregate demand equation. It links real output to real money balances (via the effect of real interest rates upon investment and consumption), the real exchange rate and overseas output

(23) Except the IS curve, (7), see below.

(via net exports)[24] and some measure of real government spending (via fiscal policy). For the moment, because we are not explicitly modelling the LM side of the system, we have substituted out for the real interest rate using real money balances. Also, throughout our simulations we treat *real* exchange rate movements as exogenous. Given that the United Kingdom is a relatively open economy, a natural extension would be to model endogenously real exchange rate movements. But we leave this (contentious) issue to future research; exogenising the real exchange rate is a reasonable assumption over the longer run anyway.

Equation **(5)** is an expectations-augmented Phillips curve with the expectations terms instrumented out. It can be considered an approximate reduced-form of a Layard and Nickell (1985) type wage-price system.[25] Such a wage-price system is expanded upon in equations **(5a)-(5c)**. And the second model (model B) combines these equations with **(4)** to give a model with a better specified supply-side. The wage-price system can be understood in the following way. Agents enter into wage-bargains at the beginning of each period. They bargain over expected real wages (equation **(5b)**). Agents' bargaining power is greater - and thus their real wage higher - the smaller is the pool of unemployed workers; or, put differently, the less is the slack in the economy (output relative to trend). This effect is captured in δ_1. Such a result could be rationalised using, for example, an insider-outsider model of the wage-bargaining process. Trend productivity is proxied here by a time trend, so that its equilibrium effect upon real wage *growth* is captured by δ_0. There is some nominal wage intertia (captured in δ_2), which might result from conventional Fischer/Taylor type overlapping contracts.

In setting their nominal wages, agents are required to form guesses about inflation over the next period. We assume a particularly simple - adaptive - expectations-generating equation, **(5c)**. This can be interpreted as a "rule of thumb", which agents follow when projecting inflation one-step-ahead. These expectations are clearly not rational in the Muthian sense, since this would require agents to solve the inflation reduced-form of the whole system. Instead we simply assume that agents form one-step-ahead price expectations on the

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(24) Given the relatively greater openness of the United Kingdom economy - gross trade flows are around a third of GDP - the aggregate demand relation includes extra international variables compared to McCallum's United States studies.

(25) Strictly speaking, such a reduced-form would model trend output in terms of factors such as the terms of trade. But for our purposes this would have created unnecessary complications.

basis of past inflation dynamics *and* past monetary policy outcomes (base money growth).[26] The former term aims to capture the inertia inherent in price dynamics and in expectations thereof. The latter term offers an expectational channel through which monetary policy actions can impinge directly upon price-setting behaviour. That is, we have built into the model some role for new classical transmission mechanism effects: monetary policy affects price outcomes with few output implications, because it works via a direct expectational channel.[27] This *direct* expectational influence complements the *indirect* Keynesian channel - working through real money balances, output and hence prices via the short-run Phillips curve - which forms the cornerstone of the model. Taken together, these two channels aim to capture both Classical and Keynesian transmission mechanism effects. Finally, prices (equation **5a**) are determined as a cost mark-up over nominal wages (set at the beginning of each period) and exogenously-given import prices (*pim*). For simplicity, we have assumed no cyclicality in the cost-price margin; the empirical and theoretical evidence is in any case undecided on the sign of such effects.[28]

The wage-price system generates a (near) vertical long-run aggregate supply curve, despite the fact that we do not impose this restriction explicitly.[29] This was, of course, not a property of the VAR models, which was one reason why we moved on to consider structural models of the supply-side. Money neutrality is a desirable long-run property of any macro system, whether Classical or Keynesian. Yet the wage-price system, as estimated, still offers ample scope for short-run, policy-induced, non-neutralities.

The third model (model C) expands the aggregate demand side of the system by modelling separately the IS and LM schedules - the demand for goods and

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(26) Conditioning expectations on past behaviour has the additional advantage of allowing us to solve the wage-price system recursively, substituting out expectations as is done in the reduced-form Phillips curve (equation (5)).

(27) We could have strengthened this credibility channel by allowing some feedback from the degree of monetary policy activism (λ) to the coefficient on money ($\hat{\eta}2$) in 5(c). But the results from this exercise are readily apparent: they would give an extra kick to more active policy and so increase its potency. Exercises of this type are only really consistent in models with fully rational expectations; the addition of ad hoc feedback channels to our semi-structural models would not add much.

(28) Contrast Bils (1989) with Domowitz *et al* (1986).

(29) This was apparent from the simulations, where long-run *average* real GDP outturns were broadly invariant to the monetary policy rule being simulated and were similar to those observed historically (though real output *variability* was affected by the various rules, as we would expect).

money respectively. It thus comprises equations (5a)-(5c), (6) and (7).(30) Equation (6) is an LM curve. It takes a very similar form to that recently estimated by Breedon and Fisher (1993) for the United Kingdom; we would refer interested readers to the paper for details. Equation (7) is the IS curve. Output demand depends upon real interest rates, the real exchange rate and real government expenditures. Finding an empirically well-determined real interest rate effect in our IS curve over the whole sample proved problematic. This problem is frequently encountered in the literature.(31) In the event, it proved much easier to find powerful real interest rate effects during the 1980s, and our preferred equation is estimated over the restricted sample 1985 Q1-1993 Q4 to reflect this.(32)

Arguably, each of our structural models is basically Keynesian in nature, and so our approach leaves untested competing alternatives.(33) This might leave our results more susceptible to the Lucas critique - the more so because our models deliberately understate the role of expectations. In defence, we would make three points. First, direct effects of monetary policy actions upon price expectations are explicitly accommodated within the models - so giving them a new classical flavour. Second, while our system posits a Phillips curve (wage-price mechanism), it leaves unrestricted this relation's dynamic coefficients. It thus accommodates the possibility of speedy goods price adjustment, should this be congruent with the data. A third - related - point is that, in practice, a Phillips curve type relation with sluggish goods price adjustment came closest to matching the data. It appeared to give a "better" structural representation of the macroeconomy than the alternatives. For instance, we attempted to estimate a model with a Lucas supply function but the associated standard errors were so large that meaningful simulation was not possible - the model was simply not data congruent.(34) This is consistent with most studies of wage-price setting in a United Kingdom context.

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(30) Clearly, model C nests models A and B.
(31) In the United Kingdom, it probably derives in part from quantitative restrictions on financial intermediation, which existed up until the early 1980s, and in part from difficulties in measuring inflation expectations during the turbulent 1970s.
(32) The residuals over the full sample were then constructed from these truncated-sample estimates of the IS curve. The resulting residuals were reasonably well-behaved when looked at over the *whole* sample - they had zero mean and were uncorrelated - though, as we might expect, they were much more variable during the 1970s.
(33) Such as the real business cycle and monetary misperceptions models that McCallum (1988, 1993) experiments with.
(34) McCallum (1993) reports a similar finding in his Japanese study.

Tables H-K summarise the results for each of the models. Most of the conclusions reached using simpler models appear to carry across in a structural setting. For example, the rules appear to reduce by almost 50% the shock-induced variation in nominal GDP, compared with the zero-feedback case (Table H). And, of course, any of the rules themselves do much better than historical outturns: under models A and C, the RMSE is again in the region of 3%-4% for $\lambda = 0.25$ or 0.5. This is true despite the fact that the summary statistics of performance tend to be slightly larger using the structural models than with earlier atheoretic formulations.[35]

Table H: RMSE for structural models: 1959-93

	$\lambda = 0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model A	0.0793	0.0429	0.0322	0.0267	0.0232	0.0174
Model B	0.0945	0.0567	0.0419	0.0346	0.0328	0.0219
Model C	0.0836	0.0383	0.0277	0.0234	0.0211	3.07

Table I: Standard deviation of quarterly base money growth: 1959-93

	$\lambda = 0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model A	0.0061	0.0084	0.0102	0.0124	0.0152	0.0348
Model B	0.0084	0.0113	0.0129	0.0151	0.0245	0.0368
Model C	0.0081	0.0096	0.0111	0.0132	0.0201	6.8

Table J: Standard deviation of annual real output growth: 1959-93

	$\lambda = 0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model A	0.0240	0.0240	0.0237	0.0235	0.0234	0.0243
Model B	0.0459	0.0437	0.0435	0.0439	0.0443	0.0442
Model C	0.0266	0.0253	0.0283	0.0251	0.0258	16.79

(35) This is particularly true of model B, which does much worse than models A and C. This seems to stem from the problems of modelling separately wage, price and expectations behaviour, the residuals from which had a strong positive covariance.

Table K: Standard deviation of annual inflation: 1959-93

	$\lambda = 0$	$\lambda = 0.25$	$\lambda = 0.50$	$\lambda = 0.75$	$\lambda = 1.0$	$\lambda = 2.0$
Model A	0.0301	0.0288	0.0285	0.0287	0.0289	0.0288
Model B	0.0459	0.0437	0.0435	0.0449	0.0443	0.0442
Model C	0.0290	0.0270	0.0248	0.0291	0.0296	3.13

While higher than in earlier models, variability of the monetary base remains at or below its historical values for λ less than unity (Table I). Taking variability of the final target (money GDP) and the instrument (base money) together, the preferred value of λ from the simulations is again in the range 0.25-0.75 - though perhaps now towards the upper end of this range. Again, this seems reasonable.

The key advantage of the structural models is that they secure a much more believable real/nominal split of money GDP than was possible using the VARs. In particular, real GDP growth is much closer to its historical average (of 2.25% per annum) under the structural models. And the corrollary of this improved real/nominal split from the structural models is that average inflation is also nearer to its target. Mean inflation outturns under the rule are almost exactly in line with their desired values - of around 1.5%. At the same time, inflation variability remains well below its historical average (of 5%) under the rule - often as much as 50% below (Table K); while real output variability remains close to its historic outturn (of around 2.4%) under each of the rules (Table J). So there are few obvious countervailing costs from adhering to the rule. Charts 7 and 8 plot actual and simulated GDP growth and inflation to illustrate these points.

Chart 7: Actual and simulated inflation

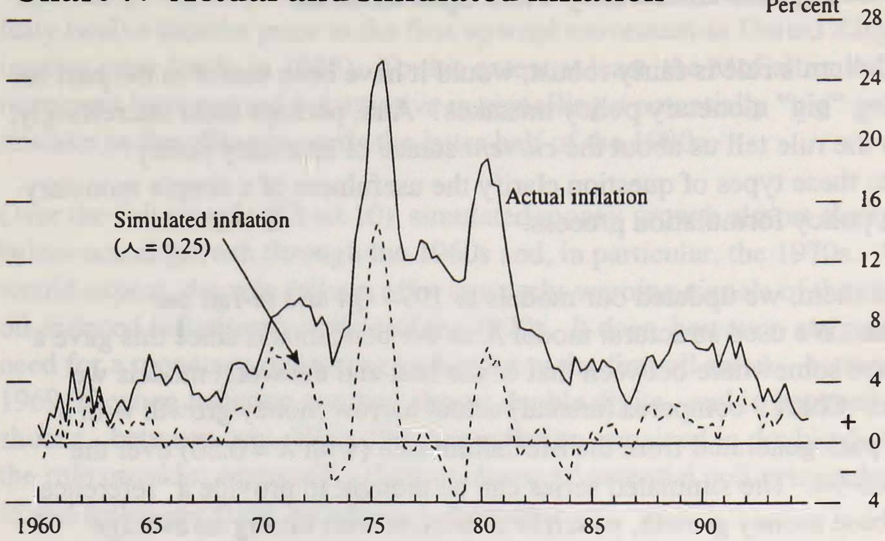
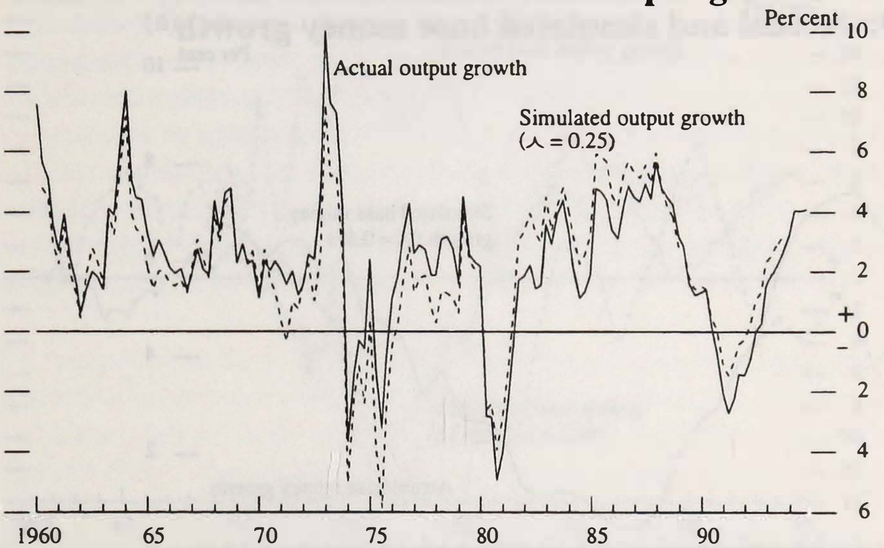


Chart 8: Actual and simulated real output growth



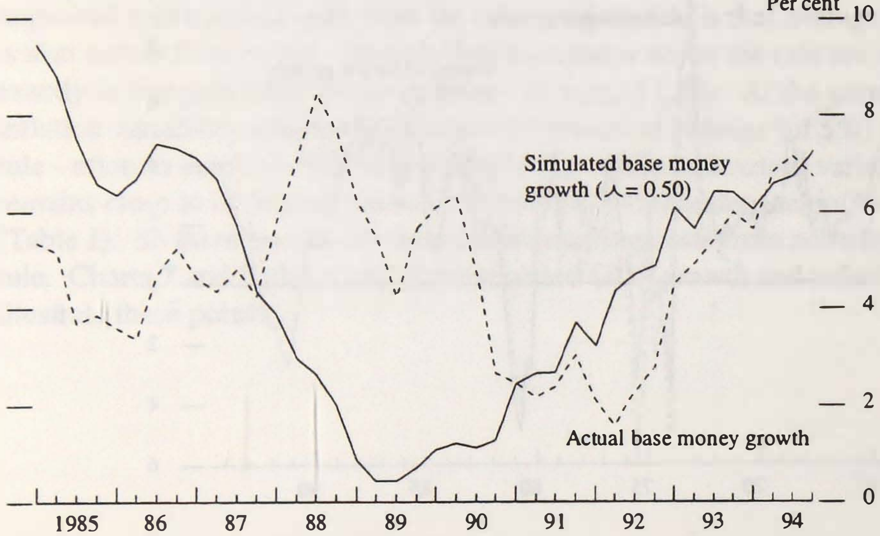
In summary, looking across a range of models, the performance of McCallum's rule appears relatively robust: it is able to secure a significant improvement in (mean-variance) inflation performance, both relative to history and relative to a fixed money-growth rule. And it does so with few countervailing costs, measured in terms of instrument or real output variability.

6 Making the monetary rule operational

So if McCallum's rule is fairly robust, would it have been useful in the *past* for highlighting "big" monetary policy mistakes? And, perhaps most interestingly, what does the rule tell us about the *current* stance of monetary policy? Answers to these types of question clarify the usefulness of a simple monetary rule in the policy formulation process.

To address them, we updated our models to 1994 Q4 and re-ran our simulations. We used structural model A as our benchmark, since this gave a performance somewhere between that of the best and the worst models we considered. Chart 9 compares (annual) actual narrow money growth with a simulated path generated from the McCallum rule (with $\lambda = 0.50$) over the period 1985-94. The simulated series can be thought to provide a "reference path" for base money growth, which is consistent with hitting an average inflation target of less than 2% (4% annual nominal GDP growth).

Chart 9: Actual and simulated base money growth[(a)]

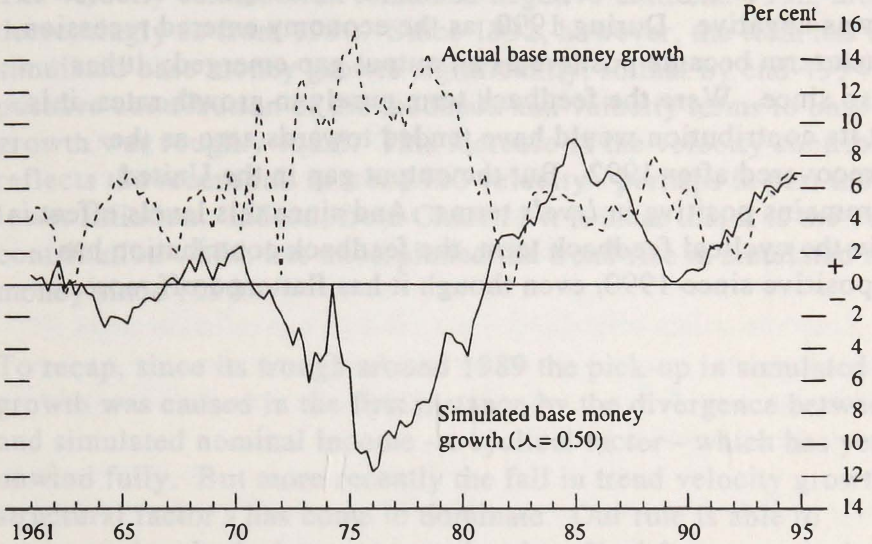


(a) Model A, mixed levels and growth rate target (2c) rule.

One striking feature from Chart 9 is the marked divergence between the two series from early 1987 onwards. The monetary rule would have suggested a protracted period of monetary tightening - proxied here by base money growth - from late 1986 to the beginning of 1989: simulated narrow money growth falls from 7.5% to less than 1% over this period. Over the same period, *actual* narrow money growth moved in the opposite direction, rising to over 8%. The "tightening" signal provided by the narrow money reference path thus came fully twelve months prior to the first upward movement in United Kingdom interest rates (early in 1988). To this extent at least, the McCallum rule may in retrospect have proved informative in signalling a potentially "big" policy mistake in the offing towards the latter half of the 1980s.

Over the full sample (Chart 10), simulated money growth almost always lies below actual growth through the 1960s and, in particular, the 1970s. As we would expect, the rule fails to offer any early-warning signals of the two oil-induced inflationary spikes of the 1970s. It does, however, suggest the need for a monetary tightening both prior to the first oil shock - between 1969-72 when inflation reached almost double digits - and in between the oil shocks - between, say, 1976-79 when inflation remained in double digits. So the rule provides reasonably clear evidence of potential policy mistakes prior to and following these inflationary episodes.

Chart 10: Actual and simulated base money growth



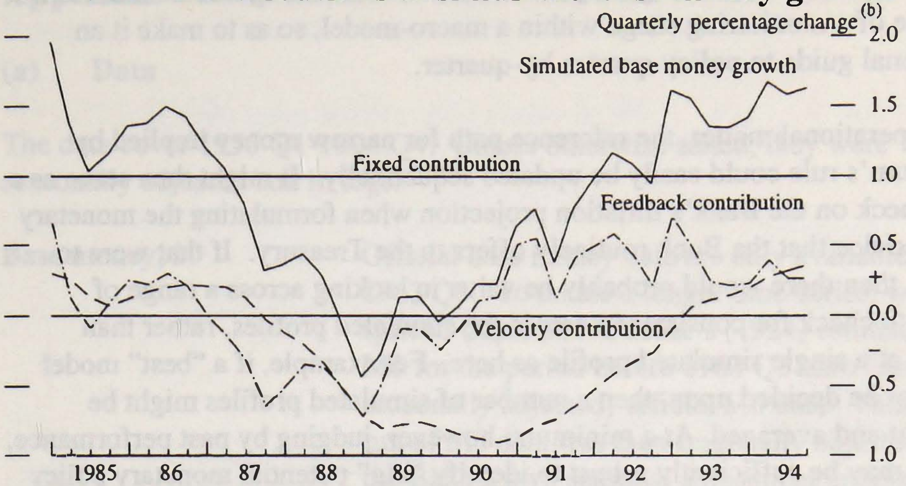
During the United Kingdom's spell inside the ERM between 1990-92, simulated money lies above actual money growth, consistent with monetary policy being "too tight". Intuitively, this sounds sensible. And, interestingly, following the United Kingdom's departure from the ERM, the paths of actual and simulated money track each other very closely, both in level and growth rate terms.[36] This offers some reassurance that the stance of monetary policy was broadly in line with inflation target objectives at the end of 1994. It also serves to dispell fears that the growth of narrow money in the United Kingdom during 1993-94 was necessarily a harbinger of inflationary pressures. Our analysis suggests that target-consistent (simulated) narrow money growth itself grew over this period.[37]

In Chart 11 we decompose simulated (quarterly) base money growth into its three components from the rule - the constant, the velocity adjustment and the feedback term - in an attempt to understand why target-consistent base money growth has risen since around 1990. This shows how the velocity and feedback terms interacted in determining simulated base money growth. Between 1987-90, both the feedback and velocity terms were negative and simulated (quarterly) money growth was below its 1% baseline. Trend velocity growth was rising, implying less money was required to finance a given level of nominal expenditure; while nominal income growth itself was excessive compared to target so feedback was negative. During 1990, as the economy entered recession, the feedback term became positive as an output gap emerged; it has remained so since. Were the feedback term purely in growth rates, it is likely that its contribution would have tended towards zero as the economy recovered after 1992. But the output gap in the United Kingdom remains positive in *levels* terms. And since this levels effect is reflected in the cyclical feedback term, the feedback contribution has remained positive since 1990, even though it has flattened off more recently.

(36) Much more closely, in fact, than at any other time since the late 1950s. The mean (absolute) deviation between actual and simulated narrow money over our full sample is 6.8%; since 1980 the mean deviation has been just over 2%; while since 1991 the mean deviation has been just over 1%.

(37) See Astley and Haldane (1995) for a similar conclusion, arrived at using different techniques.

Chart 11: Contributions to simulated base money growth [a]



(a) Model A, mixed levels and growth target rule (2.5).
(b) Two quarter moving average

The velocity contribution remained negative until end-1992, although decreasingly so from 1990. Since 1992, however, the term has boosted simulated base money growth significantly, so that by end-1994 the positive contribution of the feedback and velocity terms to base money growth was roughly equal. This increase in the velocity contribution reflects the recent fall in trend M0 velocity - perhaps in part the result of lower inflation. Indeed, from Chart 11 it is clear that it is the velocity contribution which has underpinned the trend rise in simulated narrow money since 1990.

To recap, since its trough around 1989 the pick-up in simulated M0 growth was caused in the first instance by the divergence between target and simulated nominal income - a cyclical factor - which has yet to unwind fully. But more recently the fall in trend velocity growth - a structural factor - has come to dominate. Our rule is able to accommodate both these structural and cyclical factors at work upon narrow money growth in recent years - albeit with a lag - and so provide a more meaningful reference path for current narrow money growth.

It should also be apparent that the rule gives us a *dynamic* path for narrow money growth, rather than just a range of indifference as with the existing monetary monitoring ranges in the United Kingdom. The rule responds automatically to cyclical deviations from target, and additionally to structural changes in the relationship between money and incomes. And it is in this sense that the rule gives us policy answers that are both more flexible and more precise than with monitoring ranges. The rule can be thought to nest the principle of a monitoring range within a macro-model, so as to make it an operational guide to policy quarter-by-quarter.

As an operational matter, the reference path for narrow money implied by McCallum's rule could easily be updated sequentially. It might then serve as a cross-check on the Bank's inflation projection when formulating the monetary policy advice that the Bank routinely offers to the Treasury. If that were to happen, then there would probably be value in looking across a range of models to check for consistency across the simulated profiles, rather than looking at a single simulated profile as here. For example, if a "best" model could not be decided upon, then a number of simulated profiles might be looked at and averaged. At a minimum, however, judging by past performance, the rule may be sufficiently robust to identify "big" potential monetary policy errors, the type of which have characterised the United Kingdom economy over the past twenty-five years.[38]

7 Conclusions

We have simulated the performance of a well-known and simple feedback rule for monetary policy. The rule appears to perform well across a range of related macro-models - atheoretic and structural; future research might look to a broader range of models still. In particular, the rule is able to secure average inflation of less than 2%, with few obvious costs in instrument or real output variability. As such, the rule might serve some useful supplementary role in the United Kingdom policy-setting process, even under an inflation target regime. It helps guard against "big" policy mistakes. And, given our current state of knowledge, such "coarse-tuning" is about as much as monetary policy can reasonably be expected to achieve.

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(38) Of course, using the rules in this way would also constitute the best test of their robustness. It is possible that the out-of-sample performance of the rules would prove significantly different to their in-sample performance. But this is a concern for all econometric studies - to which the only response is 'time will tell'.

Appendix

(a) Data

The data cover 1955 Q1-1994 Q4. Unless otherwise stated, they were seasonally adjusted and in logs.

Base money, b:	Official base money data are only available from 1963 Q3. To create a longer time-series, we spliced Capie and Webber's (1984) estimates of M0 for the period before 1963 Q3 onto (non seasonally adjusted) official M0 data. This long run of M0 data was then seasonally adjusted using the Bank's own seasonal adjustment programme for monetary aggregates (GLAS). Further details and a copy of this series is available from the authors upon request.
Interest rates, i:	Quarterly averages of end-month short-term interest rates: 1955-72, the Bank rate; 1973-81, the MLR; and 1982 onwards, clearing banks' base rate. (Not in logs.)
Real output, y:	CSO data - GDP at market prices.
Price level, p:	CSO data - GDP deflator.
Nominal GDP, x:	$y + p$.
Real government expenditure, g:	CSO data - general government final expenditure.
Import prices, pim:	CSO data - import price deflator.
Foreign output, y^*:	OECD data - total OECD output.
Real exchange rate, q:	Nominal United States/United Kingdom exchange rate adjusted by the ratio of foreign to domestic prices.

Wages, w:	CSO data - ratio of wages and salaries of the personal sector to the workforce in employment.
Trend output, $\bar{y}$:	Fitted values from a linear trend through y.

(b) Model

The sample period was 1959 Q2-1993 Q4, unless otherwise stated. t-ratios in parenthesis.

Equation (4): Aggregate demand curve

$$\begin{aligned}
\Delta y_t = {} & \underset{(1.16)}{0.0019} - \underset{(-1.62)}{0.131}\,\Delta y_{t-1} + \underset{(2.68)}{0.166}\,(\Delta b\text{-}\Delta p)_t \\
& + \underset{(2.34)}{0.153}\,(\Delta b\text{-}\Delta p)_{t-1} + \underset{(0.81)}{0.053}\,\Delta g_t + \underset{(1.53)}{0.099}\,\Delta g_{t-1} \\
& + \underset{(0.60)}{0.044}\,\Delta q_{t-1} + \underset{(2.04)}{0.036}\,\Delta q_{t-2} + \underset{(4.51)}{0.62}\,\Delta y^*_t
\end{aligned}$$

$\bar{R}^2 = 0.26$; SEE = 0.011; Durbin's $h = 0.11$

Equation (5): Phillips curve

$$\begin{aligned}
\Delta p_t = {} & \underset{(1.26)}{0.0204} \quad \underset{(2.10)}{0.163}\,\Delta p_{t-1} + \underset{(5.07)}{0.373}\,\Delta p_{t-2} \\
& + \underset{(2.43)}{0.231}\,\Delta b_{t-1} + \underset{(1.31)}{0.043}\,\Delta pim_{t-1} + \underset{(1.44)}{0.049}\,\Delta pim_{t-2} \\
& + \underset{(2.40)}{0.079}\,\Delta pim_{t-3} + \underset{(1.49)}{0.038}\,(y-\bar{y})_{t-1}
\end{aligned}$$

$\bar{R}^2 = 0.58$; SEE = 0.012; Durbin's $h = -2.84$

Equation (5a): Cost mark-up pricing

$$\Delta p_t = \underset{(-2.48)}{-0.0037} - \underset{(-1.45)}{0.116}\ \Delta p_{t-1} + \underset{(2.69)}{0.201}\ \Delta p_{t-2}$$

$$+ \underset{(4.41)}{0.285}\ \Delta w_t + \underset{(4.47)}{0.300}\ \Delta w_{t-1} + \underset{(2.69)}{0.199}\ \Delta w_{t-2}$$

$$+ \underset{(1.53)}{0.043}\ \Delta pim_{t-1} + \underset{(1.77)}{0.052}\ \Delta pim_{t-2} + \underset{(1.77)}{0.051}\ \Delta pim_{t-3}$$

$\overline{R}^2 = 0.68$; SEE = 0.0007; Durbin's $h = -1.89$

Equation (5b): Wage-bargaining

$$[(\Delta w_t - E_{t-1}(\Delta p_t)] = \underset{(3.68)}{0.0081} + \underset{(1.12)}{0.100}\ (y - \overline{y})_t - \underset{(-0.53)}{0.049}\ (y - \overline{y})_{t-1}$$

$$\underset{(-0.07)}{-0.006}\ \Delta w_{t-1} + \underset{(2.28)}{0.192}\ \Delta w_{t-2} - \underset{(-1.25)}{0.104}\ \Delta w_{t-3} - \underset{(-2.79)}{0.222}\ \Delta w_{t-4}$$

$\overline{R}^2 = 0.08$; SEE = 0.001; DW = 1.95

Equation (5c): Price expectations

$$E_t(\Delta p_{t+1}) = \underset{(0.86)}{0.0014} + \underset{(3.23)}{0.236}\ \Delta p_t + \underset{(4.98)}{0.354}\ \Delta p_{t-1} + \underset{(4.09)}{0.381}\ \Delta b_t$$

$\overline{R}^2 = 0.48$; SEE = 0.011; Durbin's $h = -1.91$

Equation (6): LM curve (IV estimation)

$$\Delta(b-p)_t = \underset{(3.99)}{0.105} + \underset{(3.03)}{0.245}\,\Delta(b-p)_{t-1} + \underset{(4.12)}{0.328}\,\Delta(b-p)_{t-2}$$

$$- \underset{(-12.03)}{0.839}\,\Delta p_t + \underset{(2.82)}{0.272}\,\Delta p_{t-1} + \underset{(-4.44)}{0.386}\,\Delta p_{t-2}$$

$$- \underset{(-4.12)}{0.567}\,i_t - \underset{(-3.74)}{0.632}\,ecm_{t-1}$$

$\overline{R}^2 = 0.66$; SEE = 0.0006; DW = 2.01

where $ecm = (b\text{-}p) - 0.79\,y + 0.30\,\Sigma i$

Equation (7): IS curve

Estimation Period: 1985:1 - 1993:4

$$\Delta y_t = \underset{(0.464)}{0.0018} + \underset{(2.20)}{0.395}\,\Delta y_{t-1} - \underset{(-1.17)}{0.226}\,(i_t - E_{t-1}(\Delta p_t))$$

$$+ \underset{(1.47)}{0.158}\,\Delta g_{t-1} + \underset{(0.94)}{0.015}\,\Delta q_t + \underset{(1.96)}{0.703}\,\Delta y^*_t$$

$\overline{R}^2 = 0.43$; SEE = 0.0003; Durbin's $h = -1.38$

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