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Interest Rate Setting and Inflation Targeting: Evidence of a Nonlinear Taylor Rule for the United Kingdom

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Interest Rate Setting and Inflation Targeting: Evidence of a Nonlinear Taylor Rule for the United Kingdom*

Mark P. Taylor and Emmanuel Davradakis

Abstract

We examine potential nonlinear behaviour in the conduct of monetary policy by the Bank of England. We find significant nonlinearity in this policy setting, and in particular that the standard Taylor rule really only begins to bite once expected inflation is significantly above its target. This suggests, for example, that while the stated objective of the Bank of England is to pursue a symmetric inflation target, in practice some degree of asymmetry has crept into interest-rate setting. We argue that, nevertheless, the very predictability of the policy rule, especially when set out in a highly plausible and intuitive nonlinear framework, is perhaps one reason why the United Kingdom has, since the early 1990s, enjoyed price stability combined with relatively strong growth.

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1 Introduction

In recent years a great deal of work has established the appealing features of interest rate rules in conducting and monitoring monetary policy. The virtues of an interest rate or Taylor rule[1]—in which the policy instrument interest rate is determined as a linear function of the deviations of inflation from its target and the deviations of output from its potential level (the output gap)—stem from its simplicity and its ability to serve either as an informative input or as a more decisive factor in the implementation of monetary policy.

While empirical evidence from various countries[2] indicates that Taylor rules are often able to capture the salient dynamics of the relevant short-term interest rate, it is frequently argued that simple linear rules may not be adequate to capture the complexities arising in the conduct of monetary policy. In particular, it is possible that a Taylor rule may not have a simple linear form, but instead is best described by a more complex nonlinear form; indeed, a growing body of research indicates that the likelihood of nonlinearities in the conduct of monetary policy is considerably high. For example, Blinder (1997), inter alios,[3] argues that it is not optimal for the central bank to contract demand in the event of small deviations of inflation from target; instead, it should fight inflation when it is favourable to do so, in terms of the incremental output reduction that will have to be incurred in that case: squeezing the last drop of above-target inflation out of the economy may be too costly because of a worsening trade-off between inflation and output at low levels of inflation. In addition, it may be that there are important asymmetries and nonlinearities in the business cycle, which would require policy makers to condition the interest rate response of policy nonlinearly on the output gap, and indeed the effects of monetary policy shocks do appear to be more profound in recessions than in expansions.[4]

Similarly, asymmetry in the central bank's preferences regarding the weight assigned to deviations of inflation from target and the output gap might give rise to a nonlinear interest rate reaction function. In this setup, central banks do not weigh equally positive and negative deviations of inflation from their targets, resulting in an asymmetric response of monetary policy. Dolado, Maria-Dolores and Naveira (2000), for example, provide evidence that the US

[1] After Taylor (1999a, 1999b, 1997, 1993a and 1993b).

[2] Clarida, Gali and Gertler (1998, 2000)

[3] See, e.g. Orphanides, Small, Wieland and Wilcox (1997) and Orphanides and Wilcox (1996).

[4] Recent research in this direction includes work by Peel and Speight (1998); Dolado, Maria-Dolores and Naveira (2002); Dolado, Maria-Dolores and Ruge-Murcia (2002); Surico (2002); and Nobay and Peel (2000).

Federal Reserve (Fed) and several European central banks have in the past responded more aggressively to positive compared to negative deviations of inflation from its target. In line with this finding, Gerlach (2000) attributes the high inflation found prior to Volcker's chairmanship at the Fed to Volcker's more aggressive response to the output gap in the wake of the first oil shock in 1973. In other research, the increased sensitivity of the central bank to negative output gaps along in the presence of uncertainty regarding the state of the economy is considered by Cukierman (2000) and Ruge-Murcia (2003) to be the driving forces of inflation bias.

Moreover, while nonlinearities in the Taylor rule can be the result of either nonlinearity in the macroeconomic structure of an economy (the output-inflation trade-off) or of asymmetry in the central bank's preferences, it is quite likely that both of these features are present in the economy and interact to exacerbate the degree of nonlinearity in the policy rule.

The remainder of this paper is organized as follows. In Section II we provide an exposition of our nonlinear empirical models and methods and in Section III we present background information on the implementation of monetary policy at the UK, along with a description of the data used in this study. In a fourth section, we report estimation results for the models considered while in a final section we draw some conclusions from our analysis.

2 Modelling Nonlinearity in the Taylor Rule

A simple way of capturing nonlinearities in policy behaviour is to estimate threshold models whereby the policy rule switches into a different regime whenever a certain variable (in this case inflation itself seems most appropriate) breaches one or more thresholds. It may be, for example, that when inflation is in the neighbourhood of the target level, the authorities pursue a largely accommodating monetary policy, so that changes in the interest rate are more or less random since they are responding to random shocks to the economy. Once inflation rises above a given level, however, the central bank may be more aggressive in linking interest rate movements to the implicit policy rule, so that the Taylor rule best describes short-run interest rate behaviour above that level. Similarly, if inflation falls below a certain level this may generate fears of deflation and the authorities may again implement a Taylor rule—but not necessarily the same one that is employed (explicitly or implicitly) when inflation is high. This would suggest a three-regime model on which we can impose and test various restrictions.

Following Clarida, Gali and Gertler (1998, 2000), we use the following

forward-looking Taylor rule as our baseline linear model for $t = 1, ..., n$:

$$i_t^* = i^* + \beta(E(\pi_{t,k}|\Omega_t) - \pi^*) + \gamma E(x_t|\Omega_t), \tag{1}$$

where i_t^* is the desired value of the short-term nominal interest rate, $\pi_{t,k}$ denotes the percentage change in the price level between periods t and $t+k$, π^* is the target for inflation, x_t is a measure of the output gap in period t (with the output gap defined as the percentage deviation of actual GDP from its potential level), $E(\cdot|\Omega_t)$ is the conditional expectation operator, conditioned on information available to the monetary authorities at time t, Ω_t, and i^* is, by construction, the desired nominal interest rate when inflation and output are at their target levels. This forward-looking Taylor rule nests the simple interest rate rule originally proposed by Taylor (1999a,b) if either inflation or the cross product of inflation and output gap are sufficient proxies for expected inflation. Moreover, the forward-looking specification encapsulates the view that the central bank uses all the information at its disposal in order to form an opinion about inflation and output, as implied by the inclusion of conditional expectations of inflation and output.

We assume that the central bank adjusts interest rates in a cautious way through smoothing in the form of partial adjustment as follows:

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + \upsilon_t. \tag{2}$$

The exogenous random shock υ_t could reflect either the randomness to policy or imperfect forecast of demand for reserves derived by the central bank. According to this partial adjustment behaviour, the central bank at each period adjusts its instrument in order to eliminate only a fraction $(1-\rho)$ of the gap between its current target level and some linear combination of its past values. Smooth adjustment in interest rates may be rationalised, for example, as fear of disrupting capital markets or fear of the loss of credibility that might result from large and sudden policy reversals, or the need to build a consensus, in order to support a policy change. In addition, interest-rate smoothing may be thought of as a learning device by the central bank, which may not have a full knowledge of economy due to imperfect information.

Re-parameterizing (1) using (2):

$$M4: \qquad i_t = \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t, \tag{3}$$

where $\alpha_0 = (i^* - \beta\pi^*)(1-\rho)$, $\alpha_1 = \rho$, $\alpha_2 = \beta(1-\rho)$, $\alpha_3 = \gamma(1-\rho)$ and $\epsilon_t = (1-\rho)\{\beta(E(\pi_{t,k}|\Omega_t) - \pi_{t,k}) + \gamma(x_t - E(x_t|\Omega_t))\} + \upsilon_t$. For reasons that shall presently become clear, we label this model $M4$.

The forward-looking Taylor rule $M4$ is an approximation to forecast-based rules of the kind proposed by Rudebusch and Svensson (1999) and Batini and Haldane (1998). These forecast-based rules are the outcome of dynamic structural optimizing models that take into account lags in the monetary transmission mechanism attributable, for example, to price stickiness (Rotemberg and Woodford, 1999) or to rigidities in the money market (Christiano, Eichenbaum and Evans, 1997; Christiano and Gust, 1999). Due to these lags, an unexpected monetary shock will affect output and employment after some time, while the final impact on the price level, following the change in output and employment, will require an extra lag subject to private sector's beliefs regarding how monetary policy will respond in the future. In this respect, these dynamic structural optimizing models[5] assert that welfare can be maximised following stabilization of forecast inflation around an appropriately chosen target at some horizon. Thus, in order to control for inflation the policy instrument should respond to deviations of inflation forecast from the assumed target attempting a reduction of such departures.

To develop a general, nonlinear format for the Taylor rule, we start by allowing for the possibility that the interest rate instrument might experience three regimes depending on whether inflation is above, below, or inside a band around the target level. If inflation is inside the band, the short-term interest rate will effectively be indeterminate with random changes arising from random shocks to the economy—i.e. it will follow a random walk. If inflation is below the band, the interest rate will respond to changes of expected inflation and output gap according to a Taylor rule, while it will respond according to a different Taylor rule in the event that inflation is above the band. The resulting, very general nonlinear Taylor rule is our baseline empirical model, which we term $M1$:

$$M1: \qquad i_t = \begin{cases} \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t & \text{If } \pi_t \geq \pi_1 \\ i_{t-1} + \epsilon_t & \text{If } \pi_2 < \pi_t < \pi_1 \\ \beta_0 + \beta_1 i_{t-1} + \beta_2 \pi_{t,k} + \beta_3 x_t + \epsilon_t & \text{If } \pi_t \leq \pi_2 \end{cases} \tag{4}$$

where ϵ_t, the disturbance term, is assumed to be white noise and where $\pi_1 > \pi_2$. Note that this model nests the simple linear Taylor rule model, $M4$ (set $\pi_1 = \pi_2 = 0$ so that the random walk regime and the lower regime effectively disappear—given that inflation over the sample period was not negative).

The thresholds π_1 and π_2 can be estimated along with the other parameters by minimizing an appropriate criterion function using a two-dimensional grid

[5] See Muscatelli and Trecroci (2000) and the references therein.

search over the interval $\Pi^* = [min(\pi_t), max(\pi_t)]$. Hansen (1996) has shown that, under fairly weak regularity conditions, a grid search that minimizes the total sum squared residuals will provide consistent estimates of both the thresholds and the model parameters (see also Coakley, Fuertes and Perez, 2003). In the present application, however, we are proxying expected future values of inflation and the output gap using actual values, and these will be correlated with the regression error term since the latter includes expectational errors, so that a simple least squares approach is not appropriate. In addition, there will clearly also be an endogeneity issue and, because of overlapping forecast errors entering the error term, it will have a moving average representation of order $k-1$. For these reasons, we employed a generalized method of moments (GMM) estimator and a grid search for the pair (π_2, π_1) that minimizes the value of the GMM criterion function in the range Π^*. The criterion function that GMM minimizes is defined as:

$$J = \hat{\epsilon}' Z W^{-1} Z' \hat{\epsilon} \tag{5}$$

where $\hat{\epsilon}$ is the estimated residual vector and Z is a vector of ℓ instruments that are included in the information set and are exogenous (or predetermined) so that their correlation with the regression errors is zero: $E(Z'\varepsilon) = 0$. This orthogonality condition will generally not hold exactly in-sample for estimated values of ϵ, but the GMM estimator works by minimizing a weighted average of the squared values of the ℓ sample moments $Z'\hat{\epsilon}$. An efficient GMM estimator can be constructed in the linear model using a two-step procedure to construct the weight matrix W based upon centred estimates of the moment conditions (see e.g. Hansen, 2003). With the weight matrix chosen in this way, our estimation strategy was then to use a grid-search procedure to satisfy

$$(\pi_2, \pi_1) = arg \quad min_{\pi_1, \pi_2 \in \Pi^*} \quad J, \qquad \pi_1 > \pi_2. \tag{6}$$

In effect, this approach is generalization of the estimation method originally suggested by Clarida et al. (1998) to allow for threshold effects.

The model $M1$ collapses to a two-regime, two-Taylor rules model if $\pi_1 = \pi_2 = \hat{\pi}$, that is, when the interest rate does not experience an intermediate regime of indeterminacy. In that case, the interest rate will behave according to two different Taylor rules depending on whether inflation is above or below a single threshold. We label this model $M2$:

$$M2: \qquad i_t = \begin{cases} \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_2 x + \epsilon_t & \text{If } \pi_t \geq \hat{\pi} \\ \beta_0 + \beta_1 i_{t-1} + \beta_2 \pi_{t,k} + \beta_3 x_t + \epsilon_t & \text{If } \pi_t < \hat{\pi} \end{cases} \tag{7}$$

Model $M2$ further reduces to a two-regime (one random walk–one Taylor rule) model, if $\beta_1 = 1$ and $\beta_0 = \beta_2 = \beta_3 = 0$. The resulting model postulates that the interest rate might behave either as a random walk or respond to a forward-looking Taylor rule depending on whether inflation is below or above an single inflation threshold $\hat{\pi}$. We call that model $M3$ and it takes the following form:

$$M3: \qquad i_t = \begin{cases} \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t & \text{If } \pi_t \geq \hat{\pi} \\ i_{t-1} + \epsilon_t & \text{If } \pi_t < \hat{\pi} \end{cases} \tag{8}$$

The estimation of the threshold along with the other parameters of $M2$ and $M3$ involves the implementation of GMM estimator in the context of a one-dimensional grid search over the range Π^*:

$$\hat{\pi} = arg \quad min_{\pi_1 \in \Pi^*} \quad J \tag{9}$$

where J is the function minimized by GMM, as before.

3 Background Information and Dataset Description

3.1 The evolution of inflation targeting as a policy framework for the U.K.

Within a few months of coming to power in late 1979, the Conservative government under Margaret Thatcher announced the 'Medium Term Financial Strategy' (MTFS), which was essentially a five-year programme of targets for monetary growth and public sector deficits. Although monetary targeting had in fact been introduced in Britain in the mid 1970s as a condition for IMF support in the wake of the 1976 sterling crisis, the Labour government's commitment to the targets had never been credible. The announcement of the MTFS, however, was a textbook example of how a strong and credible commitment to a transparent deflationary policy can reduce inflation expectations and shift down the short-run Phillips curve, and U.K. inflation came down rapidly from around 20 percent per annum in 1980 to about 5 percent by 1983. In the event, however, it turned out to be much more difficult to control the money supply, and in particular to control the broad measures which had formed the core of the original MTFS. To a large extent this was due to a process of financial sector reforms that the Thatcher government also carried out. For example, the government abolished special taxes on high-interest

rate bank deposits ('the corset'), abolished exchange control and also introduced new legislation that allowed banks as well as building societies to lend money for the purposes of house purchase. These reforms and the various financial innovations of the 1980s (such as the introduction of interest-bearing current accounts) affected the stability of money demand so that monetary growth was in fact much more difficult to predict and, throughout the 1980s, the government's monetary targets were generally overshot.

Towards the end of the 1980s, therefore, the government began to think of other indicators of the tightness of monetary policy and in particular the exchange rate, which in an open economy like the U.K. is a particularly important indicator of the monetary stance. Also, given the relative success of Germany in controlling its money supply in most of the postwar period, linking the value of sterling to the Deutsche mark, either informally or formally through full membership of the Exchange Rate Mechanism (ERM) of the European Monetary System, seemed an attractive way of 'importing' German monetary policy. Following a period of informal shadowing of the mark, the UK in fact entered the European Exchange Rate Mechanism (ERM) in October 1990.

Three inter-related factors conspired against sterling's membership of the ERM, however. The first was that sterling had entered the ERM at a rate at which the U.K. currency appeared overvalued according to purchasing power parity comparisons, so that it moved to the bottom of its admissable range of fluctuation from the outset. Second, the deepening recession of the British economy at this time, accompanied by relatively low inflation, called for reductions in short-term interest rates, so that there was a clear conflict between internal and external policy objectives. Third, scenting the U.K.'s policy dilemma, sterling became a focus for sustained selling in the speculative attack on the ERM of September 1992 that eventually forced sterling out of the mechanism.

With the experience of the 1980s ruling out a return to monetary targeting as a credible policy alternative, the next phase in U.K. monetary policy was a shift to a framework of inflation targeting. Such a framework had a good deal of intellectual respectability, especially when implemented by an independent and 'conservative' central bank (Rogoff, 1985). It had been pioneered, apparently with some success, by New Zealand in 1990 and by Canada in 1991, and was arguably a natural choice of policy framework for the U.K.[6] In 1997, the incoming Labour government took the next logical step of granting independence in the conduct of monetary policy to the Bank of England, a decision

[6] The same was true of Sweden, who also turned to inflation targeting after being forced out of the ERM a few months after the U.K.'s exit.

that was formally ratified in the 1998 Bank of England Act. According to that Act, the Bank of England's objectives are to promote price stability and, subject to that commitment, to support the government's economic policy with respect to economic growth and employment. The Bank was originally charged with maintaining a 2.5 percent inflation target, that was effectively symmetric in the sense that deviations above and below target were apparently deemed equally undesirable: the Governor of the Bank of England is obliged to write formally to the Chancellor of the Exchequer (the U.K. Finance Minister) to explain occasions when inflation is above 3.5 percent or below 1.5 percent, including an account of the measures that will be taken to force inflation towards its target, the estimated duration of this process and how the remedial measures may affect the government's other macroeconomic policy objectives.[7]

3.2 Data

Given that inflation targeting has been formally enshrined in British monetary policy for more than a decade, the time seems opportune to examine the data for evidence of Taylor-rule behaviour in the policy actions of the Bank of England and, in particular, whether the existence of formal targets has induced nonlinearity in this behaviour.

To that end, monthly data were retrieved from Datastream for the inflation targeting period, from October 1992 to January 2003. The interest rate used for the purposes of this analysis is the monthly average of the interbank interest rate of the three month treasury bill. We proxy inflation by the annualized month-to-month percentage change of the retail price index (RPI) that excludes mortgage interest payments, RPIX (since RPIX inflation was the measure targeted by the authorities during our sample period). For the construction of output gap, the industrial production index is used. Following the previous literature on the estimation of Taylor rules, we construct the output gap using the Hodrick-Prescott cyclical component of the logarithm of industrial production.

The list of instruments that we used for the GMM estimation of the models includes a constant and lagged values of the short term interest rate, the output gap, inflation based on the RPI and on the producer price index. The RPIX excluding mortgage interest payments and indirect taxes, RPIY, is also

[7] This policy goal has subsequently changed to 2.0 percent, and is now defined in terms of the harmonized consumer price index, although this does not affect the sample period considered in the present analysis.

included in the instrument set.[8]. We follow previous researchers, including Clarida et al. (1998), and assume an inflation target horizon of three months in our empirical work.

4 Empirical Results

In order to examine which of the models considered above fits the data best, we performed a sequence of nested tests. In this setup, we test each model against its more specific counterpart. For this purpose, we construct a quasi likelihood ratio (Q-LR) test statistic as follows:

$$Q - LR = J^{restricted} - J^{unrestricted} \tag{10}$$

where J^f for $f = restricted, unrestricted$, is the objective function that GMM minimizes for the restricted and unrestricted models, respectively. Following Hansen (1996), we perform a non-parametric bootstrap simulation procedure in order to derive the empirical significance levels of these test statistics. The non-parametric bootstrap that we apply has the following steps: 1. Estimate the restricted model using the full sample of T observations and store the residuals and the fitted values of the interest rate; 2. draw with equal probability and with replacement from the vector of residuals to make up another $T \times 1$ vector of residuals; 3. add this vector to the vector of fitted values of the interest rate obtained in step 1 to obtain an artificial vector of interest rate observations; 4. estimate the restricted and the unrestricted models using the artificial interest rate vector and construct a value of the Q-LR statistic; 5. repeat steps $2 - 4$ five thousand times. This yields five thousand simulated values for the Q-LR statistic. The percentage of occasions that the simulated values of the Q-LR statistic exceed the actual value of the Q-LR statistic then corresponds to the empirical marginal significance level of the actual statistic.

The resulting empirical marginal significance levels for the nested sequence of tests—$M2$ against $M1$, $M3$ against $M2$, and $M4$ against $M3$—are given in Table 1, and show that, using a nominal test size of five percent, while $M2$ is not rejected against $M1$, and $M3$ is not rejected against $M2$, the most restrictive, linear Taylor rule model, $M4$, is rejected at the five percent level against $M3$, indicating significant nonlinearity in the Taylor rule.

Closer scrutiny of the estimation results for $M2$ (Table 2), however, revealed that in this model, two of the four estimated coefficients in the Taylor

[8] The lag structure that we imposed follows Clarida et al. (1998). Namely, we apply six lags for the interest rate, the inflation, the output gap, RPI, RPIY and RPIX inflation and the producer price index, plus the ninth and the twelfth lags of these variables.

rule for the low-inflation regime (the intercept and the expected inflation coefficient) were insignificantly different from zero at the five percent level, while the point estimate of the partial adjustment coefficient was significant and close to unity and the output gap coefficient was also significantly different from zero at the five percent level. This suggested that the insignificant QLR statistic obtained in moving from $M2$ to $M3$ may have been largely dominated by the two insignificant coefficients. Accordingly, we investigated a further model of the form:

$$M1': \qquad i_t = \begin{cases} \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t & \text{If } \pi_t \geq \pi_1 \\ i_{t-1} + \epsilon_t & \text{If } \pi_2 < \pi_t < \pi_1 \\ i_{t-1} + \beta_3 x_t + \epsilon_t & \text{If } \pi_t \leq \pi_2 \end{cases}, \quad (11)$$

which may be viewed as a variant of $M1$, with $\beta_0 = \beta_2 = 0$ and $\beta_1 = 1$ set to unity, and which we label $M1'$. $M1'$ involves three regimes, a low-inflation regime in which the interest rate is highly persistent but does respond to some extent to the output gap, a middle regime in which interest rates are indeterminate and follow a random walk, and a high-inflation regime in which a normal, forward-looking Taylor rule applies. Since the middle and lower regimes have only the output gap coefficient differentiating them, it then seemed reasonable to examine whether they can be collapsed into a single lower regime, which would be equivalent to imposing the restrictions $\pi_1 = \pi_2 = \widehat{\pi}$ holds, which would result in a model similar to $M2$ except with $\beta_0 = \beta_2 = 0$ and $\beta_1 = 1$, and which we therefore label $M2'$.

The empirical marginal significance level for the QLR test of $M2'$ against $M1'$ is also reported in Table 1, and reveals that we cannot reject $M2'$, so that $M2'$, in which all estimated coefficients are significantly different from zero at the five percent level, becomes our final, preferred specification. The parameter estimates are given in Table 3, but we can repeat them here for convenience:

$$M2': \qquad i_t = \begin{cases} 1.53 + 0.45 i_{t-1} + 0.70 \pi_{t,k} + 0.23 x_t + \widehat{\epsilon}_t & \text{If } \pi_t \geq 3.1 \\ i_{t-1} + 0.05 x_t + \widehat{\epsilon}_t & \text{If } \pi_t < 3.1 \end{cases}. \quad (12)$$

Above the threshold inflation rate of 3.1 percent, our preferred model becomes a standard, forward-looking Taylor rule with interest-rate smoothing in which both expected inflation and the output gap appear significantly, but with greater weight attached to deviations form the inflation target, consistent

with the Bank of England's remit to give priority to price stabilisation.

If we re-parameterize (12) to a form in which the deviation of expected inflation from target appears as an explanatory variable, using the stated inflation target of 2.5 percent explicitly, it becomes:

$$\begin{aligned} i_t &= (1.53 + 0.7 \times 2.5) + 0.45 i_{t-1} + 0.70(\pi_{t,k} - 2.5) + 0.23 x_t + \widehat{\epsilon}_t \\ &= 3.28 + 0.45 i_{t-1} + 0.70(\pi_{t,k} - 2.5) + 0.23 x_t + \widehat{\epsilon}_t \end{aligned}$$

In long-run equilibrium, when the output gap is zero and the inflation target achieved, and $i_t = i_{t-1} = i$, (and we assume $\widehat{\epsilon}_t = 0$), this implies a long-run nominal interest rate of $i = 3.28/(1 - 0.45)$ or almost exactly 6 percent per annum. With an inflation rate of 2.5 percent, this in turn implies a long-run equilibrium real rate of interest of about 3.5 percent per annum, which seems reasonable. Similarly, the long-run coefficient on the inflation term is $0.70/(1 - 0.45) = 1.27$, satisfying the Taylor determinacy principle that the long-run interest rate response to deviations of inflation from target should be greater than one-to-one in order to ensure that the Taylor rule delivers an inflation rate equal to the targeted value (Clarida et al., 1998; Woodford, 2001).

When inflation is below 3.1 percent, however, our preferred model implies that the authorities largely left interest rates to be determined randomly, albeit with some weak but nevertheless statistically significant influence of the output gap on interest rates, but apparently without worrying about expected inflation at all, which would seem reasonable when the inflation target was so close to being met.

5 Conclusion

In this paper we have reported estimates of a Taylor rule that appears adequately to describe the interest rate-setting behaviour of the Bank of England since formal inflation targeting was introduced in UK monetary policy in 1992. A key finding of our research, however, was that the estimated Taylor rule exhibits significant nonlinearity such that, when inflation has been within a half percent or so below its target of 2.5 percent per annum, the Taylor rule has collapsed to a 'random walk with a dragging anchor', whereby interest rate movements more or less follow a random walk unrelated to expected inflation but with a small but statistically significant link to movements in the output gap. When the inflation rate was more than about one half percent above target, however, a standard forward-looking Taylor rule appears to kick in, in

which the estimated coefficients are strongly significant and achieve plausible values.

Indeed, we would suggest that the results of our investigation are uncontroversial. Since the shift to inflation targeting in 1992, the Bank of England has actively sought to increase the transparency of policy-making by, inter alia, publishing the minutes of the meetings of the interest-rate setting committee (the Monetary Policy Committee) as well as detailed justification of its inflation forecasts. As such, it is perhaps not surprising that its interest rate-setting behaviour appears to be well captured by a Taylor rule. What is new in our analysis is the finding of significant nonlinearity in this policy setting, and in particular the finding that the standard Taylor rule really only begins to bite once expected inflation is significantly above its target. This suggests, for example, that while the stated objective of the Bank of England is to pursue a symmetric inflation target, in practice some degree of asymmetry has crept into interest-rate setting. Nevertheless, the very predictability of the policy rule, especially when set out in a highly plausible and intuitive nonlinear framework, is perhaps one reason why the United Kingdom has, since the early 1990s, enjoyed a period of price stability combined with relatively strong growth.

Table 1. Quasi Likelihood Ratio Test Results: Marginal Significance Levels

	$(M1, M2)$	$(M2, M3)$	$(M3, M4)$	$(M1, M1')$	$(M1', M2')$
$Q-LR$	0.0880	0.998	0.0394	0.0810	0.0522

Notes: Table entries correspond to the Q-LR test defined as $Q-LR = J^{restricted} - J^{unrestricted}$, where J^f, for the f=restricted,unrestricted, is the objective function that GMM minimizes for the restricted and unrestricted models, respectively. Entries in square brackets stand for the marginal significance level obtained after bootstrap simulations. Asterisk denotes significance at the 5 percent significance level.

Table 2. Empirical Results for Models M1 to M4

$$i_t = \begin{cases} \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t & \text{If } \pi_t \geq \pi_1 \\ i_{t-1} + \epsilon_t & \text{If } \pi_2 < \pi_t < \pi_1 \\ \beta_0 + \beta_1 i_{t-1} + \beta_2 \pi_{t,k} + \beta_3 x_t + \epsilon_t & \text{If } \pi_t \leq \pi_2 \end{cases}$$

k = 3 months, 1992:10-2003:01

	M1	M2	M3	M4
		$\pi_1 = \pi_2 = \widehat{\pi}$	$\pi_2 = 0$	$\pi_1 = \pi_2 = 0$
α_0	1.6219*	1.6079*	1.5636*	0.4361*
	(0.6313)	(0.6191)	(0.6339)	(0.1661)
α_1	0.4613*	0.4402*	0.4513*	0.9087*
	(0.0757)	(0.0724)	(0.0738)	(0.0263)
α_2	0.6455*	0.7029*	0.6848*	0.0227
	(0.3116)	(0.2988)	(0.3060)	(0.0773)
α_3	0.2540*	0.2432*	0.2281*	0.0832*
	(0.1034)	(0.1010)	(0.1033)	(0.0257)
β_0	0.0313	-0.1523		
	(0.2786)	(0.1469)		
β_1	0.9454*	0.9928*		
	(0.0333)	(0.0226)		
β_2	0.0921	0.0686		
	(0.1042)	(0.0621)		
β_3	0.0836*	0.0547*		
	(0.0266)	(0.0203)		
J	40.4016	44.6321	50.4776	72.6781
π_1	3.10		3.10	
π_2	2.60			
$\widehat{\pi}$		3.10		

Notes: Values in parenthesis stand for the standard deviation of the respective estimate. Asterisk denotes significant entries at the 5% significance level. J is the criterion function that GMM minimizes computed at parameter estimates.

Table 3. Empirical Results for Models M1′ and M2′

$$i_t = \begin{cases} \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t & \text{If } \pi_t \geq \pi_1 \\ i_{t-1} + \epsilon_t & \text{If } \pi_2 < \pi_t < \pi_1 \\ i_{t-1} + \beta_3 x_t + \epsilon_t & \text{If } \pi_t \leq \pi_2 \end{cases}$$

k = 3 months, 1992:10-2003:01

	$M1'$	$M2'$ $(\pi_1 = \pi_2 = \widehat{\pi})$
α_0	1.5157*	1.5316*
	(0.6221)	(0.6216)
α_1	0.4549*	0.4502*
	(0.0724)	(0.0723)
α_2	0.6367*	0.7008*
	(0.3002)	(0.3001)
α_3	0.2342*	0.2327*
	(0.1014)	(0.1013)
β_3	0.0541*	0.0462*
	(0.0209)	(0.0193)
J	45.7704	46.8094
π_1	3.10	
π_2	2.70	
$\widehat{\pi}$		3.10

Notes: Values in parenthesis stand for the standard deviation of the respective estimate. Asterisk denotes significant entries at the 5%significance level. J is the criterion function that GMM minimizes computed at parameter estimates.

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