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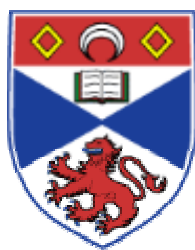
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CENTRE FOR DYNAMIC MACROECONOMIC ANALYSIS
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CDMA05/03

Inflation Targeting, Committee Decision Making and Uncertainty: The Case of the Bank of England's MPC*

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ABSTRACT

The transparency and openness of the monetary policymaking process at the Bank of England has provided very detailed information on both the decisions of individual members of the Monetary Policy Committee and the information on which they are based. In this paper we consider this decision making process in the context of a model in which inflation forecast targeting is used but there is heterogeneity among the members of the committee. We find that internally generated forecasts of output and market generated expectations of medium term inflation provide the best description of discrete changes in interest rates. We also find a role for asset prices through the equity market, foreign exchange market and housing prices. There are also identifiable forms of heterogeneity among members of the committee that improves the predictability of interest rate changes. This can be thought of as supporting the argument that full transparency of monetary policy decision making can be welfare enhancing.

JEL Classification: E420, E430, E500.

Keywords: Monetary policy; interest rates; monetary policy committee; committee decision making.

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1 Introduction

The widely recognised transparency and openness of the monetary policy-making process at the Bank of England has provided very detailed information on both the decisions of individual members of the Monetary Policy Committee and the information on which they are based. Recent literature has used such detailed information, including votes by individual policymakers, to study several aspects of monetary policymaking in the Bank of England¹. In this paper we consider this decision making process in the context of a model in which inflation forecast targeting is used but there is heterogeneity among the members of the committee. This heterogeneity does not arise so much from differences in preferences about inflation and output, as from the differences in information assimilation.

Our paper touches on a number of issues in the literature on monetary policy. There is a large literature on the usefulness of trying to characterise monetary policy in terms of a rule. More recently, Orphanides (2003) has provided a historical analysis and has been able to show that there is a degree of consistency in the conduct of US monetary policy during the 1920s and since the 1951 accord that gave effective independence to the Federal Reserve. In many cases across the world, the Taylor rule provides a useful way of analysing policy.

However, another theme running through much of the policy discussion has concerned the potential use of simple monetary rules such as those advocated by Taylor (1993). To some extent the use of a simple rule assumes the sort of well defined preferences which are conspicuously absent in the current monetary arrangement. However, simple rules have a number of advantages chiefly, perhaps, by making the operation of monetary policy transparent and therefore easily monitored by the private sector. The question remains as to what form such a simple rule should take. Taylor conditions short term interest rates on current deviations of output and inflation from target while Svensson (1997a, 1997b) argues that, given the long and variable lags inherent in policy, it might make more sense to target a forecast of inflation rather than its current value. Orphanides (1998) has also pointed out that decisions about interest rates are made in real time when there is consider-

¹See, for example, Chadha and Nolan (2001), Cobham (2002a, 2002b, 2003) and Gerlach-Kristen (2004). There is also a substantial literature in the US which uses information provided by transcripts of the proceedings of the FOMC. See Belden (1989), Havrilesky and Gildea (1991), Edison and Marquez (1998) and Chappell *et al.* (2004).

able uncertainty about the current state of the economy. In this paper we assume that the filtering which is required of current (imperfect) measure of economic activity takes place as part of the internal procedures of the Bank of England (see Budd (1998) for a description).

In this paper we take advantage of the considerable volume of information that the Bank of England makes available about the decision-making processes of the Monetary Policy Committee to examine the kinds of policy rule that the MPC operates implicitly. As has been emphasised repeatedly by a number of commentators, it is clear that the Bank operates an inflation forecast type of rule, but with some evidence to suggest that developments in asset markets also matter (Bernanke and Gertler, 2001; Cobham, 2002a).

The contrast between the degree of transparency that the Bank of England aspires to and the traditional practices of Central Bankers could not be greater². Transparency serves the need of accountability but it also improves predictability. Previous research has argued that dissenting votes can be attributed to policy-makers' possibly different policy preferences. Further, these dissents may contain information about uncertainty in the macroeconomic environment³. We find in this paper that explicit modeling of the individual decisions of MPC members improves the predictability of interest rate changes compared with the case where only the aggregate decision is known. The heterogeneity across the MPC is valuable information. This throws some light on the current debate about the extent to which central banks should make decision making processes as transparent as possible⁴.

The granting of operational independence to the Bank of England in 1997 put in place a mechanism for making decisions on monetary policy based on a 9 member Monetary Policy Committee made of 5 internal and 4 external members. Operational decisions on interest rate policy are made by the MPC. It comprises the Governor of the Bank of England, the two deputy Governors, two members of the Bank with responsibility in the Bank for monetary policy and market operations and four outside members with rele-

²See Chadha and Nolan (2001) for an early analysis of the post-1997 policy regime.

³See, for example, Belden's (1989) analysis of dissents in FOMC votes and Chadha and Nolan's (2001) analysis in the UK context. Other measures of uncertainty discussed in the literature include forecast revisions (Chadha and Nolan, 2001) and dispersion in survey correspondents' views on inflation (Bomberger, 1996).

⁴See Geraats (2002) for an extensive survey of the question of transparency in monetary policymaking, and Gerlach-Kristen (2004) for a recent empirical analysis of predictability in MPC decision-making.

vant expertise who are appointed by the Chancellor. The internal members are permanent appointments while the externals serve for a 3 year period, with the possibility of reappointment. A large amount of information is provided on both the information set that is at the disposal of the Committee and the eventual vote that each member casts. This provides an invaluable dataset to study what is actually the basis for decisions on interest rates. We find that the decision making process is best thought of as an inflation forecast regime⁵ (Svensson, 1997a) but with some responsiveness to asset market developments. This suggests that the common approach of conditioning interest rates on current and lagged output and inflation may be misplaced.

There is now an extensive literature on the role that asset market developments should play in monetary policy decisions. For example, Bernanke and Gertler (2001) argue that policy should not respond to changes in assets prices, except in so far as they signal changes in expected inflation. Cecchetti *et al.* (2000), by contrast, have argued that monetary policy should respond to bubbles or misalignments in asset prices.⁶

The plan of the paper is as follows. In section 2 we briefly discuss some simple models of the inflation process and introduce a role for transparency and for a committee structure for decision-making and consider the signal extraction problem that the MPC and the members individually face. In Section 3 we discuss the estimation problem. In section 4 we report some empirical results. Finally, in section 5, we present our conclusions.

2 Models of the inflation process

We adopt the most simple form of a model of the monetary policymaking process and abstract from many issues that have been the focus of much of

⁵It should be emphasised that since the inception of inflation targetting at the Bank of England, officials have always described their actions as been conditioned on what inflation is expected to be in the future, since the delays in the transmission mechanism of monetary policy means nothing can be done about the current rate of inflation.

⁶For other views see Vickers (1999), Goodhart (2001), Bean (2003) and Bullard and Schalling (2002).

the recent literature⁷. The model is structured as follows:

$$\pi_t = \pi_{t-1} + \alpha y_{t-1} + \epsilon_t \quad (1)$$

$$y_t = \beta_1 y_{t-1} - \beta_2 (i_{t-1} - \pi_{t-1}) + \eta_t \quad (2)$$

π_t is the inflation rate in period t , y_t is the output gap (the difference between the log of output and the log of potential output), i_t is the nominal interest rate. η_t and ϵ_t are iid shocks in period t not observable in period $t - 1$. The coefficients α and β_2 are positive; β_1 ($0 < \beta_1 < 1$) measures the degree of persistence in the output gap. The output gap depends negatively on the real lagged interest rate. The change in inflation depends on the lagged output gap. The output gap is normalised to zero in the long run.

These pure delays in the impact of the output gap on inflation and of interest rates on the output gap captures in the most straightforward way the central bankers' stylised model of the monetary transmission process. The modern generation of New Keynesian models with nominal inertia and imperfect competition still exhibit jumps in output and inflation in response to shocks⁸ which will blur the pure delays embodied in equations (1) and (2). The intertemporal loss function is:

$$L_t = \frac{1}{2} E_t \sum_{\tau=t} \delta^{\tau-t} [(\pi_t - \pi^*)^2] + \lambda y_t^2 \quad (3)$$

E_t denotes expectations conditional on information available in period t . π^* is the inflation target; δ , is the discount rate and satisfies $0 < \delta < 1$. The policymaker minimises the present discounted value of squared deviations of inflation from its target and the output gap. λ is the weight the policymaker attaches to the output gap being zero, with the weight on inflation normalised to one.

For the special case of $\lambda = 0$, so the policymaker only targets inflation, the central bank can (in expectation) use the current interest rate to hit the target for inflation two periods hence. So perfect controllability in this case allows the intertemporal problem to be written as a sequence of single period problems. In this case (Svensson, 1997a)

⁷In particular, for expositional purposes we ignore forward-looking expectations and issues arising consequently from time inconsistency.

⁸See Corrado and Holly (2004) for an example in which inertia comes partly from habit persistence in household consumption.

$$L_t = \frac{1}{2} [\pi_{t+2|t} - \pi^*]^2 \quad (4)$$

$\pi_{t+2|t}$ is the forecast of inflation at time period $t + 2$ based on information available in period t . The central bank minimises the squared deviation of the current two-year inflation forecast, $\pi_{t+2|t}$, from the target. The forecast of π_{t+2} at t is

$$\pi_{t+2|t} = \pi_{t+1|t} + \alpha y_{t+1|t} \quad (5)$$

and

$$y_{t+1|t} = \beta_1 y_{t|t} - \beta_2 (i_t - \pi_{t|t}) \quad (6)$$

where the subscript $t|t$ indicates that current realisations of the output gap and inflation may well be imperfectly observed, and need to be forecasted.

So:

$$\pi_{t+2|t} = \alpha [\beta_1 y_{t|t} - \beta_2 (i_t - \pi_{t|t})] \quad (7)$$

Then the inflation ‘feed forward’ rule is

$$i_t = (\pi_{t|t} - \pi^*) + \frac{1}{\alpha\beta_2} \pi_{t+1|t} + \frac{\beta_1}{\beta_2} y_{t|t} \quad (8)$$

This satisfies the Taylor Principle since $\partial i / \partial \pi > 1$, as long as there is persistence in inflation. Although there is not an explicit weight attached to output losses, current (forecasted) output appears in the rule because the current output gap is informative about future inflation. In Svensson’s original formulation $\pi_{t|t}$ and $y_{t|t}$ are known. In practice, as Orphanides (1998) has pointed out, in real time current inflation and the current output gap are not observed.

2.1 Committee decision-making

In contrast to the Federal Reserve⁹ and the ECB, where decision making is by ‘consensus’, the Monetary Policy Committee of the Bank of England

⁹See Edison and Marquez (1998) for a detailed description of the decision making processes of the Federal Open Markets Committee.

uses majority voting so it is the median vote that decides the outcome for monetary policy. One way to model decision making by committee is to assume that preferences with respect to inflation and output vary across the committee (Sibert, 2003; Neuman, 2002). In this case we can write a loss function for the i th committee member as:

$$L_{it} = \frac{1}{2} E_t \sum_{\tau=t} \delta^{\tau-t} [(\pi_\tau - \pi^*)^2] + \lambda_i y_\tau^2, \quad \text{for } i = 1, \dots, m \quad (9)$$

If we confine ourselves to the case considered earlier when only inflation matters, preference heterogeneity is not meaningful. Instead we adopt the alternative approach in which heterogeneity arises from differing views about the state of the economy¹⁰. Each member has the same (public) information set but will augment this with private information. This can take different forms. An individual member may dissent from the consensus forecast or an individual member may have particular expertise that leads to more weight being attached to particular kinds of information compared to the average. Since the internal dynamics of committee decision making can result in a measure of sharing of expertise, we shall assume that each decision is ultimately based on information that cannot be shared fully with the MPC, or to which the other members of the Committee do not attach importance. The decision rule for the i th member is:

$$i_{it} = (\pi_{t|t} - \pi^*) + \frac{1}{\alpha\beta_2} \pi_{t+1|t} + \frac{\beta_1}{\beta_2} y_{t|t} + \varsigma_{it} \quad \text{for } i = 1, \dots, m \quad (10)$$

ς_{it} need not be a zero mean process. There are two main forms of heterogeneity. First, members may differ, for example, about the size of the output gap. Some members may believe that the central estimate of the output gap generated by the staff of the Bank of England underestimates improvements on the supply side that widens the output gap and places less pressure on inflation. In these circumstances a member may prefer on average a lower interest rate. This we capture by the fixed effect, ς_{it} , that (in absolute value)

¹⁰As King (2002) has pointed out, most of the discussion that takes place among the MPC members is focused on a technical economic judgment about what it is necessary to do to hit the inflation target. A sense of this process can be got from the summary of discussions in each MPC meeting discussed in Cobham (2003). Chadha and Nolan (2001) examine whether the perceived variation in preferences across MPC members (as revealed in their votes) is related to volatility in interest rates.

is increasing in the forecast standard deviation of output gap. However, we assume that there are zero covariances among the ς_{it} . In other words, this assumes that the common information set across all members of the MPC spans the common information between any pair of members, though not necessarily the private information of each MPC member.

Secondly, views may differ about the effect of interest rates on output and inflation. Suppose, for example, a member of the Committee believes that the effect of interest rates on the output gap captured by β_2 , is actually smaller than the central estimate. In this case interest rate setting will need to be more variable in response to shocks to output and inflation. This member will vote for more changes in interest rates, both positive and negative, compared to the average. We interpret this as the actions of an activist member¹¹.

2.2 Information Processing

The problem of determining $y_{t|t}$ and $\pi_{t+1|t}$ (and implicitly the uncertainty associated with the forecasts) can be cast as an optimal filtering or signal extraction problem (Holly and Hughes Hallett, 1989). Define the state vector $\tilde{y}_t = (\pi_t, y_t)'$. So that

$$\tilde{y}_t = A\tilde{y}_{t-1} + Bu_t + e_t \quad (11)$$

where \tilde{y}_t is a 2×1 vector, A a 2×2 matrix, B is 2×1 vector and $u_t = i_t$. e_t is a 2×1 vector of iid shocks. We assume that we observe the current state of the economy imperfectly so

$$z_t = H\tilde{y}_t + \psi_t, \quad (12)$$

where $E(\psi_t) = 0$ and $E(\psi_t'\psi_t) = \Gamma_t$ and z_t is a 2×1 vector of observations of the state vector. We want the best estimate of \tilde{y}_t conditional on information available, which is $\tilde{y}_{t|t}$.

Prior knowledge of the conditional density of \tilde{y}_{t-1} based on the information set Ω_t gives

$$E(\tilde{y}_{t-1} | \Omega_t) = \tilde{y}_{t-1|t} \quad (13)$$

¹¹In the empirical analysis presented later in the paper, we segregate these two sources of heterogeneity from one another. The first source of heterogeneity is related to uncertainty about forecasts of output gap, which can be measured from the fan charts of output growth published by the Bank of England. The second source of heterogeneity is related to the level of activism of a particular member, and can be identified from the residuals of a regression model in which the first source of heterogeneity has been controlled for.

and

$$E(\tilde{y}_t | \Omega_t) = A\tilde{y}_{t-1|t} + Bu_t. \quad (14)$$

The conditional covariance of $\tilde{y}_{t-1|t}$ is defined as

$$Cov(\tilde{y}_{t-1} | \Omega_t) = \Lambda_{t-1} \quad (15)$$

so

$$Cov(\tilde{y}_t | \Omega_t) = A\Lambda_{t-1}A' + \Gamma_t = \Lambda_t \quad (16)$$

In this framework the time varying quality and reliability of information is captured by Γ_t . The solution to this problem provides a way of optimally updating estimates of \tilde{y}_t .

$$\tilde{y}_{t|t} = \tilde{y}_{t|t-1} + F_t(z_t - H\tilde{y}_{t|t-1}) \quad (17)$$

where $F_t = \Lambda_t H' (H\Lambda_t H' + \Gamma_t)^{-1}$.

So the best estimate is a linear combination of the previous best estimate and on a correction for the difference between the previous estimate and the latest observations.

The central point from the perspective of monetary control is that the usefulness of new observations on the economy varies over time. In some periods with a large Γ_t , there will be little if any revisions to the optimal estimate of $\tilde{y}_{t|t}$, so a change in the interest rate setting will not take place¹².

We assume that this multivariate filtering is the domain of the Bank of England and the MPC. However, we can also allow for individual members of the MPC to optimally update their private forecasts. Assume that ς_{it} for each member follows an autoregressive process.

$$\varsigma_{it} = \kappa_i + \theta_i \varsigma_{it-1} + \gamma_{it}, 0 < \theta_i < 1. \quad (18)$$

$$\gamma_{it} \sim N(0, \sigma_{\gamma_t}^2) \quad (19)$$

and we observe this via

¹²It may also be that interest rate setting by the MPC is affected by the frequency with which the central forecasts of the Bank of England are updated. The *Inflation Report* is published 4 times a year in February, May, August and November.

$$z_{it} = \varsigma_{it} + \delta_{it} \tag{20}$$

$$\text{with } \delta_{it} \sim N(0, \sigma_{\delta_{it}}^2) \tag{21}$$

Where now z is a scalar. Then the optimal private estimate for the i 'th committee member is

$$\varsigma_{it|t} = \varsigma_{it|t-1} + [\sigma_{\gamma_{it}}^2 / (\sigma_{\gamma_{it}}^2 + \sigma_{\delta_{it}}^2)](z_t - \varsigma_{it|t-1}) \tag{22}$$

Again the revisions to private information will vary with the quality of observations.

The standard separation of observation from control means that these optimal estimates of $\tilde{y}_{t|t}$ and $\varsigma_{it|t}$ can be plugged into the feedback rule given in equation (10)¹³. Note, however, that whereas the form of the feedback rule is independent of the observation process, the *actual* interest rate decision is not. This will be affected by the quality and reliability of the information that flows into the monetary decision making process.

3 Data and Econometric models

3.1 The information set and measurement of variables

In this section we turn to an empirical examination of monetary policy in the UK. In the previous section the model suggested that an inflation forecast rule has been used and we attempt to test for this using information provided regularly by the Bank of England in the Inflation Report. We collected information on the kinds of data that the MPC looked at for each monthly meeting. Not all of this information is made use of in this paper but the important thing was to ensure that we conditioned only on what information was actually available at the time of each meeting.

Our dependent variable is the change in base rate agreed by the MPC at each of its meetings, from June 1997 to December 2003; these meetings are monthly and held in the first week of each month, except September 2001 when an additional meeting was held following the events on September 11.

¹³This separation also carries over to a more general model in which expectations are forward looking (Pearlman, 1992).

Our study of heterogeneity among the members of the MPC is based on decisions of the individual members. The source for these data are the minutes of the MPC meetings. We evaluate our models using data on monthly meetings in 2004.

Assessing monetary policy decisions in the presence of uncertainty about forecast levels of inflation and the output gap (including uncertainty both in forecast output levels and perception about potential output) requires collection of real-time data available to the policymakers when interest rate decisions are made as well as measures of forecast uncertainty. This contrasts with many studies of monetary policy which are based on realised (and subsequently revised) measures of economic activity (see Orphanides, 2003). The extent to which there is uncertainty about the forecast of the Bank of England can be inferred from the fan charts published in the Inflation Report (Britton *et al.*, 1998).

We also collected information on unemployment (where this typically refers to unemployment three months prior to the MPC meeting, as well data on the underlying state of asset markets (housing prices, share prices and exchange rates). We measure unemployment by the year-on-year change in ILO rate of unemployment, lagged 3 months. The ILO rate of unemployment is computed using 3 months rolling average estimates of the number of ILO-unemployed persons and size of labour force (ILO definition), both collected from the ONS Labour Force Survey. Housing prices are measured by the year-on-year growth rates of the Nationwide housing prices index (seasonally adjusted) for the previous month (Source: Nationwide). Share prices and exchange rates are measured by the year-on-year growth rate of the FTSE 100 share index and the effective exchange rate respectively at the end of the previous month (Source: Bank of England). The other current information included in the model is the current level of inflation; this is measured by the year-on-year growth rate of RPIX headline inflation lagged 2 months (Source: ONS).

Our model also includes expected rates of future inflation and forecasts of current and future output. One difficulty with using the Bank's forecasts of inflation is that they are not really informative. By definition, the Bank targets inflation over a two year horizon, so it always publishes a forecast in which (in expectation) inflation hits the target in two years time. To do anything else would be internally inconsistent. Instead, as a measure of future inflation, we use the 4 year ahead inflation expectations implicit in bond markets at the time of the MPC meeting, data on which can be inferred

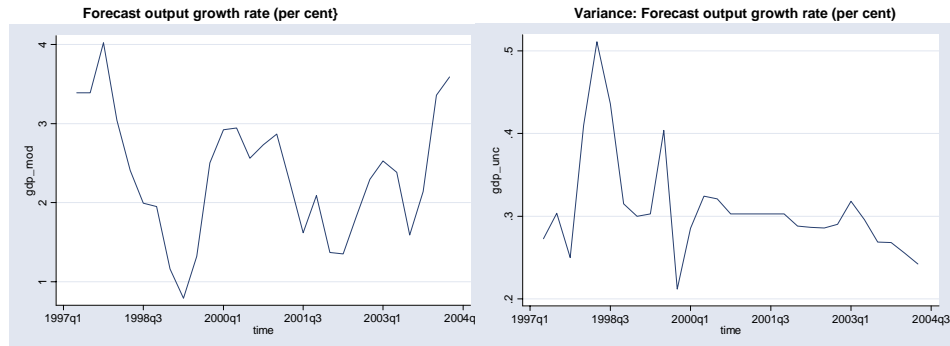


Figure 1: Variation in forecast output growth and its variance over time

from the Bank of England’s forward yield curve estimates obtained from index linked bonds. For output, we use the Bank of England’s model based mean quarterly forecasts of current and one-year-ahead GDP. As a measure of forecast uncertainty, we use the standard deviation of the one-year-ahead forecast. These measures are obtained from the Bank of England’s fan charts of output; details regarding these measures are discussed elsewhere (Britton *et al.*, 1998). The forecasts of one-year-ahead output growth and its variance show substantial variation over time (Figure 1).

3.2 An interval censoring model of base rate changes

Interest rate changes are highly clustered, with a majority of the meetings proposing no change in the base rate (see Figure 2). For the Bank of England MPC over the period of our analysis, 69 per cent of the meetings decided to keep the base rate at its current level, 12 per cent recommended a rise of 25 basis points, 14 per cent recommended a reduction of 25 basis points, and 5 per cent a reduction of 0.50 per cent. This clustering has to be taken into account when studying decisions of the MPC. We do not observe changes in interest rates on a continuous or unrestricted scale, we have a non-continuous or limited dependent variable. Moreover, changes in interest rates are in multiples of 25 basis points. So, in this paper, we use an interval regression framework for analysis; other authors have used other limited dependent variable frameworks, like the logit/ probit or multinomial logit/ probit framework (for recent contributions, see Chevapatrakul *et al.*,

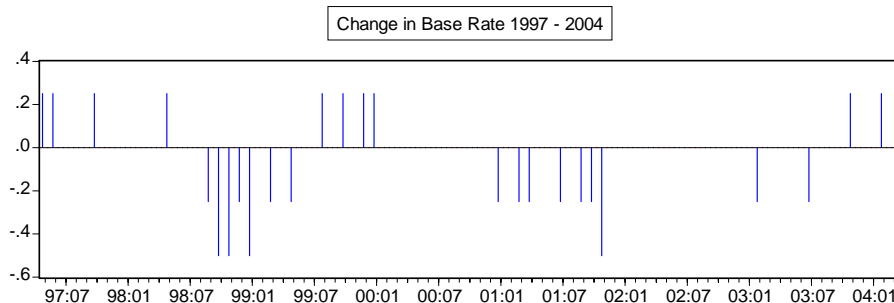


Figure 2: Discrete (Limited Dependent) nature of interest rate changes

2001, and Gascoigne and Turner, 2003). Our choice of model is based on the need to use all the information that is available when monetary policy decisions are made, as well as problems relating to model specification and interpretation of multinomial logit models (Greene, 1993). We also explored a multinomial logit formulation, and found the broad empirical conclusions to be similar.

The interval regression model (Amemiya, 1973) is a generalisation of the tobit model where the truncation in the dependent variable is possibly different for different observation units, and the truncation cut-offs are known. The observed dependent variable in our case, $\Delta r_{t,obs}$, is the truncated version of the latent monetary policy response variable, Δr_t , where

$$\begin{aligned}
 \Delta r_{t,obs} &= -0.5 && \text{if } \Delta r_t \in (-\infty, -0.375) \\
 &= -0.25 && \text{if } \Delta r_t \in [-0.375, -0.20) \\
 &= 0 && \text{if } \Delta r_t \in [-0.20, 0.20] \\
 &= 0.25 && \text{if } \Delta r_t \in (0.20, 0.375] \\
 &= 0.5 && \text{if } \Delta r_t \in (0.375, \infty)
 \end{aligned}$$

The wider truncation interval when interest rates are maintained (*ie.*, for $\Delta r_{t,obs} = 0$) may be interpreted as reflecting the conservative stance of monetary policy under uncertainty with a bias in favour of leaving interest rates unchanged.

Under this observation scheme, we estimate the following model of MPC

inflation targeting:

$$\begin{aligned} \Delta r_t = & \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y 0} \cdot y_t + \beta_{y 1} \cdot y_{t+1|t} \\ & + \beta_{\sigma} \cdot \sigma(y_{t+1|t}) + \lambda' \cdot \underline{Z}_{t-1} + \varepsilon_t, \end{aligned} \quad (23)$$

where \underline{Z}_{t-1} represents current observations on unemployment (Δu_t) and the underlying state of asset markets ($P_{hsg,t}$, $P_{FTSE,t}$ and $P_{exch,t}$). $\sigma(y_{t+1|t})$ is the standard deviation of the one-year ahead forecast of output growth; this term is included to incorporate the notion that the stance of monetary policy may depend on the uncertainty relating to forecast future levels of output and inflation. As was shown in the previous section, increased uncertainty about the current state of the economy will tend to bias policy towards caution in changing interest rates. In particular, this strand of the literature suggests that optimal monetary policy may be more cautious (rather than activist) under greater uncertainty in the forecast or real-time estimates of output gap and inflation (see Issing, 2002; Aoki, 2003; and Orphanides, 2003). Since, as previously discussed the published inflation forecast is not informative, we confined ourselves to uncertainty relating to forecasts of future output growth.

3.3 Fixed effects model of base rate changes with heterogeneity among members

Each member of the MPC arrives at his/ her own decision regarding interest rates, and consensus interest rate decisions are arrived at by voting on these individual proposals. In addition to consensus decisions, the Bank of England also publishes interest rate change proposals of each individual member of the MPC. The voting pattern of individual members of the MPC suggests substantial systematic differences across the committee (Table 1)¹⁴. These

¹⁴For example, of the 37 meetings which Allsopp attended, the votes for 11 were against the consensus decision, and all of these were for a lower interest rate. Similarly, Julius voted against the consensus motion in 14 of the 45 meetings; all of these in favour of a lower interest rate. Wadhvani disagreed 13 out of 37 times, each time in favour of a lower interest rate. On the other hand, King disagreed with the consensus decision in 12 of the 82 meetings he attended, voting for a higher interest rate each time. Buitert dissented in 17 meetings out of 36, voting on 8 occasions for a lower interest rate and 9 times in favour of a higher one. Nickell favoured a different interest rate decision in 10 of the 49 meetings; 6 for a lower interest rate and 4 for a higher interest rate. See also King (2002) and Gerlach-Kristen (2004).

data on individual votes offers the opportunity to examine the voting pattern in MPC meetings, and resulting majority decision that is arrived at as a consequence.

In the model of section 2 we have suggested that uncertainty about forecasts will affect monetary policy decisions. Moreover, that there will be heterogeneity in the way individual members incorporate this uncertainty about future levels of output (or different notions about full employment level of future output) into their decisions. This appears to justify a model of individual MPC members' decisions, where there may be heterogeneity in the effect that $\sigma(y_t)$ has on the interest rate decisions (*ie.*, the coefficient β_σ).

**TABLE 1: Heterogeneity among members:
Voting records of selected MPC members**

Member	Meetings	Votes			Dissent		
		Lower	No change	Raise	Total	High	Low
Allsopp	37	18	19	0	11	0	11
Barker	37	9	24	4	4	1	3
Bean	45	10	32	3	1	0	1
Buiter	36	10	10	16	17	9	8
George	74	15	51	8	0	0	0
Goodhart	36	7	18	11	3	3	0
Julius	45	18	25	2	14	0	14
King	85	14	50	21	12	12	0
Nickell	49	15	27	7	10	4	6
Wadhvani	37	16	18	3	13	0	13

Under a similar interval regression framework as above, we would then have the model:

$$\begin{aligned} \Delta r_{it} = & \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y 0} \cdot y_t + \beta_{y 1} \cdot y_{t+1|t} \\ & + \beta_{\sigma i} \cdot \mathbf{I}[i \in MPC_t] \cdot \sigma(y_{t+1|t}) + \underline{\lambda}' \cdot \underline{Z}_{t-1} + \varepsilon_{it}, \end{aligned} \quad (24)$$

where $\mathbf{I}[i \in MPC_t]$ is the indicator that member i was present at the MPC meeting on date t , $\beta_{\sigma i}$ represents the responsiveness of member i 's decision to uncertainty in future output, and $\pi_{t+4|t}$ and $y_{t+1|t}$ denote the expected/ forecasted value for inflation and output. The latent variables Δr_{it} are assigned to intervals in the same way as earlier. However, here there are occasions when individuals MPC members have voted for a reduction

of 40 or 75 basis points, or an increase of 50 basis points, hence all votes for change of more than 25 basis points have been assigned to the intervals $[\Delta r_{it,obs} - 0.125, \Delta r_{it,obs} + 0.125)$.

3.4 Random effects models of base rate changes with heterogeneity among members

The above fixed effects formulation, however, cannot capture one important aspect of the heterogeneity in the decision processes of MPC members – namely, the degree of activism. As noted earlier, some MPC members’ decisions are characterized by a greater degree of variability than some others¹⁵. A convenient way of modeling the decision processes of MPC members that captures such features would be through a random effects model; the response of a more activist member would be characterised by a higher variance of the effect of $\sigma(y_t)$.

A typical application of random effects in this context would have been through the model

$$\begin{aligned} \Delta r_{it} = & \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y 0} \cdot y_t \\ & + \beta_{y 1} \cdot y_{t+1|t} + \underline{\lambda}' \cdot \underline{Z}_{t-1} + u_{it}, \end{aligned}$$

where

$$u_{it} = \beta_{\sigma i} \cdot \mathbf{I}[i \in MPC_t] \cdot \sigma(y_{t+1|t}) + \varepsilon_{it},$$

$\beta_{\sigma i} \sim N(\mu_i, \sigma_i^2)$, $\varepsilon_{it} \sim N(0, \sigma^2)$, ε_{it} and $\beta_{\sigma i}$ independently distributed. However, this model is not identifiable. One can only work with this model if $\sigma^2 = 0$, which is not satisfactory.

¹⁵Buiter and Nickell are prominent examples (Table 1). Both have disagreed from the consensus interest rate decisions at a substantial number of meetings, but their proposals have not been predominantly above or below the consensus decision.

An alternative random effects model may be the following:

$$\begin{aligned} \Delta r_{it} &= \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y 0} \cdot y_t + \beta_{y 1} \cdot y_{t+1|t} \\ &\quad + \underline{\lambda}' \cdot \underline{Z}_{t-1} + (\beta_{\sigma}^* + \beta_{\sigma i}) \cdot \mathbf{I}[i \in MPC_t] \cdot \sigma(y_{t+1|t}), \\ &\quad \left(\begin{array}{c} \beta_{\sigma}^* \\ \beta_{\sigma i} \end{array} \right) \sim N \left[\left(\begin{array}{c} \mu \\ \mu_i \end{array} \right), \left(\begin{array}{cc} \sigma^2 & \sigma_{0i} \\ \sigma_{0i} & \sigma_i^2 \end{array} \right) \right], \\ 0 &= n\mu + \sum_{i=1}^I n_i \mu_i, \\ &\quad \beta_{\sigma i} \text{'s are independent of each other,} \end{aligned} \tag{25}$$

where β_{σ}^* represents the typical response of monetary policy to uncertainty, $\beta_{\sigma i}$ is the response of the specific MPC member¹⁶, and n and n_i 's are the total number of meetings, and the number of meetings that member i attends respectively. Recall the discussion in the previous regarding the two sources of heterogeneity. This model allows the segregation of the uncertainty term into these two parts, one that is common to all members (depending only on the overall degree of forecast uncertainty), and the other incorporates individual-specific heterogeneity in the degree of activism.

We have implemented this model by assuming that new MPC members go with the general flow for a period of time (the first 3 meetings in our case) before their individual views start getting expressed¹⁷. Thus, we can use the votes in these three initial meetings to estimate μ and σ^2 , and votes in the subsequent meetings to estimate the individual specific heterogeneity parameters. We further assume that $\sigma(y_t)$ is uncorrelated with the other regressors¹⁸. We first estimate the regression

$$\Delta r_{it} = \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y 0} \cdot y_t + \beta_{y 1} \cdot y_{t+1|t} + \underline{\lambda}' \cdot \underline{Z}_{t-1} + u_{it}$$

¹⁶Note that it is not necessary to assume that β_{σ}^* and $\beta_{\sigma i}$ are independently distributed, but that they are jointly normally distributed.

¹⁷Some recent work (Sibert, 2003, for example) suggest that such an assumption is justifiable from a theoretical point of view. This assumption also appears to be justified in the present context of members of the Bank of England MPC. The first vote against the motion for the 19 MPC members have been in meeting number (1, 1, 2, 4, 4, 5, 8, 8, 8, 9, 9, 9, 9⁺, 10, 18, 19, 20, 23, 74⁺) (+ denotes censored to the right). Further, none of the 19 members have proposed an interest rate lower than the consensus decision within the first 3 meetings.

¹⁸This is not an unreasonable assumption; the squared multiple correlation coefficient of $\sigma(y_{t+12})$ on all the other regressors is 0.336 and that on the two expected output variables is only 0.054, while the correlation coefficient between $\sigma(y_{t+12})$ and $\mathbb{E}y_{t+12}$ is only -0.096 .

(using a heteroscedasticity-consistent estimator) and use the computed residuals to construct $\widehat{u}_{it}/\sigma(y_{t+12})$ ¹⁹. Finally, we compare the means in an analysis of variance (ANOVA) framework, after taking account of the differences in variance for different levels of the design variable (in this case, one for each member and a common effect corresponding to β_σ^*). In this way, we can identify significant contrasts (difference in means) between μ and the μ_i 's, and between different μ_i 's, while allowing the variances of the heterogeneity term to differ across the members.

3.5 A random coefficients model

The random effects model in the previous subsection has the limitation that the restriction on the magnitudes of the random effect means (μ and μ_i 's) depends on the design through n and the n_i 's. This limitation can be overcome by considering the following random coefficients model:

$$\begin{aligned} \Delta r_{it} = & \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y0} \cdot y_t + \beta_{y1} \cdot y_{t+1|t} \\ & + \underline{\lambda}' \cdot \underline{Z}_{t-1} + \beta_{\sigma, it} \cdot \mathbf{I}[i \in MPC_t] \cdot \sigma(y_{t+1|t}) + \varepsilon_{it}, \end{aligned} \quad (26)$$

$\beta_{\sigma, it}$ are random coefficients independent of each other and of ε_{it} ,
 $\beta_{\sigma, it} \sim N(\mu_i, \sigma_i^2)$, $\varepsilon_{it} \sim N(0, \sigma^2)$.

Under the interval regression framework considered earlier, we first estimate the slope-heterogeneity fixed effects model:

$$\begin{aligned} \Delta r_{it} = & \alpha + \beta_{\pi 0} \cdot \pi_t + \beta_{\pi 4} \cdot \pi_{t+4|t} + \beta_{y0} \cdot y_t + \beta_{y1} \cdot y_{t+1|t} \\ & + \underline{\lambda}' \cdot \underline{Z}_{t-1} + \beta_{\sigma i} \cdot \mathbf{I}[i \in MPC_t] \cdot \sigma(y_{t+1|t}) + \varepsilon_{it}. \end{aligned}$$

Now, if we can estimate the regression residuals, $\widehat{\varepsilon}_{it}$, the significance of differences in means (contrasts) can be tested, using

$$\widehat{\beta}_{\sigma, it} = \frac{\widehat{\varepsilon}_{it}}{\sigma(y_{t+12})} + \widehat{\beta}_{\sigma i}$$

as a pseudo-sample from the distribution of $\beta_{\sigma, it}$. In our application, the residuals cannot be directly obtained, since the response variable is censored.

¹⁹Since r_{it} and Δr_{it} are not directly available, we use $\widehat{u}_{it} = r_{it, obs} - \widehat{r}_{it}$ as an estimator, where \widehat{r}_{it} is obtained using the estimates obtained from the above regression. This construction of pseudo realisations of \widehat{u}_{it} would be asymptotically valid if the widths of the censoring windows reduces to zero as $n \rightarrow \infty$.

However, one can either use $\widehat{\varepsilon}_{it} = r_{it,obs} - \widehat{r}_{it}$ as pseudo-estimates (as earlier), or bootstrap from the distribution of the ε_{it} , and then use this sample to evaluate the contrasts. This would constitute another way to identify significant contrasts between different μ_i 's, while allowing the variances of the heterogeneity term to differ across the members.

4 Results

We estimate the fixed effects models (Equations 23 and 24) and the random effects model (Equation 25); estimates of the random coefficients model (Equation 26) give results similar to the random effects model, and are not presented here.

4.1 Majority decisions of the MPC

Table 2 presents parameter estimates and goodness-of-fit measures for the estimated model for majority MPC interest rate decisions. These are the change in interest rates that are actually implemented. Results using OLS and interval regression are presented here; the implications of estimates of a multinomial logit model are similar.

It is clear that expected inflation and expected output matter for the interest rate decision, with currently observed inflation and output playing no role. This confirms the assertion of Section 2 that the Bank of England follows an inflation forecast regime. It is also noticeable that movements in the stock market play a significant role. The coefficients on unemployment, house price inflation and the exchange rate have the right sign but are not significant. The impact of output uncertainty is negative, but not significant.

**TABLE 2: Inflation Targeting Model Estimates,
Majority MPC Interest Rate Decisions**

Variables	Ordinary Least Squares	Interval Regression
π_t	0.012 (0.808)	0.031 (0.590)
$\pi_{t+4 t}$	0.069 (0.048)*	0.081 (0.031)*
y_t	0.001 (0.977)	0.043 (0.369)
$y_{t+1 t}$	0.145 (0.004)**	0.200 (0.000)**
Δu_t	-0.083 (0.479)	-0.040 (0.755)
$P_{hsg,t}$	1.009 (0.123)	1.040 (0.184)
$P_{FTSE,t}$	0.307 (0.112)	0.742 (0.000)**
$P_{exch,t}$	0.005 (0.191)	0.005 (0.162)
$\sigma(y_{t+1 t})$	-0.504 (0.378)	-0.355 (0.587)
constant	-0.273 (0.653)	-0.714 (0.287)
Number of meetings	80	80
Goodness of fit	$F(9, 70) = 5.75$ $Prob. > F = 0.0000$ $\mathbb{R}^2 = 0.5062$	Wald $\chi^2(9) = 219.56$ $Prob. > \chi^2 = 0.0000$ Log pseudo-likelihood $= -37.1674$

1. p-values in parentheses.
2. **, *, +: Significant at 1 percent, 5 percent and 10 percent level respectively.

4.2 Decisions of individual members with fixed effects heterogeneity

Table 3 presents interval regression estimates and goodness-of-fit measures for the fixed effects model of MPC members' interest rate decisions. In this case we are exploiting the extra information that is provided by the published voting records of each of the Committee members. In addition to a model where votes of individual MPC members reveal their own (heterogeneous) types, we also estimate a model where the members belong to two types, depending on whether they are internal members (from the Bank of England) or external MPC members.

**TABLE 3: Inflation Targeting Model Estimates,
Individual MPC Members' Interest Rate Decisions**

Variables	Heterogeneity: Indiv. members	Heterogeneity: Int. vs. Ext.	No heterogeneity
π_t	-0.023 (0.349)	-0.018 (0.460)	-0.019 (0.460)
$\pi_{t+4 t}$	0.092 (0.000)**	0.088 (0.000)**	0.088 (0.000)**
y_t	-0.000 (0.991)	-0.009 (0.585)	-0.012 (0.506)
$y_{t+1 t}$	0.205 (0.000)**	0.202 (0.000)**	0.198 (0.000)**
Δu_t	-0.156 (0.001)**	-0.160 (0.001)**	-0.161 (0.001)**
$P_{hsg,t}$	1.570 (0.000)**	1.870 (0.000)**	1.869 (0.000)**
$P_{FTSE,t}$	0.650 (0.000)**	0.686 (0.000)**	0.690 (0.000)**
$P_{exch,t}$	0.007 (0.000)**	0.006 (0.000)**	0.006 (0.000)**
$\sigma(y_t)$			-0.286 (0.230)
– × Allsopp	-0.218 (0.363)		
– × Barker	-0.140 (0.564)		
– × Bean	-0.140 (0.562)		
– × Bell	-0.194 (0.431)		
– × Budd	-0.088 (0.711)		
– × Buiter	-0.161 (0.504)		
– × Clementi	-0.146 (0.542)		
– × George	-0.152 (0.526)		
– × Goodhart	-0.147 (0.540)		
– × Julius	-0.278 (0.241)		
– × King	-0.107 (0.652)		
– × Lambert	-0.174 (0.507)		
– × Large	-0.052 (0.830)		
– × Lomax	-0.112 (0.665)		
– × Nickell	-0.153 (0.526)		
– × Plenderleith	-0.159 (0.504)		
– × Tucker	-0.074 (0.763)		
– × Vickers	-0.113 (0.633)		
– × Wadhvani	-0.263 (0.269)		

**TABLE 3 Contd.: Inflation Targeting Model Estimates,
Individual MPC Members' Interest Rate Decisions**

Variables	Heterogeneity: Indiv. members	Heterogeneity: Int. vs. Ext.	No heterogeneity
- × INTERNAL		-0.251 (0.286)	
- × EXTERNAL		-0.318 (0.178)	
constant	-0.848 (0.001)**	-0.737 (0.004)**	-0.718 (0.006)**
No. of member-meetings	696	696	696
Goodness of fit: Wald χ^2	$\chi^2(27) = 1384.87$	$\chi^2(10) = 1165.54$	$\chi^2(9) = 1080.18$
<i>Prob.</i> > χ^2	0.000	0.000	0.000
Log pseudo-likelihood	-494.5954	-517.6366	-534.0035

1. p-values in parentheses.
2. **, *, +: Significant at 1 percent, 5 percent and 10 percent level respectively.
3. Joint significance of the 19 individual member heterogeneity terms (LRT): $-2 \cdot \ln L = 78.816$, 19 d.f., p-value 0.000.
4. Joint significance of the INTERNAL and EXTERNAL heterogeneity terms (LRT): $-2 \cdot \ln L = 32.734$, 2 d.f., p-value 0.000.

The broad conclusions from the model are similar to those for the overall decisions of the MPC. However, we now find that developments in asset markets do have a significant role to play in monetary policymaking. Though none of the heterogeneity coefficients are individually significant, they are jointly significant. The signs of the heterogeneity parameters are in the direction of our *a priori* belief.

4.3 Decisions of individual members with random effects heterogeneity

The fixed effects estimates obtained in the previous subsection were not entirely satisfactory for two reasons. First, none of the estimated heterogeneity coefficients were significant at the 10 percent level, and second, this setup does not allow us to explore individual specific heterogeneity after controlling for the “activism” apparent in some MPC members. Further, these two

issues may indeed be related; while the lack of significance may be due to a lower sample size, we would like to control for the differences in variance in a random effects framework to have a closer look at the contrasts (differences in mean responses). Table 4 reports estimates of our random effects model.

TABLE 4: Inflation Targeting Model Estimates, Individual MPC Members' Interest Rate Decisions – Random Effects

Variables	$\hat{\mu} + \hat{\mu}_i$	$Var(\beta_{\sigma}^* + \beta_{\sigma i})$
Allsopp	0.1326-0.6936**	0.1322
Barker	0.1326-0.1811	0.1492
Bean	0.1326-0.1071	0.1135
Bell	0.1326-0.7809	0.1163
Budd	0.1326+0.3991	0.1505
Buiter	0.1326+0.0582	0.2089
Clementi	0.1326+0.0974	0.1412
George	0.1326+0.0029	0.1378
Goodhart	0.1326+0.2002	0.1782
Julius	0.1326-0.6655**	0.1392
King	0.1326+0.2764	0.1450
Lambert	0.1326+0.0000	0.1526
Large	0.1326+0.3000	0.1365
Lomax	0.1326+0.0000	0.1079
Nickell	0.1326-0.2393	0.1657
Plenderleith	0.1326+0.0700	0.1450
Tucker	0.1326+0.1295	0.1069
Vickers	0.1326+0.2731	0.1554
Wadhvani	0.1326-0.6711*	0.1492

1. **, *, +: Significant at 1 percent, 5 percent and 10 percent level respectively.
2. The estimates do not explicitly assume independence of β_{σ}^* and $\beta_{\sigma i}$.
3. Other significant contrasts are: $\mu_{\text{King}} - \mu_{\text{Allsopp}} : 0.8938^{**}$, $\mu_{\text{King}} - \mu_{\text{Bell}} : 1.0275^{+}$, $\mu_{\text{King}} - \mu_{\text{Julius}} : 0.9362^{**}$, $\mu_{\text{King}} - \mu_{\text{Wadhvani}} : 0.9342^{**}$, and $\mu_{\text{Clementi}} - \mu_{\text{Julius}} : 0.7529^{*}$.

The estimates capture several of the interesting features of heterogeneity discussed earlier. There are several significant contrasts, both with respect to the typical average response of monetary policy μ and between member-specific average responses (μ_i 's), and that the estimates reflect the expected

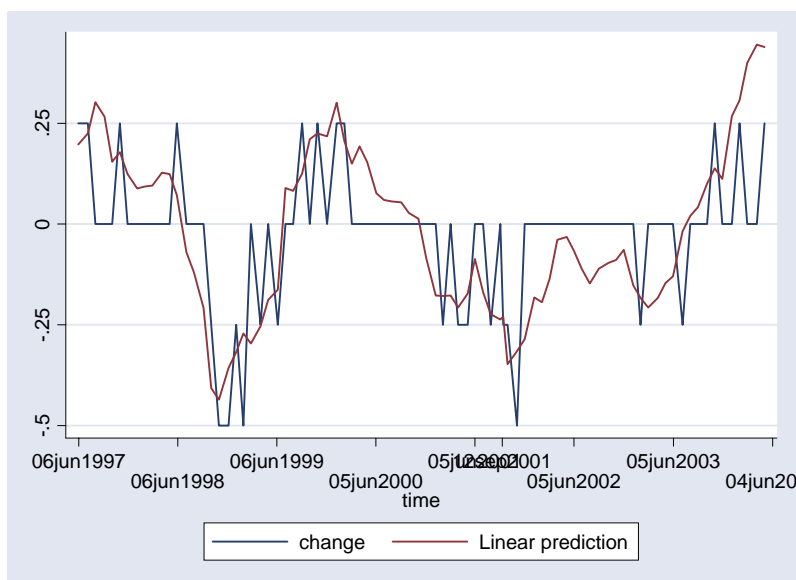


Figure 3: Interest rates, predicted and actual (Based on Table 2)

direction of these contrasts. The degree of “activism” in any member is reflected in the estimated variance of $\beta_{\sigma}^* + \beta_{\sigma i}$. For example, Willem Buiter is the most activist of all MPC members, but he did not have a particular bias in favour of lower or higher interest rates on average. By contrast, DeAnne Julius had a significant bias in favour of lower interest rates along with Christopher Allsopp, but they were not more activist than the average. Charlie Bean stands out as being both close on average to the actual MPC decision and the least activist. Thus, this appears to be a reasonable model of monetary policy decision-making in the presence of uncertainty.

4.4 Forecast performance of the estimated models

The comparison of actuals and (in sample) predicted decisions of the MPC, in terms of level of the base rate and interest rate changes are shown in Figures 3 and 4 respectively. These predictions based on estimates in Table 2, *ie.*, they do not incorporate heterogeneity in the decisions of the individual MPC members. The last five months in each of the figures are out-of-sample, and represent forecast performance of the models.

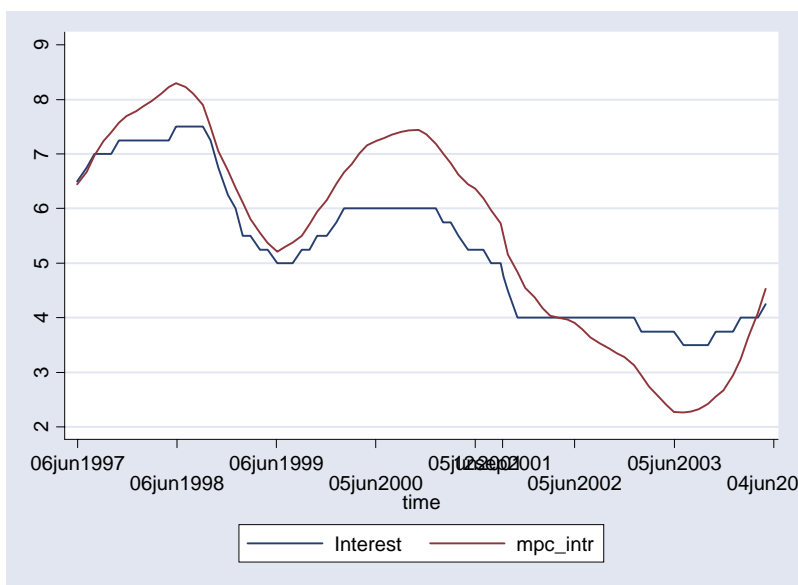


Figure 4: Interest rate changes, predicted and actual (Based on Table 2)

Figure 3 indicates good conformity between the model predictions and the actual level of the base rate. Figure 4 indicates that monetary policy decisions follow the direction predicted by our model, while at the same time indicating a degree of cautiousness in policy. To explore whether such policy cautiousness may be reflected in the heterogeneity of the individual MPC members' decisions, we use the model with fixed effects heterogeneity to predict the decisions of individual members (and consequently consensus decisions of the committee) for the first five months of 2004. These out-of-sample predictions are summarised in Tables 5 and 6.

Table 6 also presents MPC committee predictions for our estimated random effects model. These predictions are obtained using the Poisson subnormal approximation to the binomial distribution with different probabilities for different independent draws (Johnson and Kotz, 1969). The first half of 2004 represents a period of high upward pressure on interest rates. This is reflected fairly well in the predictions of MPC decisions generated through the estimated models.

**TABLE 5: Predictions of MPC Members' Decisions
(January to May, 2004)**

January 2004

	Actual: 0.00	Actual: 0.25	
Predicted: 0.00	5	0	5
Predicted: 0.25	3	1	4
	8	1	9

February 2004

	Actual: 0.00	Actual: 0.25	
Predicted: 0.00	0	2	2
Predicted: 0.25	0	7	7
	0	9	9

March 2004

	Actual: 0.00	Actual: 0.25	
Predicted: 0.00	0	0	0
Predicted: 0.25 or higher	9	0	9
	9	0	9

April 2004

	Actual: 0.00	Actual: 0.25	
Predicted: 0.00	0	0	0
Predicted: 0.25 or higher	8	1	9
	8	1	9

May 2004

	Actual: 0.00	Actual: 0.25	
Predicted: 0.00	0	0	0
Predicted: 0.25 or higher	0	9	9
	0	9	9

TABLE 6: Predictions of MPC Consensus Decisions

Meeting	Actual	Fixed Effects (predicted)	Rdm. Eff. (pred. prob.)		
			Lower	No change	Raise
Jan. 2004	0.00	0.00	0.083	0.001	0.907
Feb. 2004	0.25	0.25	0.040	0.004	0.956
Mar. 2004	0.00	0.25	0.000	0.000	1.000
Apr. 2004	0.00	0.25	0.000	0.000	1.000
May 2004	0.25	0.25	0.000	0.000	1.000

5 Conclusions

In this paper we have considered the conduct of UK monetary policy from 1997. Since then the Bank of England has had operational independence and decisions on interest rates made by the majority verdict of a Monetary Policy Committee. An enormous amount of information is provided about the data made available to the MPC and the decisions on interest rates decided upon by individual members. We find that an inflation forecast regime best describes what the MPC does but we also find an important role for developments in foreign exchange, equity and housing markets, once we exploit the extra information that is available in the individual voting records of MPC members. A role can also be found for unemployment. It is an open question whether our ability to detect a role for variables other than inflation and output is due to heterogeneity across the members of the MPC. In other words individual members may attach some importance to developments in asset markets and reflect these in an individual decision, which does not get carried through to the collective decision.

We find evidence of heterogeneity in the way uncertainty about future levels of output and output gap affect the interest rate decisions of individual MPC members. This heterogeneity is reflected in the consensus decisions of the MPC. Further, information about the voting intentions of MPC members can be exploited for forecasting. This suggests that transparency and predictability are best served by the publication of voting records of individual members.

Our estimated models predict the stance of monetary policy in the Bank of England fairly well. It has been suggested in the literature that past monetary policy decisions (and, voting behaviour in past meetings) contain information about future changes in interest rates (Cobham, 2003; Gerlach-Kristen, 2004). We have not taken these issues into account in our models, and these seem to affect our predictions somewhat.

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