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

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June 2005

CWPE 0530

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

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June 2, 2005

**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: E42, E43, E50, E58.

Keywords: Monetary policy, interest rates, Monetary Policy Committee, Committee decision making.

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# 1 Introduction[1]

There is a substantial literature in the US that uses information from transcripts of the proceedings of the FOMC to study the monetary policymaking process. See for example Belden (1989), Havrilesky and Gildea (1991), Edison and Marquez (1998) and Chappell *et al.* (2004). This has provided a number of insights into how committees work and the role played by individual members, especially the Chairman. This body of work has helped to strip away the traditional mystic of monetary policy, and has been followed much more recently by studies of the monetary policymaking process of the Bank of England. In 1992, the United Kingdom, following New Zealand and Sweden, adopted inflation targeting. This was augmented by a much more open system of decision-making, but ultimately decisions on interest rates were still made by the Government. In 1997 the Bank of England was given full operational independence. To support this new policy regime, very detailed information about interest rate decisions has been provided. Recent literature has used such detailed information, including votes by individual members of the Monetary Policy Committee, to study several aspects of monetary policymaking at the Bank of England[2].

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 differences in information assimilation.

Our paper touches on a number of issues connected to monetary policy. There is a large literature that examines the usefulness of characterising 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. This involves the use of simple monetary rules such as those advocated by Taylor (1993). Simple rules have a number of advantages chiefly,

[1]We are grateful to Stephanie Daniel for research assistance. The paper has benefited from comments by Jagjit Chadha, David Cobham, Andrew Hughes Hallett, Marcus Miller and Charles Nolan, as well as participants at the MMF Conference, the ECB and European University Institute. Remaining errors are the responsibility of the authors.

[2]See, for example, Chadha and Nolan (2001), Cobham (2002a, b, 2003) and Gerlach-Kristen (2004).

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 (1993) conditions short term interest rates on current deviations of output and inflation from target while Svensson (1997a, b) 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 and based on current information, and that there is often considerable uncertainty about the current state of the economy. In this paper we assume that the filtering which is required of current, imperfect measures of economic activity takes place as part of the internal procedures of the Bank of England (see Budd (1998) for a description). Our empirical results suggest that a rule, whereby interest rates respond to forecasts of inflation and output, provides the best explanation of UK monetary policy since 1997. This confirms what has been emphasised repeatedly by a number of commentators, that the Bank operates an inflation forecast type of rule, but we also find some evidence that developments in asset markets matter. 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[3].

Our ability to detect some role for asset market developments in part depends on a significant degree of heterogeneity across the Monetary Policy Committee. Because we know the precise voting record of each member of the MPC we can increase the degrees of freedom we have by modelling both the collective interest rate decision that is actually implemented, and the interest rate settings that each member voted for. This brings us to the question why there is heterogeneity across the Committee in the first place given that they all share a common pool of information, there is considerable discussion among the members of the Committee prior to an interest rate decision being made and individual members have many opportunities to make their views known. One possibility is to assume that preferences concerning output and inflation vary between members (Neumann, 2002; Sibert, 2003). Here we

[3] For other views see Vickers (1999), Goodhart (2001), Bullard and Schalling (2002), Cobham (2002a) and Bean (2003).

assume that the heterogeneity reflects differing views of the world, with some members attaching greater importance to particular developments in the economy such as the housing market or equity prices than others. Some other individual members may also differ in their view on the size of the output gap because they attach greater importance to developments on the supply side. Equally, some members may disagree with the majority view because they believe the transmission mechanism of monetary policy is different[4]. We seek to model this process as a signal extraction problem, with individual members optimally combining the forecast of the majority with their own views.

There is a long-standing debate in policy and academic circles about the role openness and transparency should play in policymaking. The contrast between the degree of transparency that the Bank of England aspires to and the traditional practices of Central Bankers could not be greater[5].

Transparency serves the need of accountability but it also improves predictability. We find that knowing the voting records of committee members improves our ability to predict interest rates compared to when 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 possible[6]. In this sense our empirical results would suggest that transparency is desirable.

The plan of the paper is as follows. In section 2 we discuss briefly 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 its members face individually. In Section 3 we discuss the estimation problem. In section 4 we report our empirical results. Finally, in section 5, we present our conclusions.

[4] See, 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).

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

[6] See 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.

# 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 the recent literature. We do this deliberately in order to have a model that appears to allign best with how central banks view the monetary transmission process and to provide a justification for the way in which policy appears to be conducted.[7]. The model is structured as follows:

$$\pi_t = \pi_{t-1} + \alpha y_{t-1} + \epsilon_t \tag{1}$$

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

$\pi_t$ 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. $\eta_t$ and $\varepsilon_t$ are iid shocks in period $t$ not observable in period $t-1$. The coefficients $\alpha$ and $\beta_2$ are positive; $\beta_1$ $(0 < \beta_1 < 1)$ 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 shocks[8] which will blur the pure delays embodied in equations (1) and (2). The intertemporal loss function is:

$$L_t = \frac{1}{2} E_t \sum_{\tau=t}^{\infty} \left[ \delta^{\tau-t} \left[ (\pi_\tau - \pi^*)^2 \right] + \lambda y_\tau^2 \right]. \tag{3}$$

Here, $E_t$ denotes expectations conditional on information available in period $t$. $\pi^*$ is the inflation target, and $\delta$ is the discount rate $(0 < \delta < 1)$. The policymaker minimises the present discounted value of squared deviations of inflation from its target and the output gap. $\lambda$ is the weight the policymaker attaches to the output gap, with the weight on inflation normalised to unity.

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

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

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 allows the intertemporal problem to be written as a sequence of single period problems. In this case (Svensson, 1997a):

$$L_t = \frac{1}{2}\left[\pi_{t+2|t} - \pi^*\right]^2, \tag{4}$$

where $\pi_{t+2|t}$ 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 $\pi_{t+2}$ at $t$ is

$$\pi_{t+2|t} = \pi_{t+1|t} + \alpha y_{t+1|t} \tag{5}$$

and

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

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:

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

Then the inflation 'feed forward' rule is

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

This satisfies the Taylor Principle since $\partial i/\partial\pi > 1$, as long as there is persistence in inflation. Although an explicit weight is not 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. For expositional purposes we are assuming that the decision period coincides with the observation period. In practice data are available at different frequencies from daily to yearly[9].

[9]It is straight forward to cast this problem of optimally combining data of different frequencies as a filtering problem. See for example, Corrado and Green (1988).

## 2.1 Committee decision-making

In contrast to the Federal Reserve[10] and the ECB, where decision making is by 'consensus', the Monetary Policy Committee of the Bank of England 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 (Neuman, 2002; Sibert, 2003). In this case we can write a loss function for the jth committee member as:

$$L_{jt} = \frac{1}{2} E_t \sum_{\tau=t} \delta^{\tau-t} \left[ (\pi_t - \pi^*)^2 \right] + \lambda_j y_t^2, \qquad \text{for } j = 1, ..., m. \tag{9}$$

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 economy[11]. 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 (see Geanakoplos, 1992; Bicchieri, 1993), we shall assume that the decision of each individual member is ultimately based on commonly shared information as well as private views that cannot be shared fully with the other members of the MPC, or to which the other members of the Committee do not attach importance.

We can also model this process in the following way. There is a growing game theoretic literature on committee decision making involving issues such as strategic voting, the acquisition of information, possible conflicts of interest, and how information is communicated in committees (see Gerling

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

[11] As 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.

*et al.* (2003) for a recent survey). Following this literature, we can think of the decision-making process by the MPC as a two-stage process. In this first stage there is deliberation about the state of the economy (Gerlach-Kristen, 2003; Meade and Stasavage, 2004), staff economists present conjunctural analyses of recent events, members share information and views and eventually a central forecast, with agreed error bands in the form of a fan chart, is arrived at. Nevertheless, at the second stage, despite this sharing of knowledge many MPC members will choose an interest setting different to the central estimate.

This process can be cast as a simple signal extraction problem. Suppose there is an estimate of the output gap $y_t^b$, which is agreed upon after deliberation. This is an unbiased estimate of the true output gap with[12]

$$y_t^b = y_t + \omega_t^b \text{ with } \omega_t^b \backsim N(0, \sigma_{\omega^b}^2). \tag{10}$$

Each committee member in turn formulates her own (unbiased) estimate of the output gap as:

$$y_t^j = y_t + \omega_t^j \text{ with } \omega_t^j \backsim N(0, \sigma_{\omega^j}^2), \text{ for } j = 1, ..m \tag{11}$$

Crucially this estimate reflects private views not shared by the rest of the committee so $E(\omega_t^j \omega_t^k) = 0$, for $j \neq k$. The jth variance term $\sigma_{\omega^j}^2$ captures both objective and subjective confidence in the estimate of $y_t$'s.

Let $x^j$ be a $g \times 1$ vector of possible variables that the $j$-th MPC member may take notice of (including private information contained in asset and labour market developments, for example). Then the underlying model is

$$y_t^j = \beta x_t^j + \omega_t^j \tag{12}$$

It may be the case that new members take some time to find their feet and at the early meetings vote with the sense of the meeting, only dissenting once an understanding of the process has been built up. In this instance there will be a very diffuse prior on the estimate of the output gap. For the $j$-th member the estimate of $y_t$ that minimises the forecast error variance and combines optimally the bank forecast and the private forecast is given by:

$$y_t^{dj} = y_t^b + \kappa^j (y_t^j - y_t^b), \tag{13}$$

[12] Strictly speaking, the fan charts that the Bank produces allow for possible asymmetry,and hence the errors may not be normally distributed. We assume normality for the sake of simplicity.

where $y_t^{dj}$ is the final decision by the $j$-th member on what the best estimate of the output gap is. The Kalman gain, $\kappa^j$, is:

$$\kappa^j = \frac{\sigma^2_{\omega^b}}{\sigma^2_{\omega^b} + \sigma^2_{\omega^j}} \tag{14}$$

Clearly the more confident the committee member is in her own judgement the smaller $\sigma^2_{\omega^j}$, and the less weight is attached to the collective forecast. We then have the forecast error variance for the combined estimate of $y_t$ as:

$$\sigma^2_{y^{dj}} = \frac{\sigma^2_{\omega^b}\sigma^2_{\omega^j}}{\sigma^2_{\omega^b} + \sigma^2_{\omega^j}} \tag{15}$$

The decision rule for the jth member can now be written as:

$$i_{jt} = (\pi_{t|t} - \pi^*) + \frac{1}{\alpha\beta_2}\pi_{t+1|t} + \frac{\beta_1}{\beta_2}y_{t|t} + \varsigma_{jt} \quad \text{for } j = 1, ..., m, \tag{16}$$

where $\varsigma_{jt}$ need not be a zero mean process and captures the extent to which the $j$-th member deviates from the central interest rate projection that is implied by the central bank forecast. The decision that is actually implemented, $\Delta i_t$, is then a multiple of 25 basis points, and is the vote of the median member[13].

There are two main forms of heterogeneity in this model. 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, $\varsigma_{jt}$, that (in absolute value) is increasing in the forecast standard deviation of the output gap. However, we assume that there are zero covariances among the $\varsigma_{jt}$. 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.

[13]Strictly the voting is sequential, where the initial options are to raise, lower or the keep the interest rate unchanged. If a majority votes for no change there is no further voting. If the vote is for a change, either higher or lower, a vote is then needed on the magnitude of the change.

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 $\beta_2$, 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 member[14].

This can be seen if we write an expression for the volatility of interest rates implied by equation (8) for given unconditional variances for output and inflation as:

$$\sigma_i^2 = (1 + \frac{1}{\alpha^2 \beta_2^2})\sigma_\pi^2 + (\frac{\beta_1}{\beta_2})^2 \sigma_y^2, \tag{17}$$

where $\sigma_i^2$ is the variance of the nominal interest rate, $\sigma_\pi^2$ the variance of inflation and $\sigma_y^2$ the variance of output. Clearly for given variances of output and inflation, a fall in the slope of the IS curve raises the volatility of interest rates. The term on the variance of inflation, which is greater than one, can be thought of the volatility equivalance of the Taylor principle.

## 2.2 Recursive Information Processing

In the previous section the signal extraction problem was cast as one in which individual members decide on their interest rate recommendation by combining optimally the common and the private forecast. But it is also worthwhile to think of the process by which the signal is extracted as recursive. In particular, the MPC meets and makes decisions on a monthly basis. New information is analysed relative to what was known in the previous month. This is because in each month the MPC explicitly sets the interest rate at that level which it believes will achieve the inflation target 18 months to two years into the future. It must therefore be the case that if no new (reliable) information is available about the state of the economy then

[14] In 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 the 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.

interest rates will remain unchanged[15]. Moreover, given that interest rates are only changed in multiples of 25 basis points, there has to be sufficient new information to trigger a change.

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

$$\widetilde{y}_t = A\widetilde{y}_{t-1} + Bu_t + e_t, \tag{18}$$

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

$$z_t = H\widetilde{y}_t + \psi_t, \tag{19}$$

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

Prior knowledge of the conditional density of $\widetilde{y}_{t-1}$ based on the information set $\Omega_t$ gives

$$E(\widetilde{y}_{t-1} \mid \Omega_t) = \widetilde{y}_{t-1|t} \tag{20}$$

and

$$E(\widetilde{y}_t \mid \Omega_t) = A\widetilde{y}_{t-1|t} + Bu_t. \tag{21}$$

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

$$Cov(\widetilde{y}_{t-1} \mid \Omega_t) = \Lambda_{t-1}, \tag{22}$$

so

$$Cov(\widetilde{y}_t \mid \Omega_t) = A\Lambda_{t-1}A' + \Gamma_t = \Lambda_t \tag{23}$$

[15] Recently there has been a controversy in the literature about the use of what can be called constant interest rate forecasts (see Leitemo, 2003, and Honkapohja and Mitra, 2004). As Goodhart has put it: "When I was a member of the MPC I thought that I was trying, at each forecast round, to set the level of interest rates so that, without the need for future rate changes, prospective (forecast) inflation would on average equal the target at the policy horizon". In the context of the model of this paper where it takes two years for interest rates to impact on inflation, the constant interest setting is optimal. However, in New Keynesian models with forward looking expectations, it may not be.

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

$$\widetilde{y}_{t|t} = \widetilde{y}_{t|t-1} + F_t(z_t - H\widetilde{y}_{t|t-1}) \tag{24}$$

where $F_t = \Lambda_t H'(H\Lambda_t H' + \Gamma_t)^{-1}$. Thus, the best estimate is a linear combination of the previous best estimate and 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 $\Gamma_t$, there will be little if any revisions to the optimal estimate of $\widetilde{y}_{t|t}$, so a change in the interest rate setting will not take place[16]. Information about the state of the economy appears more or less continuously if we are observing asset markets while other forms of information appear as discrete packages in the form of flash estimates of GDP, full sets of national accounts and regularly compiled forecasts.

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 $\varsigma_{jt}$ for each member follows an autoregressive process.

$$\varsigma_{jt} = \phi_j + \theta_j \varsigma_{jt-1} + \gamma_{jt}, 0 < \theta_j < 1, \gamma_{jt} \backsim N(0, \sigma^2_{\gamma_t}) \tag{25}$$

and we observe this via

$$z_{jt} = \varsigma_{jt} + \delta_{jt} \quad \text{with } \delta_{jt} \backsim N(0, \sigma^2_{\delta_{jt}}), \tag{26}$$

where now $z$ is a scalar. Then the optimal private estimate for the $j$-th committee member is

$$\varsigma_{jt|t} = \varsigma_{jt|t-1} + [\sigma^2_{\gamma_{jt}}/(\sigma^2_{\gamma_{jt}} + \sigma^2_{\delta_{jt}})(z_{jt} - \varsigma_{jt|t-1})] \tag{27}$$

As earlier, the revisions to private information will vary with the quality of new observations.

[16] It 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.

The standard separation of observation from control means that these optimal estimates of $\widetilde{y}_{t|t}$ and $\varsigma_{it|t}$ can be plugged into the feedback rule given in equation (16)[17]. 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 issue 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. 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 and the first quarter of 2005.

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 Eng-

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

land 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 International Labor Organization (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 Office of National Statistics (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 sufficiently 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 from the Bank of England's forward yield curve estimates obtained from index linked bonds[18]. For current output, we use annual growth of 2-month-lagged monthly GDP published by the National Institute of Economic and Social Research (NIESR) and for one-year-ahead forecast GDP growth, we use the Bank of England's model based mean quarterly forecasts. 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

[18] We use the four year expected inflation figure because the two year figure is not available for the full sample. In practice the inflation yield curve tends to be very flat after two years.


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

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 (June 1997 to March 2005), 69 per cent of the meetings decided to keep the base rate at its current level, 14 per cent recommended a rise of 25 basis points, 13 per cent recommended a reduction of 25 basis points, and 4 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.*, 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

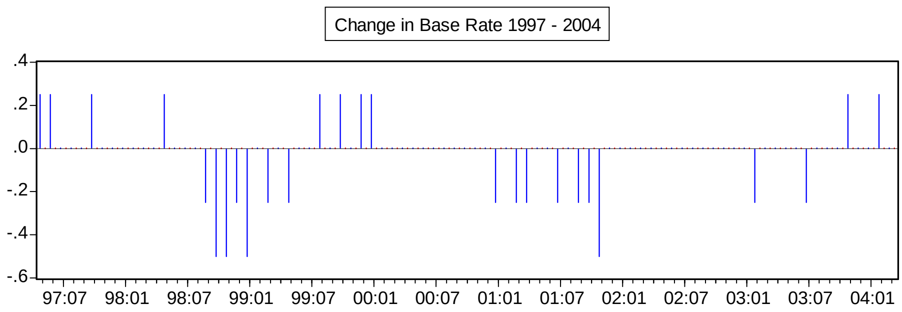


Figure 2: Discrete (Limited Dependent) nature of interest rate changes

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, $\triangle r_{t,obs}$, is the truncated version of the latent monetary policy response variable, $\triangle r_t$, which we model as

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

The wider truncation interval when interest rates are unchanged (*ie.*, for $\triangle r_{t,obs} = 0$) 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:

$$\begin{aligned}
\triangle r_t &= \alpha + \beta_r.\triangle r_{t-1,obs} + \beta_{\pi 0}.\pi_t + \beta_{\pi 4}.\pi_{t+4|t} + \beta_{y0}.y_t|t \\
&\quad + \beta_{y1}.y_{t+1|t} + \beta_\sigma.\sigma\left(y_{t+1|t}\right) + \underline{\lambda}^{/}.\underline{Z}_{t-1} + \varepsilon_t,
\end{aligned} \tag{28}$$

where $\underline{Z}_{t-1}$ represents current observations on unemployment ($\triangle u_t$) and the underlying state of asset markets: housing, equity and the foreign exchange market ($P_{hsg,t}$, $P_{FTSE,t}$ and $P_{exch,t}$ respectively). Standard deviation of the one-year ahead forecast of output growth is denoted by $\sigma\left(y_{t+1|t}\right)$; 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 sufficiently 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 her own decision regarding interest rates, and committee interest rate decisions are arrived at by voting on these individual proposals. In addition to the majority decision, the Bank of England also publishes what each member of the committee wished to do. The voting pattern of individual members of the MPC suggests substantial systematic differences across the committee (Table 1)[19]. These data on individual votes offers the opportunity to examine the voting pattern in MPC meetings, and the resulting majority decision.

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

[19] For 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. Wadhwani 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. Buiter 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).

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, $\beta_\sigma$, that $\sigma\left(y_{t+1|t}\right)$ has on the interest rate decisions.

**TABLE 1: Heterogeneity among members:**
**Voting records of selected MPC members (Jun. 1997 to Dec. 2003)**

| 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 |
| Wadhwani | 37 | 16 | 18 | 3 | 13 | 0 | 13 |

However, a simple analysis of the voting records of individual members does not necessarily on its own establish whether a member is a hawk or a dove and/or an activist. Most external members serve for three years and it is possible that their term of office coincides with a period, when because of the position of the business cycle, interest rates are rising or falling. We need to condition the analysis of heterogeneity on the state of the economy. Under a similar interval regression framework as above, we would then have the model:

$$\begin{aligned}\triangle r_{it} &= \alpha+\beta_r.\triangle r_{t-1,obs}+\beta_{\pi 0}.\pi_t+\beta_{\pi 4}.\pi_{t+4|t}+\beta_{y0}.y_t+\beta_{y1}.y_{t+1|t} \\ &\quad +\beta_{\sigma i}.\mathbf{I}\left[i\in MPC_t\right].\sigma\left(y_{t+1|t}\right)+\underline{\lambda}^{/}.\underline{Z}_{t-1}+\varepsilon_{it}, \qquad (29)\end{aligned}$$

where $\mathbf{I}\left[i\in MPC_t\right]$ 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 $\triangle r_{it}$ 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 others'[20]. 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

$$\begin{aligned}\triangle r_{it} &= \alpha + \beta_r.\triangle r_{t-1,obs} + \beta_{\pi 0}.\pi_t + \beta_{\pi 4}.\pi_{t+4|t} + \beta_{y0}.y_t \\ &\quad + \beta_{y1}.y_{t+1|t} + \underline{\lambda}^{/}.\underline{Z}_{t-1} + u_{it},\end{aligned}$$

where

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

$\beta_{\sigma i} \backsim N\left(\mu_i, \sigma_i^2\right), \varepsilon_{it} \backsim N\left(0, \sigma^2\right)$, $\varepsilon_{it}$ 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.

An alternative random effects model is the following:

$$\begin{aligned}\triangle r_{it} &= \alpha + \beta_r.\triangle r_{t-1,obs} + \beta_{\pi 0}.\pi_t + \beta_{\pi 4}.\pi_{t+4|t} + \beta_{y0}.y_t + \beta_{y1}.y_{t+1|t} \\ &\quad + \underline{\lambda}^{/}.\underline{Z}_{t-1} + \left(\beta_\sigma^* + \beta_{\sigma i}\right).\mathbf{I}\left[i \in MPC_t\right].\sigma\left(y_{t+1|t}\right), \\ &\quad \begin{pmatrix}\beta_\sigma^* \\ \beta_{\sigma i}\end{pmatrix} \backsim N\left[\begin{pmatrix}\mu \\ \mu_i\end{pmatrix}, \begin{pmatrix}\sigma^2 & \sigma_{0i} \\ \sigma_{0i} & \sigma_i^2\end{pmatrix}\right], \qquad (30) \\ 0 &= n\mu + \sum_{i=1}^{I} n_i \mu_i, \\ &\quad \beta_{\sigma i}\text{'s are independent of each other,}\end{aligned}$$

[20]Buiter 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.

where $\beta_\sigma^*$ represents the typical response of monetary policy to uncertainty, $\beta_{\sigma i}$ is the response of the specific MPC member[21], 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 section 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 expressed[22]. Thus, we can use the votes of all the MPC members in these three initial meetings to estimate $\mu$ and $\sigma^2$, 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 regressors[23]. We first estimate the regression

$$\triangle r_{it} = \alpha + \beta_r.\triangle r_{t-1,obs} + \beta_{\pi 0}.\pi_t + \beta_{\pi 4}.\pi_{t+4|t} + \beta_{y0}.y_t + \beta_{y1}.y_{t+1|t} + \underline{\lambda}^{/}.\underline{Z}_{t-1} + u_{it}$$

(using a heteroscedasticity-consistent estimator) and use the computed residuals to construct $\widehat{u}_{it}/\sigma\left(y_{t+1|t}\right)$[24]. 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 $\beta_\sigma^*$). In this way, we can identify significant contrasts (difference in means) between $\mu$ and the $\mu_i$'s,

[21] Note that we do not assume independence of $\beta_\sigma^*$ and $\beta_{\sigma i}$, but assume that they are jointly normally distributed.

[22] Some 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.

[23] This is not an unreasonable assumption; the squared multiple correlation coefficient of $\sigma\left(y_{t+1|t}\right)$ 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 $\sigma\left(y_{t+1|t}\right)$ and $y_{t+1|t}$ is only $-0.096$.

[24] Since $r_{it}$ and $\triangle r_{it}$ are not directly observable, we use $\widehat{u}_{it} = r_{it,obs} - \widehat{r}_{it}$ as a proxy, where $\widehat{r}_{it}$ is obtained using the estimates from the above regression. This construction of pseudo residuals, $\widehat{u}_{it}$, would be asymptotically valid if the widths of the censoring windows reduce to zero as $n \longrightarrow \infty$.

and between different $\mu_i$'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 ($\mu$ and $\mu_i$'s) depends on the design through $n$ and the $n_i$'s. This limitation can be overcome by considering the following random coefficients model:

$$\begin{aligned}\triangle r_{it} &= \alpha + \beta_r.\triangle r_{t-1,obs} + \beta_{\pi 0}.\pi_t + \beta_{\pi 4}.\pi_{t+4|t} + \beta_{y0}.y_t + \beta_{y1}.y_{t+1|t} \\ &\quad + \underline{\lambda}^{/}.\underline{Z}_{t-1} + \beta_{\sigma,it}.\mathbf{I}\left[i \in MPC_t\right].\sigma\left(y_{t+1|t}\right) + \varepsilon_{it}, \qquad (31) \\ &\quad \beta_{\sigma,it} \text{ are random coefficients independent of each other and of } \varepsilon_{it}, \\ &\quad \beta_{\sigma,it} \backsim N\left(\mu_i, \sigma_i^2\right), \varepsilon_{it} \backsim N\left(0, \sigma^2\right).\end{aligned}$$

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

$$\begin{aligned}\triangle r_{it} &= \alpha + \beta_r.\triangle r_{t-1,obs} + \beta_{\pi 0}.\pi_t + \beta_{\pi 4}.\pi_{t+4|t} + \beta_{y0}.y_t + \beta_{y1}.y_{t+1|t} \\ &\quad + \underline{\lambda}^{/}.\underline{Z}_{t-1} + \beta_{\sigma i}.\mathbf{I}\left[i \in MPC_t\right].\sigma\left(y_{t+1|t}\right) + \varepsilon_{it}.\end{aligned}$$

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

$$\widehat{\beta}_{\sigma,it} = \frac{\widehat{\varepsilon}_{it}}{\sigma\left(y_{t+1}\right)} + \widehat{\beta}_{\sigma i}$$

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. However, one can either use $\widehat{\varepsilon}_{it} = r_{it,obs} - \widehat{r}_{it}$ as pseudo-residuals (as earlier), or bootstrap from the distribution of the $\varepsilon_{it}$, and then use this sample to evaluate the contrasts. This would constitute another way to identify significant contrasts between different $\mu_i$'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 29) and the random effects model (Equation 30); estimates of the random coefficients model

(Equation 31) give results similar to the random effects model, and are not reported 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; currently observed inflation and output play no significant 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 and housing market are significant. The coefficients on unemployment and 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 (Jun.1997-Dec.2003)**

| Variables | Ordinary Least Squares | Interval Regression |
|---|---|---|
| $\triangle r_{t-1,obs}$ | -0.074 (0.516) | -0.110 (0.288) |
| $\pi_t$ | 0.017 (0.731) | 0.022 (0.695) |
| $\pi_{t+4\|t}$ | 0.075 (0.029)* | 0.086 (0.026)* |
| $y_t$ | -0.005 (0.902) | 0.020 (0.656) |
| $y_{t+1\|t}$ | 0.154 (0.001)** | 0.193 (0.000)** |
| $\triangle u_t$ | -0.109 (0.345) | -0.075 (0.562) |
| $P_{hsg,t}$ | 1.141 (0.052)+ | 1.306 (0.049)* |
| $P_{FTSE,t}$ | 0.329 (0.083)+ | 0.641 (0.001)** |
| $P_{exch,t}$ | 0.005 (0.220) | 0.006 (0.153) |
| $\sigma\left(y_{t+1\|t}\right)$ | -0.538 (0.367) | -0.525 (0.453) |
| constant | -0.314 (0.611) | -0.531 (0.452) |
| Number of meetings | 79 | 79 |
| Goodness of fit | $F(10,68) = 5.33$ | Wald $\chi^2(10) = 140.65$ |
| | $Prob. > F = 0.0000$ | $Prob. > \chi^2 = 0.0000$ |
| | $\mathbb{R}^2 = 0.5032$ | Log pseudo-likelihood |
| | $RMSE = 0.1249$ | $= -44.8800$ |

**TABLE 3: Model Estimates – Individual MPC Members' Decisions**

| Variables | Heterogeneity: Indiv. members | Heterogeneity: Int. vs. Ext. | No heterogeneity |
|---|---|---|---|
| $\triangle r_{t-1,obs}$ | -0.143 (0.000)$^{**}$ | -0.141 (0.000)$^{**}$ | -0.140 (0.001)$^{**}$ |
| $\pi_t$ | -0.018 (0.431) | -0.009 (0.689) | -0.009 (0.695) |
| $\pi_{t+4\|t}$ | 0.104 (0.000)$^{**}$ | 0.099 (0.000)$^{**}$ | 0.099 (0.000)$^{**}$ |
| $y_t$ | -0.009 (0.566) | -0.017 (0.287) | -0.019 (0.244) |
| $y_{t+1\|t}$ | 0.220 (0.000)$^{**}$ | 0.220 (0.000)$^{**}$ | 0.216 (0.000)$^{**}$ |
| $\triangle u_t$ | -0.196 (0.000)$^{**}$ | -0.199 (0.000)$^{**}$ | -0.198 (0.000)$^{**}$ |
| $P_{hsg,t}$ | 1.807 (0.000)$^{**}$ | 2.062 (0.000)$^{**}$ | 2.055 (0.000)$^{**}$ |
| $P_{FTSE,t}$ | 0.687 (0.000)$^{**}$ | 0.727 (0.000)$^{**}$ | 0.731 (0.000)$^{**}$ |
| $P_{exch,t}$ | 0.007 (0.000)$^{**}$ | 0.006 (0.000)$^{**}$ | 0.006 (0.000)$^{**}$ |
| $\sigma\left(y_{t+1\|t}\right)$ | | | -0.414 (0.087)$^{+}$ |
| – × Allsopp | -0.343 (0.160) | | |
| – × Barker | -0.265 (0.284) | | |
| – × Bean | -0.262 (0.285) | | |
| – × Bell | -0.319 (0.202) | | |
| – × Budd | -0.215 (0.377) | | |
| – × Buiter | -0.288 (0.239) | | |
| – × Clementi | -0.271 (0.266) | | |
| – × George | -0.277 (0.256) | | |
| – × Goodhart | -0.273 (0.262) | | |
| – × Julius | -0.400 (0.097)$^{+}$ | | |
| – × King | -0.232 (0.338) | | |
| – × Lambert | -0.289 (0.276) | | |
| – × Large | -0.174 (0.484) | | |
| – × Lomax | -0.229 (0.381) | | |
| – × Nickell | -0.276 (0.260) | | |
| – × Plenderleith | -0.284 (0.242) | | |
| – × Tucker | -0.198 (0.427) | | |
| – × Vickers | -0.238 (0.324) | | |
| – × Wadhwani | -0.385 (0.112) | | |
| – × INTERNAL | | -0.386 (0.100)$^{+}$ | |
| – × EXTERNAL | | -0.453 (0.059)$^{+}$ | |
| constant | -0.849 (0.001)$^{**}$ | -0.739 (0.003)$^{**}$ | -0.726 (0.005)$^{**}$ |
| No. of member-meetings | 690 | 690 | 690 |
| Goodness of fit: Wald $\chi^2$ | $\chi^2(28) = 1494.98$ | $\chi^2(11) = 1237.26$ | $\chi^2(10) = 1123.24$ |
| *Prob.* $> \chi^2$ | 0.000 | 0.000 | 0.000 |
| Log pseudo-likelihood | $-480.6630$ | $-503.4762$ | $-520.2405$ |

## 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 when we use the published interest rate decisions of individual MPC members (over the period June 1997 to December 2003). 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 the 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[25].

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. The higher significance of unemployment and asset market indicators may arise from either differing views among the MPC members or from larger sample size (since we are modelling individual decisions here). In particular, heterogeneity seems to be part of the explanation for the strong effect of unemployment; the coefficient in the committee decision regression (Table 2) lies outside the 95 per cent confidence interval of the estimate in Table 3.

Though none of the heterogeneity coefficients are individually significant, they are jointly significant[26]. 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 5 percent level, and second, this setup does

[25] See also Gerlach-Kristen (2003) for some similar analysis.

[26] Joint significance of the 19 individual member heterogeneity terms – Likelihood ratio test (LRT): $-2.\ln L = 82.236$, 19 d.f., p-value 0.000. Joint significance of the INTERNAL and EXTERNAL heterogeneity terms (LRT): $-2.\ln L = 36.610$, 2 d.f., p-value 0.000.

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)[27]. Table 4 reports estimates of our random effects model (estimation sample: June 1997 to December 2003).

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

| **Variables** | $\widehat{\mu}+\widehat{\mu}_i$ | $Var\left(\beta_\sigma^*+\beta_{\sigma i}\right)$ |
|---|---|---|
| Allsopp | 0.0263-0.0804* | 0.1266 |
| Barker | 0.0263-0.0185 | 0.1512 |
| Bean | 0.0263+0.0004 | 0.1145 |
| Bell | 0.0263-0.1052 | 0.1164 |
| Budd | 0.0263+0.0204 | 0.1651 |
| Buiter | 0.0263-0.0043 | **0.2282** |
| Clementi | 0.0263+0.0134 | 0.1558 |
| George | 0.0263+0.0006 | 0.1388 |
| Goodhart | 0.0206+0.0173 | **0.1822** |
| Julius | 0.0263-0.1006** | 0.1424 |
| King | 0.0263+0.0405 | 0.1512 |
| Lambert | 0.0263-0.0263 | 0.1526 |
| Large | 0.0263+0.0588 | 0.1365 |
| Lomax | 0.0263+0.0703 | 0.1079 |
| Nickell | 0.0263-0.0259 | **0.1668** |
| Plenderleith | 0.0263+0.0097 | 0.1599 |
| Tucker | 0.0263+0.0204 | 0.1069 |
| Vickers | 0.0263+0.0225 | 0.1600 |
| Wadhwani | 0.0263-0.0953* | 0.1460 |

1. The estimates do not explicitly assume independence of $\beta_\sigma^*$ and $\beta_{\sigma i}$.

2. Other significant contrasts are: $\mu_{\text{Clementi}}-\mu_{\text{Julius}}: 0.1140^{**}$, $\mu_{\text{George}}-\mu_{\text{Julius}}: 0.1011^{*}$, $\mu_{\text{Goodhart}}-\mu_{\text{Julius}}: 0.1179^{+}$, $\mu_{\text{King}}-\mu_{\text{Allsopp}}: 0.1209^{**}$, $\mu_{\text{King}}-\mu_{\text{Julius}}: 0.1411^{**}$, $\mu_{\text{King}}-\mu_{\text{Wadhwani}}: 0.1358^{**}$, and $\mu_{\text{Plenderleith}}-\mu_{\text{Julius}}: 0.1102^{*}$.

[27] This procedure ensures that the differences in individual (mean) effects are not masked by differences in variance – the so-called Behrens-Fisher problem.

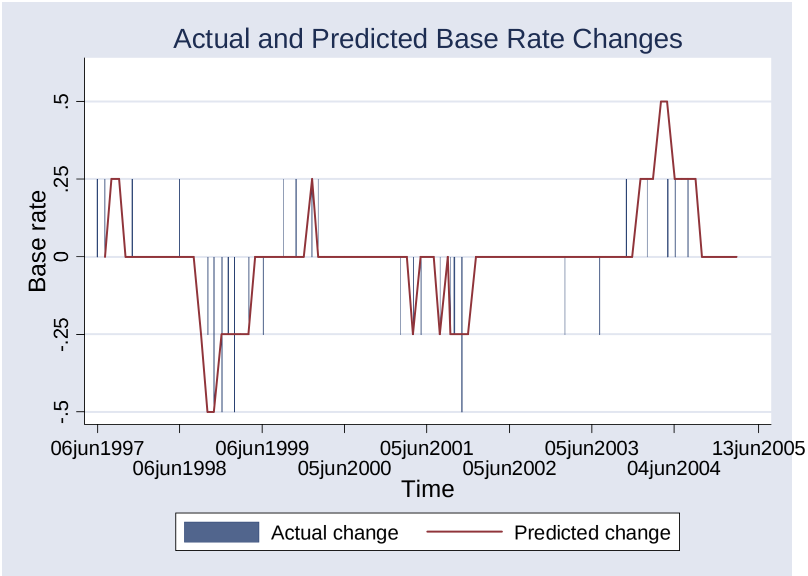


Figure 3: Interest rate changes, predicted and actual (Based on Table 2)

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 $\mu$ and between member-specific average responses ($\mu_i$'s), and the estimates reflect the expected 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 and Sushil Wadhwani, 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 about 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 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 are based on estimates in Table 2, *ie.*,

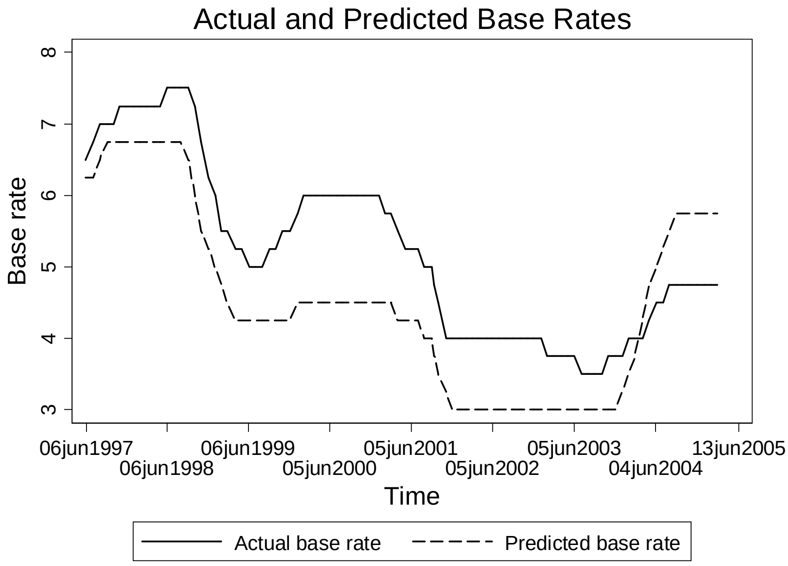


Figure 4: Interest rates, predicted and actual (Based on Table 2)

they do not incorporate heterogeneity in the decisions of the individual MPC members. The final 15 months (January 2004 to March 2005) in each of the figures are out-of-sample, and represent forecast performance of the models.

Figures 3 and 4 indicate good conformity between the model predictions and the actual level of the base rate and base rate changes. Figure 4 also indicates indicates a degree of cautiousness in policy, particularly in the later half of the period under study. 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 forecast period. These out-of-sample predictions are summarised in Tables 5 and 6.

Table 5 presents $2 \times 2$ contingency tables for the actual and predicted votes of MPC members for each of the months, January 2004 to March 2005. The Table for January 2004 can be read as follows. The second column shows that eight members out of nine voted for no change in January 2004. Of these eight, the model predicts that five members would have voted for no change and three for an increase. One member voted for an increase in the base rate: the model predicts this vote correctly.

**TABLE 5: Predictions of MPC Members' Decisions (January 2004 to March 2005)**

| **Predicted votes:** | **Actual votes** No change | Raise | **Total** (pred.) |
|---|---|---|---|
| **January 2004** | | | |
| No Change | 5 | 0 | **5** |
| Raise | 3 | 1 | **4** |
| **Total** (actual) | **8** | **1** | **9** |
| **February 2004** | | | |
| No change | 0 | 3 | **3** |
| Raise | 0 | 6 | **6** |
| **Total** (actual) | **0** | **9** | **9** |
| **March 2004** | | | |
| No change | 0 | 0 | **0** |
| Raise | 9 | 0 | **9** |
| **Total** (actual) | **9** | **0** | **9** |
| **April 2004** | | | |
| No change | 0 | 0 | **0** |
| Raise | 8 | 1 | **9** |
| **Total** (actual) | **8** | **1** | **9** |
| **May 2004** | | | |
| No change | 0 | 0 | **0** |
| Raise | 0 | 9 | **9** |
| **Total** (actual) | **0** | **9** | **9** |
| **June 2004** | | | |
| No change | 0 | 0 | **0** |
| Raise | 0 | 9 | **9** |
| **Total** (actual) | **0** | **9** | **9** |
| **July 2004** | | | |
| No change | 1 | 0 | **1** |
| Raise | 8 | 0 | **8** |
| **Total** (actual) | **9** | **0** | **9** |
| **August 2004** | | | |
| No change | 0 | 0 | **0** |
| Raise | 0 | 9 | **9** |
| **Total** (actual) | **0** | **9** | **9** |

**TABLE 5 (contd.)**

| Predicted votes: | Actual votes: No change | Raise | Total (pred.) |
|---|---|---|---|
| **September 2004** | | | |
| No change | 0 | 0 | **0** |
| Raise | 9 | 0 | **9** |
| **Total** (actual) | **9** | **0** | **9** |
| **October 2004** | | | |
| No change | 7 | 0 | **7** |
| Raise | 2 | 0 | **2** |
| **Total** (actual) | **9** | **0** | **9** |
| **November 2004** | | | |
| No change | 9 | 0 | **9** |
| Raise | 0 | 0 | **0** |
| **Total** (actual) | **9** | **0** | **9** |
| **December 2004** | | | |
| No change | 9 | 0 | **9** |
| Raise | 0 | 0 | **0** |
| **Total** (actual) | **9** | **0** | **9** |
| **January 2005** | | | |
| No change | 9 | 0 | **9** |
| Raise | 0 | 0 | **0** |
| **Total** (actual) | **9** | **0** | **9** |
| **February 2005** | | | |
| No change | 8 | 1 | **9** |
| Raise | 0 | 0 | **0** |
| **Total** (actual) | **8** | **1** | **9** |
| **March 2005** | | | |
| No change | 7 | 2 | **9** |
| Raise | 0 | 0 | **0** |
| **Total** (actual) | **7** | **2** | **9** |

The 'success' of the the model may be measured by the total number of correct predictions, given by the sum of the first two diagonal elements: out of nine votes the model correctly predicted six. The model predicted the direction of change in base rates correctly in January, February, May and June 2004, and for the period October 2004 to March 2005. In March and April 2004 the model predicted that further increases in interest rates were warrented. These increases did not actually materialise until May 2004.

The results are quite reasonable, given that the results pertain to a strictly non-sample period, and includes a period (March to September 2004) of consistently strong upward pressure on interest rates. The results can be summarised (summed up) in the following $2\times2$ contingency (frequency) table (also sometimes called a *Confusion matrix*), where the figures in parentheses are estimated probabilities of each cell in the matrix (*e.g.*, $52/135 = 0.385$). Let the elements of the matrix (probabilities) be denoted by $p_{ij}$'s, the row totals by $p_{i.}$'s, and the column totals by $p_{.j}$'s.

The combined period contingency table is given by:

| **Predicted votes:** | **Actual votes** | | **Total** |
|---|---|---|---|
| | **No change** | **Raise** | (pred.) |
| No change | 55(0.407) | 6(0.044) | **61**(**0.452**) |
| Raise | 39(0.289) | 35(0.259) | **74**(**0.548**) |
| **Total** (actual) | **94**(**0.696**) | **41**(**0.304**) | **135**(**1.000**) |

The overall accuracy measure is $0.667(= 90/135)$ and the odds ratio is $8.226(= \frac{55/6}{39/35})$. Cohen's *kappa* is estimated at $\widehat{\kappa} = 0.358$ (standard error estimate $= 0.087$), implying that the model avoided 36% of the errors that a completely random vote assignment would generate. The Pearson's $\chi^2$ is 22.19 and the $\phi$-coefficient is 0.405. These measures reflect a high degree of predictive power of our fixed effects model.

Table 6 presents predictions for the MPC as a whole using our estimated fixed and random effects models. Our estimated random effects model incorporates heterogeneity among the decisions of MPC members which is expressed in terms of different probabilities of voting for changes in interest rates. The decision making process may thus be seen as a binomial experiment with 9 independent draws with a different probability of success for each draw. The predicted probabilities using the random effects model are estimated using 1000 Monte Carlo simulations of random draws. The fixed effects results have been derived from the results in Table 5.

The random effects model predicts that based on information available in January 2004, the probability of a rise in interest rates was around 0.47. However, interest rates were not raised. Similarly for February 2004, the model predicts that given the current economic environment at that time the probability of a rise would have been 0.42. Interest rates were raised in

February. In March, April and May 2004 the model predicts with probability almost 1.00 that interest rates should have been raised. In fact they were not raised until May 2004. Thus, the models predicts the strong upward pressure on interest rates in the first half of 2004 reasonably well. Similarly, the models predict unchanged interest rates over the period October 2004 to March 2005 very well.

**TABLE 6: Predictions of MPC Consensus Decisions**

| **MPC meeting month** | **Actual change** | **Fixed Effects Model** (predicted) | **Random Effects** (pred. prob.) **Lower** −0.25 | **No change** | **Raise** 0.25 | 0.50 |
|---|---|---|---|---|---|---|
| **Jan. 2004** | 0.00 | 0.00 | 0.000 | 0.530 | 0.470 | 0.000 |
| **Feb. 2004** | 0.25 | 0.25 | 0.000 | 0.579 | 0.421 | 0.000 |
| **Mar. 2004** | 0.00 | 0.25 | 0.000 | 0.004 | 0.746 | 0.250 |
| **Apr. 2004** | 0.00 | 0.50 | 0.000 | 0.000 | 0.430 | 0.570 |
| **May 2004** | 0.25 | 0.50 | 0.000 | 0.000 | 0.545 | 0.455 |
| **June 2004** | 0.25 | 0.50 | 0.000 | 0.000 | 0.371 | 0.626 |
| **July 2004** | 0.00 | 0.25 | 0.000 | 0.097 | 0.896 | 0.007 |
| **Aug. 2004** | 0.25 | 0.25 | 0.000 | 0.144 | 0.852 | 0.004 |
| **Sep. 2004** | 0.00 | 0.25 | 0.000 | 0.102 | 0.890 | 0.008 |
| **Oct. 2004** | 0.00 | 0.00 | 0.000 | 0.938 | 0.062 | 0.000 |
| **Nov. 2004** | 0.00 | 0.00 | 0.000 | 1.000 | 0.000 | 0.000 |
| **Dec. 2004** | 0.00 | 0.00 | 0.000 | 0.999 | 0.001 | 0.000 |
| **Jan. 2005** | 0.00 | 0.00 | 0.000 | 0.997 | 0.003 | 0.000 |
| **Feb. 2005** | 0.00 | 0.00 | 0.000 | 1.000 | 0.000 | 0.000 |
| **Mar. 2005** | 0.00 | 0.00 | 0.002 | 1.000 | 0.000 | 0.000 |

# 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 majority 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 into account committee decision in the past month but not the voting behaviour of individual members in past meetings; this seems to affect our predictions somewhat.

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