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How Experts Decide: Preferences or Private Assessments on a Monetary Policy Committee?

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Abstract

Using voting data from the Bank of England, we show that different individual assessments of the economy strongly influence votes after controlling for individual policy preferences. We estimate that internal members form more precise assessments than externals and are also more hawkish, though preference differences are very small if members vote strategically. Counterfactual analysis shows that committees add value through aggregating private assessments, but that gains to larger committees taper off quickly beyond five members. There is no evidence that externals add value through preference moderation. Since their assessments also have lower precision, mixed committees may not be optimal.

JEL-Code: E520, E580, D780.

Keywords: committees, monetary policy.

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1 Introduction

Committees are used widely for decision making; for example, there are numerous legislative committees, academic departments have tenure-review committees, and cases brought to the Supreme Court are assessed by a committee of judges. The trend towards using committees is also evident in areas of macroeconomic policy (such as recently established fiscal policy committees), but is especially true in monetary policy where, according to a survey by Fry, Julius, Mahadeva, Roger, and Sterne (2000), 79 of 88 surveyed central banks use committees to decide interest rates. Despite the widespread adoption of committees for decision making, much remains unknown about how they make decisions in practice and why committees outperform individuals.[1] Without such information, it is impossible to make important committee design decisions with any certainty.

In this paper we analyse empirically the votes cast by members of one such committee - the Bank of England's Monetary Policy Committee (MPC). While the existing literature has examined differences in behaviour stemming from preference differences ("hawkishness" or "dovishness"), we believe that this limited assessment of how members differ is inadequate. Both the designers of such committees and theoretical models of decision making emphasize that committee members serving together may form different assessments about the state of the economy; even if they share the same preferences, different "views" held by members may lead to different interest rate votes. If members form individual assessments of the economy, then the precision of these assessments, which we call *expertise*, is just as important a characteristic for understanding their behavior as their preferences.

Our empirical analysis is unique in the context of monetary policy committee analysis in that we allow for both sources of heterogeneity. In order to do this, we follow Iaryczower and Shum (2012), who estimate measures of preferences and expertise for US Supreme Court justices using a two-step approach that we detail below. Identification of preferences and signal precision separately is possible because these characteristics have different impacts on the probability that a member votes for high rates both across inflationary states and in reaction to changes in the common prior. We augment Iaryczower and Shum (2012) in two ways: first, we explicitly construct two proxies for public forecasts of inflation shocks - one based on surveys of financial economists and another based on LIBOR option prices - and use them in estimation; and, second, we use a Quasi-Bayesian approach to construct confidence intervals for the estimated structural parameters.

This paper makes three contributions. The first is to show that individual assess-

[1] Blinder and Morgan (2005) and Lombardelli, Proudman, and Talbot (2005) both conclude from monetary policy experiments that committees outperform individuals.

ments play an important role in individual voting behavior. The average probability that individual members make the correct decision regarding the interest rate choice hovers around 88 percent, a 15 percentage point gain relative to a model in which private views play no role. Modelling private views is therefore important for explaining voting behavior, and differences in these views can be expected to lead to different votes even when members share the same preferences.

The second contribution is to examine how expertise and preferences differ across different members on the MPC. In particular, we examine whether externally appointed experts (members appointed solely to make the decision each month) display different characteristics to internal members (those who also have other responsibilities in the central bank). Some countries make use of them (for example, Poland and Hungary), presumably to take advantage of diversity, while others (for example, the USA and Sweden) do not. By identifying the precise ways that externals and internals are diverse, the paper permits one to study the welfare effects of mixed versus homogenous committees.

We estimate that the difference between internals' and externals' expertise is positive and significantly different from zero. In terms of preference differences, we find internal members are more hawkish than external members. However, recovering voters' preferences requires specifying whether they vote sincerely, in which case they vote as they would if acting alone, or strategically, in which case they condition on changing the committee's decision when casting their vote. In the sincere case, we estimate a preference difference that is large in magnitude and significant. This finding is in line with the existing literature. With strategic voting, however, although the difference remains significant, external and internal members appear much closer in terms of preferences. These strategic voting estimates suggest that preference differences may play less of a role in vote heterogeneity than suggested by existing research.

To try to uncover the source of these differences, we examine the behavior of members who have worked in central banking prior to their MPC appointment, "insiders," in order to assess whether prior experience or current position matters most for the behavior of internals. We find that insiders are more hawkish and have more expertise than outsiders, which suggests that it is prior experience as central bankers rather than holding a senior position in the central bank that drives the internal-external differences.[2]

Our final contribution is to explore the implications of our results for committee design using counterfactual simulations. As Blinder (2007) points out, members' arriving

[2]We also examine splits based on age, education and prior career; while in no case do we find significant preference (both sincere and strategic) or expertise differences, in all cases members' decisions are importantly influenced by their private assessments of the economic situation. This corroborates our view that members' individual views of the unknown state of economy are an important driver of vote heterogeneity and that the committee adds value through pooling private knowledge.

at different private views provides a channel for committees to outperform individuals via aggregation of dispersed private information. To test this idea, we quantify the effect of increasing the committee's size on the probability that the correct decision is made. We find that, in periods where the economic environment is most uncertain, and regardless of whether the voting is sincere or strategic, a committee of five internal members is between 7 and 12 percentage points more likely to make the correct decision than an individual internal member. This indicates that the gain from committees' pooling imperfect knowledge is potentially significant. We next compute the effect of adding four additional internal members (making a committee of nine internal members), and find much smaller gains of about 1-2 percentage points. So, the additional members on large committees, such as the 23-member Governing Council of the ECB, may improve decision making only marginally. This suggests that, given potentially large costs from adding more and more members,[3] a smaller committee is likely better.

The second design idea we test is whether a mixed committee composed of external and internal members outperforms a homogenous one composed of just internals. If voting is strategic, then externals and internals essentially differ just in terms of expertise, and the homogenous committee does better. If voting is sincere and preference differences are meaningful, then one might argue, as does Blinder (2007), that externals serve to offset the narrow and potentially extreme hawkish preferences of internals. We test this idea but do not find support for it. It is true that a nine-person committee composed of five internals and four externals outperforms a nine-person internal committee when members have a prior belief that rates should be high, but for lower values of the prior externals worsen decision making so that overall there is no gain.

In short, we find that a relatively small, homogenous committee of members with high expertise performs very well even if they have a hawkish bias. Of course, further work remains to be done on whether members vote strategically or not, the exact nature of deliberation in the committee meeting, and alternative sources of value that external members might bring. Still though, the paper is the first to separately identify the role of preferences and individual assessments in monetary policymaking, and so provides potentially valuable facts for extending our knowledge of both the "how" and "why" of policymaking by committee.

Our work is related to a number of strands of the existing literature. Firstly, since at least the work of Brainard (1967), monetary economists have understood that monetary policymakers do not have full information about the structure of the economy, or the current state of the economy (Orphanides (2003)) and therefore monetary policy decisions

[3]These costs include information exchange problems and free-riding by members (see Sibert (2006) for a discussion).

must be made with imperfect information. Secondly, there is a growing literature on all aspects of the use of committees to make monetary policy decisions; for example, this includes important summaries of the state of the knowledge (such as Gerling, Gruner, Kiel, and Schulte (2005), in general, or Blinder (2007) specific to monetary policy), issues of agenda-setting (Riboni and Ruge-Murcia (2010)), reputation building on monetary policy committees Sibert (2003), credibility of the committee (Mihov and Sibert (2006)), and the desirability of a committee over an individual when there is uncertainty about the economic situation Gerlach-Kristen (2006). Committee decision making has been extensively studied by social psychologists; Sibert (2006) provides a wonderful discussion of the main findings and how it applies to monetary policy committees. Lastly, there are a number of other papers which empirically study the monetary policy committee of the Bank of England and these papers also discuss internal-external differences within the MPC; these include Gerlach-Kristen (2003), Bhattacharjee and Holly (2005), Spencer (2006), Besley, Meads, and Surico (2008), Harris and Spencer (2008) and Hix, Hoyland, and Vivyan (2010). As mentioned above, these all focus exclusively on preference differences[4] and the general conclusion is that external members are more dovish the internals.

After providing background information on the MPC in section 2, we present the voting model that serves as the basis of our empirical analysis in section 3. We detail our estimation strategy in section 4, describe the data we use to implement this strategy in section 5, and provide results in section 6. Section 7 presents counterfactual results on the committee structure and section 8 concludes.

2 The Monetary Policy Committee

The MPC provides a natural setting for our analysis because there is a one-person, one-vote philosophy, meaning that members express their own views in their vote, and because the committee of nine members is made up of both internal and external members. The Bank's explicit aim in appointing external members is their ostensible heterogeneity vis-à-vis internal members; according to Bank of England (2010a), external appointments "ensure that the MPC benefits from thinking and expertise in addition to that gained inside the Bank of England."

The MPC took over responsibility for setting interest rates in the UK immediately after the UK general election in May 1997; until then, the Chancellor of the Exchequer (the government minister in charge of the UK Treasury) set the interest rate. The new Labour government established the MPC as an independent committee of experts for

[4]By and large, these papers assume member preferences derive from a weighted sum of inflation and output, with different members having different weights.

setting interest rates and the MPC remit, as defined in the Bank of England Act (1998), is to "maintain price stability, and subject to that, to support the economic policy of Her Majesty's government, including its objectives for growth and employment." In practice, the committee seeks to achieve a target inflation rate of 2%, based on the Consumer Price Index.[5] If inflation is greater than 3% or less than 1%, the Governor of the Bank of England must write an open letter to the Chancellor explaining why. The inflation target is symmetric; missing the target in either direction is treated with equal concern.

The MPC first convened on 6 June 1997, and has met every month since. Throughout the paper we analyze the MPC voting records between June 1997 and March 2009, when the main focus of the decision (temporarily) shifted to asset purchase decisions related to quantitative easing.[6] The voting records indicate both the proposed interest rate decision (such as +50 basis points), as well as the alternative preference for those who do not back the proposal (such as +25bps).[7]

Of the nine MPC members; five of these are internal members serving as executives of the Bank of England: the Governor, two Deputy Governors, the Chief Economist, and the Executive Director for Markets. The Chancellor also appoints four external members (subject to approval from the Treasury Select Committee) from outside the Bank. There are no restrictions on who can serve as external members, and they have come from many different backgrounds.[8] Bar the governors, all members serve three year terms; the governors serve five year terms. When members' terms end, they can either be replaced or re-appointed. Our sample contains a total of 13 internal and 14 external members. Table 1 splits the members that served on the MPC during our sample by internal and external (their tenure is reported in brackets). For later use in the analysis, it also reports whether members had worked within the Bank prior to their appointment; such members we call *insiders*.

Each member is independent in the sense that they do not represent any interest group or faction. The Bank encourages members to simply determine the rate of interest that they feel is most likely to achieve the inflation target,[9] and majority vote determines the

[5]There was a change from RPIX to CPI as the measure of inflation in January 2004, and with this change, the inflation target was reduced from 2.5% to 2%.

[6]These data are available from the Bank of England (2010b). We use each regular MPC meetings in this period but we drop from the dataset the (unanimous) emergency meeting held after 9/11.

[7]Before June 1998 there is information about whether members preferred higher or lower interest rates compared with the decision, but not about their actual preferred rate. In these cases, we treat a member's vote as either 25 basis points higher or lower than the decision, in the direction of disagreement. Given how we use the voting data, discussed below, this assumption has no implications for our analysis.

[8]Of course, to avoid conflicts of interest, there are restrictions on what the members can do while serving on the committee.

[9]According to the Bank of England (2010a)

> Each member of the MPC has expertise in the field of economics and monetary policy.

Table 1: MPC Members

Central Bank Career	Appointment: External	Appointment: Internal
Outsider	C. Allsopp (06/00-05/03)	
	K. Barker (06/01-03/09)	
	M. Bell (06/02-06/05)	C. Bean (10/00-03/09)
	T. Besley (06/06-03/09)	D. Clementi (11/97-08/02)
	D. Blanchflower (06/06-03/09)	J. Gieve (01/06-03/09)
	A. Budd (12/97-05/99)	A. Large (11/02-01/06)
	W. Buiter (06/97-05/00)	R. Lomax (07/03-06/08)
	D. Julius (11/97-05/01)	J. Vickers (06/98-11/00)
	R. Lambert (06/03-03/06)	
	S. Nickell (06/00-05/06)	
	A. Sentance (10/06-03/09)	
	S. Wadhwani (06/99-05/02)	
	D. Walton (07/05-06/06)	
Insider	C. Goodhart (06/97-05/00)	E. George (06/97-06/03)
		H. Davies (06/97-07/97)
		P. Fisher (03/09-03/09)
		S. Dale (07/08-03/09)
		I. Plenderleith (06/97-05/02)
		M. King (06/97-03/09)
		P. Tucker (06/02-03/09)

Notes: This table shows committee members serving on the MPC for the period 06/97-03/09 and splits them into whether they are internal or external, and whether they are insiders or outsiders. The former distinction is based on how they are appointed while the latter is determined by whether they had prior experience in the Bank of England. For example, Eddie George served from 06/97 to 06/03 as an internal member who was also an insider on account of his career at the Bank of England. In contrast, Kate Barker, who served from 06/01 to 03/09, was appointed as an external members and had no prior experience in the Bank before her appointment.

outcome. As such, the observed votes should reflect members' genuine policy preferences. Consistent with its one-person one-vote philosophy, the MPC displays substantial dissent. 64% of the 142 meetings in the sample have at least one deviation from the committee majority. Figure 1 shows the level of interest rates that the MPC has implemented, how many votes were cast in each meeting in opposition to this final decision, and highlights the periods of interest rate loosening[10]; within the set of non-unanimous meetings, 5-4 and 6-3 decisions are not uncommon.

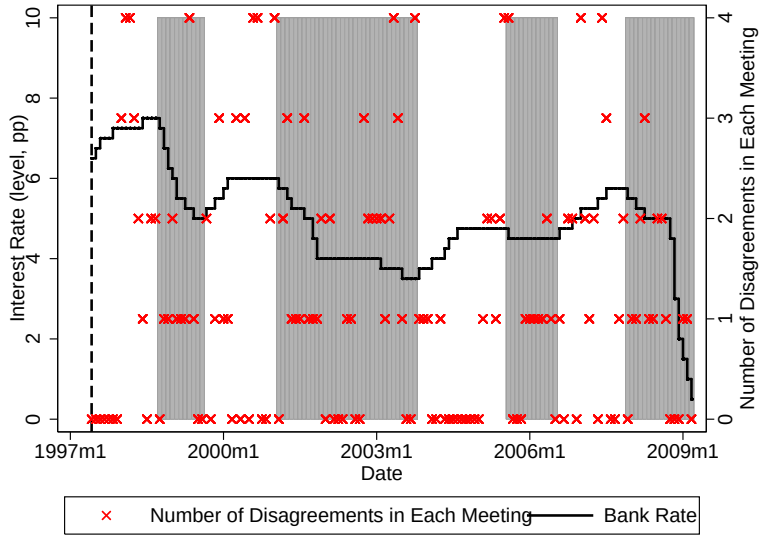


Figure 1: Interest rate decisions and deviant votes

Notes: The black line shows the level of interest rates chosen by the MPC between June 1997 and March 2009. The red Xs show the number of dissents against the MPC decision in each meeting; given nine members and a majority voting rule, four dissents is the maximum possible. The dark shaded area represents a loosening cycle which begins at the first cut in interest rates and continues until the first increase in interest rates.

The MPC meets on the first Wednesday and Thursday of each month. In the month between meetings, members receive numerous briefings from Bank staff and regular updates of economic indicators. On the Friday before MPC meetings, members gather for a meeting in which they are given the latest analysis of economic and business trends. Then on Wednesday members discuss their views on several issues. The discussion continues

Members are not chosen to represent individual groups or areas. They are independent. Each member of the Committee has a vote to set interest rates at the level they believe is consistent with meeting the inflation target. The MPC's decision is made on the basis of one-person, one vote. It is not based on a consensus of opinion. It reflects the votes of each individual member of the Committee.

[10]The loosening cycle is defined as the period from the first cut in interest rates until the next increase in interest rate.

on Thursday morning, when each member is given some time to summarize his or her views to the rest of the MPC and to suggest what vote they favor (although as Lambert (2006) notes they can, if they wish, wait to hear the others views before committing to a vote). This process begins with the Deputy Governor for monetary policy and concludes with the Governor, but the order for the others is not fixed. To formally conclude the meeting, the Governor proposes an interest rate decision that he believes will command a majority. Each member then chooses whether to agree with the Governor's proposal, or dissent and state an alternative interest rate. The MPC decision is announced at noon, and two weeks after each meeting, attributed members' votes are published as part of otherwise unattributed minutes.

3 Model

This section presents a reduced-form model of monetary policy decision-making under uncertainty, which will serve as the basis for the estimation approach we employ in this paper. This model is based on a standard voting model[11] in which members must choose one of two interest rates - one higher than another - to implement in response to an unobserved inflationary state. All members agree that the higher (lower) rate is appropriate when there is more (less) inflationary pressure, but they differ in how averse to wrongly choosing low interest rates they are; such member-specific preferences or biases determine how much evidence they need that the economy is inflationary in order to vote high. Members also form individual assessments of the state of the economy on the basis of public information and the realization of a privately observed signal, whose precision measures expertise. The model yields a voting rule in which members vote for high rates if and only if they are sufficiently convinced that the economy is in an inflationary state.

Before turning to the details of the model, it is worth pausing to consider its applicability to the decision facing members of the MPC. There are two issues here; the reduced form nature of the decision rule, and the mapping between the modelling devices and the decision making of MPC members. In terms of the first, we show in appendix A that a standard New Keynesian model of the macroeconomy [Clarida, Galí, and Gertler (1999), Galí (2008)] gives rise to a similar threshold interest rate rule. In such a model, the member-specific voting threshold arises from different beliefs about the structural parameters of the economy; we shall simply assume a single parameter captures the member-specific preferences or bias.

[11] While many theory papers in the voting literature feature voting over a binary agenda with private information, the formal structure of the model is closest to Duggan and Martinelli (2001), who study voting over binary outcomes with continuous signals.

In terms of the second issue, as Blinder (2007) points out, there are several admissible interpretations of preference heterogeneity and private assessments in the context of monetary policy. Members might literally have different preferences over the trade off between inflation and unemployment, but they might also have different models of the macroeconomy, models with a particular bias, in their heads. A member who analyzes an issue using a model that required less evidence to vote for higher interest rates would have a hawkish bias, which is observationally equivalent to hawkish preferences. In terms of private assessments (modelled as private signals), viewing them as private information, which is common in many theory models, is rather unconvincing in monetary policy since members typically receive the same data prior to voting.[12] Instead, a more natural interpretation is that the diverse models and forecasting methods that members use give them imperfect, heterogeneous views about underlying economic conditions.

3.1 Model Details

In each period t the committee must implement a decision $d_t \in \{0, 1\}$, where 0 represents the lower of two possible rate changes and 1 the higher.[13] The restriction to a two-decision agenda is rather unrestrictive since there are three unique votes in only 7 of the 142 meetings in our sample and in no meeting are there four or more unique votes. We assume an odd number N of voters compose the committee. Each one chooses a vote $v_{it} \in \{0, 1\}$ each period and $d_t = 1$ if and only if $\sum_i v_{it} \geq \frac{N+1}{2}$.

Member i's utility from decision d_t is given by

		decision d_t	
		0	1
state ω_t	0	0	$-(1-\theta_i)$
	1	$-\theta_i$	0

where ω_t is a state variable representing unknown economic conditions relevant to inflation and the choice of interest rates at time t, for example the magnitude of a demand shock or the output gap of the economy. We call $\omega_t = 1$ the "high interest rate state" and $\omega_t = 0$ the "low interest rate state." In our formulation of preferences, all members agree that decision $d_t = \omega_t$ is best, but they have different utilities from mismatches in different

[12] In fact, internal and external members may differ in their exposure to data related to financial stability and/or regulatory data. Despite the finding of Peek, Rosengren, and Tootell (2003) that central bankers can use such information to provide useful information for monetary policy, it is not clear that such information was widely analyzed until, perhaps, the onset of the financial crisis which comes only at the very end of our sample.

[13] We do not attempt to model the two rates that form the agenda; Riboni and Ruge-Murcia (2010) study this issue.

states. A member with a higher θ_i suffers more when the committee incorrectly chooses the lower rate than when they wrongly choose the higher rate. One could therefore interpret him as being more "hawkish" while a member with a lower θ_i is more "dovish."

Before voting, members form beliefs about the unknown state of the economy ω_t by relying on two sources. First, there is public information about the current state of the economy like market data, Bank forecasts, and each others' stated opinions. Let $q_t = \Pr[\omega_t = 1]$ denote the belief that the economy is in the high state that is consistent with this information. Second, member i privately observes the signal $s_{it} \mid \omega_t \sim N(\omega_t, \sigma_i^2)$. These signals are independent conditional on ω_t, and σ_i measures member i's expertise or precision of private assessment.

We assume that member i's belief - or view - on the state $\widehat{\omega}_{it} = \Pr[\omega_t = 1 \mid s_{it}]$ is formed by updating q_t, which he treats as his prior belief on $\omega_t = 1$, via Bayes' Rule. Basic manipulations reveal that[14]

$$\ln\left[\frac{\widehat{\omega}_{it}}{1-\widehat{\omega}_{it}}\right] = \ln\left[\frac{q_t}{1-q_t}\right] + \frac{2s_{it}-1}{2\sigma_i^2}. \tag{1}$$

(1) reveals the effect of private signals on belief heterogeneity. Suppose $\sigma_i = \infty$ for all members, so that their private signals are wholly uninformative. Then clearly $\widehat{\omega}_{it} = q_t \ \forall i$, and there are no differences in beliefs. If instead $\sigma_i < \infty$, then $\widehat{\omega}_{it} \neq \widehat{\omega}_{jt}$ for any two members i and j and there is belief heterogeneity. An important point is that, even if members draw signals from the same distribution, they will have divergent private assessments unless they happen to draw the same signal in a given meeting (a zero probability event). A separate point is that if members differ in their expertise, they will put different weights on their private signals; members with more accurate assessments will rely more on their own view and less on the public's.

Two clarifications are worth making. First, it is important to keep in mind that q_t represents members' prior belief at the moment at which they vote. If members reveal to colleagues their private signals prior to voting, as in Gerlach-Kristen (2006), then q_t pools all private assessments and becomes the common, shared belief. In this sense, our estimates of σ_i represent the upper bound on expertise. Second, one might imagine that ω_t is a persistent shock, but as appendix A shows, the model can accommodate this if ω_t is observed prior to period $t+1$. In this case, ω_t is reflected in q_{t+1}; voting in period

[14]Note that the private view satisfies

$$\ln\left[\frac{\widehat{\omega}_{it}}{1-\widehat{\omega}_{it}}\right] = \ln\left[\frac{q_t}{1-q_t}\right] + \ln\left[\frac{f_1}{f_0}\right]$$

where $f_1 \sim \left(1, \sigma_i^2\right)$ is the distribution of s_{it} conditional on $\omega_t = 1$ and $f_0 \sim \left(0, \sigma_i^2\right)$ is the distribution of s_{it} conditional on $\omega_t = 0$. (1) follows from normality.

$t+1$ depends on q_{t+1}, θ_i, and $s_{i,t+1}$; and everything can be solved as in the case with no persistence.

There are two behavioral assumptions that the voting literature makes about committee members (Austen-Smith and Banks 1996). First, when they vote *sincerely* they behave as if they get utility from matching their vote to the state. Under this assumption member i's expected utility from $v_{it} = 1$ is $-(1-\theta_i)\Pr[\omega_t = 0 \mid s_{it}]$, while his expected utility from $v_{it} = 0$ is $-\theta_i \Pr[\omega_t = 0 \mid s_{it}]$. He thus chooses $v_{it} = 1$ whenever

$$\ln\left[\frac{\widehat{\omega}_{it}}{1-\widehat{\omega}_{it}}\right] \geq \frac{1-\theta_i}{\theta_i} \tag{2}$$

which implies choosing $v_{it} = 1$ whenever

$$s_{it} \geq \frac{1}{2} - \sigma_i^2 \left[\ln\left(\frac{\theta_i}{1-\theta_i}\right) + \ln\left(\frac{q_t}{1-q_t}\right)\right] \equiv s_{it}^*(\text{SIN}). \tag{3}$$

In other words, member i adopts a threshold voting rule in which he votes for high rates if and only if he receives sufficient evidence for the high state having arisen. This threshold is both time and member specific, and depends on both preferences and expertise.

An alternative assumption is that committee members behave *strategically*. This requires modelling players' voting rules as strategies in a Bayesian game. The main modification from the sincere case is that members only condition their votes on the event in which they are pivotal for the committee's decision - that is, that there are exactly $\frac{N-1}{2}$ votes for $d_t = 0$ and $\frac{N-1}{2}$ votes for $d_t = 1$. Duggan and Martinelli (2001) show that all voters continue to adopt a cutoff voting rule, and that i votes 1 whenever

$$\frac{\Pr\left[\text{PIV}_i \;\middle|\; s_{-i}^*, \omega_t = 1\right]}{\Pr[\text{PIV}_i \mid s_{-i}^*, \omega_t = 0]} \ln\left[\frac{\widehat{\omega}_{it}}{1-\widehat{\omega}_{it}}\right] \geq \frac{1-\theta_i}{\theta_i}, \tag{4}$$

where $\Pr\left[\text{PIV}_i \;\middle|\; s_{-i}^*, \omega_t\right]$ is the probability that he is pivotal given other members' cutoffs s_{-i}^* and the inflation state ω_t. Thus, member i selects $v_{it} = 1$ if and only if

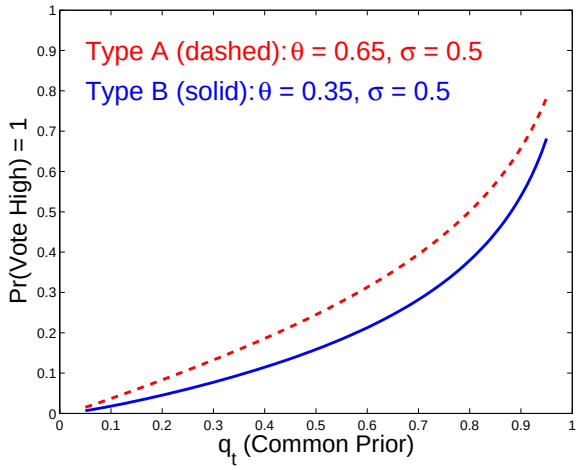
$$s_{it} \geq \frac{1}{2} - \sigma_i^2 \left[\ln\left(\frac{\theta_i}{1-\theta_i}\right) + \ln\left(\frac{q_t}{1-q_t}\right) + \ln\left(\frac{\Pr\left[\text{PIV}_i \;\middle|\; s_{-i}^*, \omega_t = 1\right]}{\Pr[\text{PIV}_i \mid s_{-i}^*, \omega_t = 0]}\right)\right] \equiv s_{it}^*(\text{STR}). \tag{5}$$

An equilibrium is a collection of these cutoffs $\{s_{it}^*(\text{STR})\}_{i=1}^N$ such that all N equations described in (5) are satisfied. Clearly in general $s_{it}^*(\text{STR}) \neq s_{it}^*(\text{SIN})$, and obtaining a closed form solution for the former is not possible.[15] Since both appear in the literature,

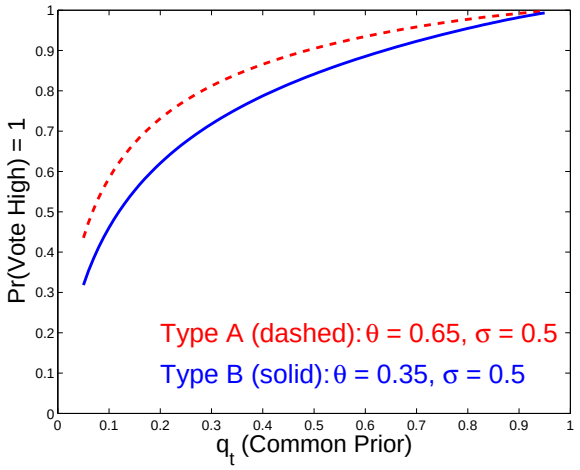
[15] In principle there can be multiple equilibria of the strategic voting game corresponding to different cutoffs, but specifying which one is being played is not important for the estimation strategy we use.

we estimate both models.

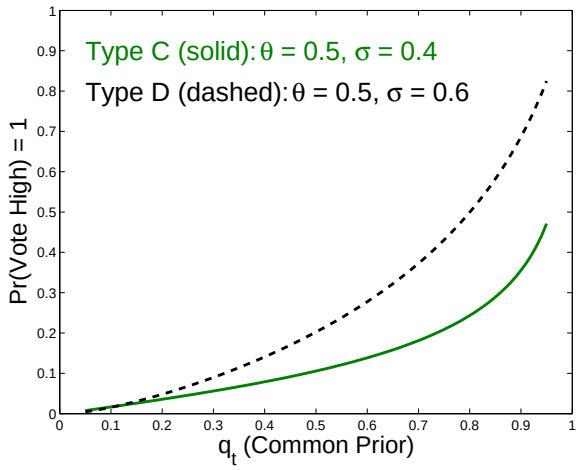
(a) Sincere Model: Preference Change, State=0



(b) Sincere Model: Preference Change, State=1



(c) Sincere Model: Information Change, State=0



(d) Sincere Model: Information Change, State=1

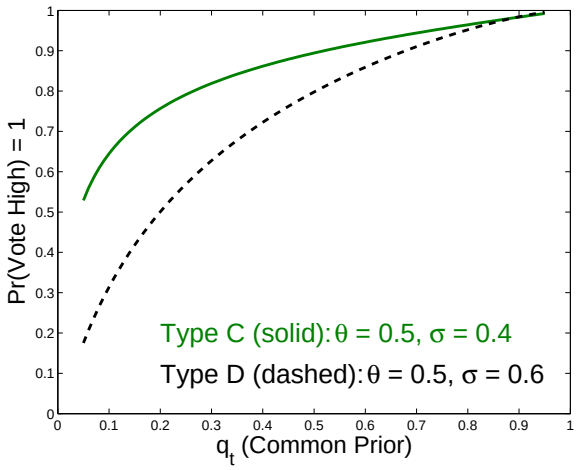


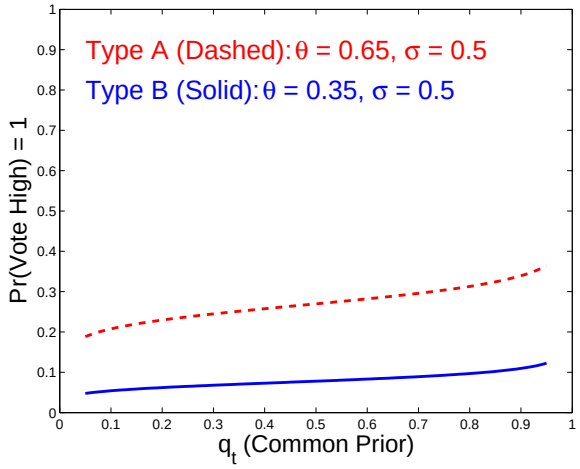
Figure 2: Distinguishing Information and Preferences: Sincere Voting

Notes: These figures show the theoretical probability that a member votes for the high interest rate ($\Pr(v_{it} = 1)$) in a meeting as a function of the prior belief that the economy is in an inflationary state (q_t). The different curves represent different combinations of signal precision and hawkishness to show how the probability of voting high changes.

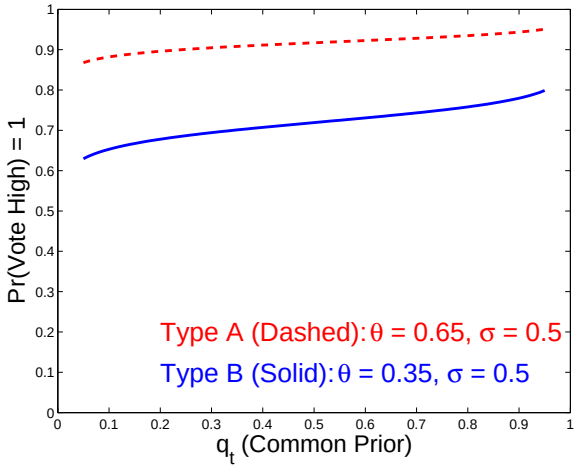
To understand why preferences and signal precisions are separately identifiable, it is useful to analyze how each impacts the probability of voting for the higher rate ($v_{it} = 1$) in different inflationary states. Consider first figure 2, which plots the probability that members with different combinations of θ and σ parameters vote high as a function of the prior probability q_t in the sincere model.[16] Figures 2a and 2b compare two members

[16]The plots in these figures are representations of the equation $1 - \Phi\left(\frac{s^*_{it}(\text{SIN}) - \omega_t}{\sigma_i}\right)$.

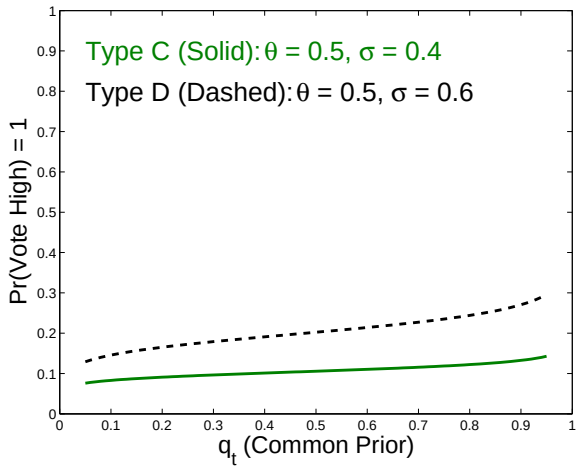
(a) Strategic Model: Preference Change, State=0



(b) Strategic Model: Preference Change, State=1



(c) Strategic Model: Information Change, State=0



(d) Strategic Model: Information Change, State=1

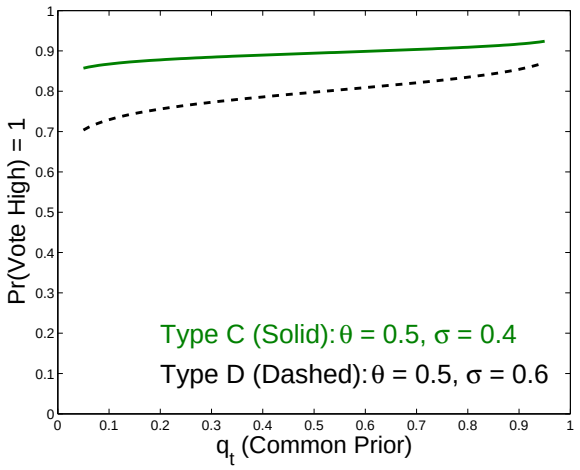


Figure 3: Distinguishing Information and Preferences: Strategic Voting

Notes: These figures show the theoretical probability that a member votes for the high interest rate ($\Pr(v_{it} = 1)$) in a meeting as a function of the prior belief that the economy is in an inflationary state (q_t). The different curves represent different combinations of signal precision and hawkishness to show how the probability of voting high changes.

A and B who have the same signal precision ($\sigma_A = \sigma_B = 0.5$) but different preferences ($\theta_A = 0.65$; $\theta_B = 0.35$). As the prior increases, both have a higher chance of voting for the high rate. However, member B always has a lower probability of choosing the high rate than member A because he is inherently less inflation-averse.

Now consider two members C and D who have the same preferences ($\theta_C = \theta_D = 0.5$) but different signal precisions ($\sigma_C = 0.4$; $\sigma_D = 0.6$). The probabilities they vote high in the two states are plotted in figures 2c and 2d. Because C has a more precise signal and can better identify the state ω_t, his vote tends to match the state more often than that of D. So, he is on average more likely to choose $v_{it} = 0$ ($v_{it} = 1$) when $\omega_t = 0$ ($\omega_t = 1$). While this argument is about how C and D differ across states, there is another source of identification that comes from how voting reacts to *changes* in the prior. In general, a more informed member's probability of voting high reacts less to changes in q_t; in the limit with perfect information his probability does not change at all because his vote always matches the state. Because our dataset contains heterogeneity in the prior, we are also able to exploit this alternative source of identification.

Figure 3 plots the probabilities that members vote high in the strategic model.[17] The basic identification arguments outlined above in the sincere case continue to hold. The main difference is that the probabilities of voting high do not approach 0 (1) for values of the prior that are close to 0 (1) in both states. This is because $\frac{\Pr\left[\text{PIV}_i \,\middle|\, s^*_{-i},\omega=1\right]}{\Pr\left[\text{PIV}_i \,\middle|\, s^*_{-i},\omega=0\right]}$ is large for low values of the prior and vice versa.

4 Econometric Methodology

Having introduced the theoretical model accounting for how members of the MPC vote, our next task is to specify a likelihood function that will allow us to recover the structural parameters of interest. To fix ideas, consider a meeting at time t. Under the high inflation state at time t, we know that member i votes for the low rate with probability $\Phi\left(\frac{s^*_{it}(\cdot)-1}{\sigma_i}\right)$ and for the high rate with probability $1 - \Phi\left(\frac{s^*_{it}(\cdot)-1}{\sigma_i}\right)$. Under the low inflation state, member i votes for the low rate with probability $\Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)$ and for the high rate with probability $1 - \Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)$. The probability that the economy is in the high inflation state is q_t and under the low inflation state $(1 - q_t)$. Therefore, the likelihood function for a set of votes v_t given $s^*_{it}(\cdot)$ and σ_i is:[18]

[17] These are numerically simulated since $s^*_{it}(\text{STR})$ does not have a tractable closed form solution.

[18] The two structural parameters of interest are θ_i and σ_i but $s^*_{it}(\cdot)$, given by equations (3) and (5) for sincere and strategic voting respectively, provides a compact representation of the role of preferences when discussing the likelihood.

$$
\begin{aligned}
&q_t \prod_{i \in M(t)} \left[1 - \Phi\left(\frac{s^*_{it}(\cdot) - 1}{\sigma_i}\right)\right]^{v_{it}} \left[\Phi\left(\frac{s^*_{it}(\cdot) - 1}{\sigma_i}\right)\right]^{1-v_{it}} + \\
&(1 - q_t) \prod_{i \in M(t)} \left[1 - \Phi\left(\frac{s^*_{it}(\cdot) - 1}{\sigma_i}\right)\right]^{v_{it}} \left[\Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)\right]^{1-v_{it}}
\end{aligned} \tag{6}
$$

where $M(t) = \{\, i \mid v_{it} \neq \emptyset \,\}$ is the set of voters who cast a vote in period t. It follows then that likelihood of observing the vector of votes $\mathbf{v}$ (i.e. all individual votes across all meetings) is:

$$
\prod_t \left\{ \begin{array}{l} q_t \prod_{i \in M(t)} \left[1 - \Phi\left(\frac{s^*_{it}(\cdot)-1}{\sigma_i}\right)\right]^{v_{it}} \left[\Phi\left(\frac{s^*_{it}(\cdot)-1}{\sigma_i}\right)\right]^{1-v_{it}} + \\ (1 - q_t) \prod_{i \in M(t)} \left[1 - \Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)\right]^{v_{it}} \left[\Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)\right]^{1-v_{it}} \end{array} \right\}. \tag{7}
$$

The most natural way to estimate the parameters from this likelihood function would be to model directly the prior and the individual structural parameters of interest as a function of covariates theoretically linked to them. Indeed, given expression (3), this can be quite easily done for the case of the sincere voting model. However, for the strategic model, direct estimation is not possible because of the complex functional forms for the cutoffs. In order to stay agnostic about which model generates the data during estimation, we follow the two-step estimation approach introduced by Iaryczower and Shum (2012). In particular, we redefine the likelihood function (7) as

$$
\prod_t \left[q_t \prod_{i \in M(t)} (\kappa_{1it})^{v_{it}} (1 - \kappa_{1it})^{1-v_{it}} + (1 - q_t) \prod_{i \in M(t)} (\kappa_{0it})^{v_{it}} (1 - \kappa_{0it})^{1-v_{it}} \right] \tag{8}
$$

where $\kappa_{1it} \equiv 1 - \Phi\left(\frac{s^*_{it}(\cdot)-1}{\sigma_i}\right)$ and $\kappa_{0it} \equiv 1 - \Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)$. We then model q_t and the κ terms as functions of observed covariates.

Our model for the prior (or, in econometric terms, the mixing probability) is

$$
q_t = \frac{\exp\left(\alpha_0 + \alpha_1 q^R_t + \alpha_2 q^M_t\right)}{1 + \exp\left(\alpha_0 + \alpha_1 q^R_t + \alpha_2 q^M_t\right)}, \tag{9}
$$

where q^R_t and q^M_t are proxy variables correlated with the true q_t whose construction we describe below. Another option would be to model q_t as a function of a number macroeconomic variables, but here our main concern is simply prediction of the state. As such, we follow Imai and Tingley (2012) and favor parsimony in the model.

We model the κ terms as

$$\kappa_{0it} = \frac{\exp(\beta \cdot S_{it})}{1 + \exp(\beta \cdot S_{it})} \tag{10}$$

$$\kappa_{1it} = \frac{\kappa_{0it} + \exp(\gamma \cdot S_{it})}{1 + \exp(\gamma \cdot S_{it})} \tag{11}$$

where

$$\beta \cdot S_{it} = \beta_0 + \beta_1 \cdot q_t^R + \beta_2 \cdot q_t^M + \beta_3 \cdot X_i + \beta_4 \cdot X_i \cdot q_t^R + \beta_5 \cdot X_i \cdot q_t^M + \beta_6 \cdot Z_t,$$

$$\gamma \cdot S_{it} = \gamma_0 + \gamma_1 \cdot q_t^R + \gamma_2 \cdot q_t^M + \gamma_3 \cdot X_i + \gamma_4 \cdot X_i \cdot q_t^R + \gamma_5 \cdot X_i \cdot q_t^M + \gamma_6 \cdot Z_t,$$

and X_i is a vector of individual characteristics that we also interact with the proxies for q_t. These interactions capture the fact that members with different signal precisions react differently to changes in the prior, as explained in section 3. Z_t are meeting-specific variables that potentially affect voters' tradeoff between errors in states 0 and 1 without influencing their beliefs on economic conditions. The dependence of κ_{1it} on κ_{0it} ensures that $\kappa_{1it} \geq \kappa_{0it}$; i.e., that members have a higher probability of voting high in the high state rather than the low.

The first stage of our estimation approach is to estimate the α, β, and γ parameters via the mixture model captured by (8). Since the state of the world is unobserved, the literature suggests using the EM algorithm or a Bayesian approach in estimating mixture models (Imai and Tingley 2012). However, since our model is quite similar under each state of the world, identification becomes difficult. Thus, as in Iaryczower and Shum (2012), we opted instead for direct maximization of the log-likelihood function given by (8).[19]

After the first stage, we obtain fitted values $\widehat{q}_t$, $\widehat{\kappa}_{0it}$, and $\widehat{\kappa}_{1it}$. The second stage uses these to recover the structural parameters of interest. By definition $\kappa_{0it} \equiv 1 - \Phi\left(\frac{s_{it}^*(\cdot)}{\sigma_i}\right)$ and $\kappa_{1it} \equiv 1 - \Phi\left(\frac{s_{it}^*(\cdot)-1}{\sigma_i}\right)$. Under both the sincere and strategic voting models, we can use the empirical counterparts for these two expressions to recover estimates for signal accuracy and equilibrium voting threshold as follows:

$$\widehat{\sigma}_{it} = \frac{1}{\Phi^{-1}(1 - \widehat{\kappa}_{0it}) - \Phi^{-1}(1 - \widehat{\kappa}_{1it})} \quad \text{and} \quad \widehat{s}_{it}^* = \frac{\Phi^{-1}(1 - \widehat{\kappa}_{0it})}{\Phi^{-1}(1 - \widehat{\kappa}_{0it}) + \Phi^{-1}(\widehat{\kappa}_{1it})}. \tag{12}$$

Obtaining estimates for the preferences parameter θ requires specifying the sincere or strategic model. Under the former (latter), $\widehat{\theta}_{it}$ can be obtained by plugging $\widehat{q}_t$, $\widehat{\sigma}_{it}$, and

[19] We used different starting values in maximizing expression (8) in order to avoid potentially obtaining estimates corresponding to local-maxima.

$\widehat{s}_{it}^{*}$ into the equations defined in (3) [(5)] and solving directly.

The second stage gives an estimate of preference and precision parameters for each member in each time period - or, more accurately, for each different value of $\widehat{q}_t$. Rather than interpret variation across time in these parameter estimates as variation in the true parameter, we interpret it as deriving from noise in the estimation procedure. Our estimates of σ_i and θ_i - $\widehat{\sigma}_i$ and $\widehat{\theta}_i$ - are therefore their average values over time. Monte Carlo exercises show that $\widehat{\sigma}_{it}$ and $\widehat{\theta}_{it}$ vary over time when recovered from voting datasets generated with constant σ_i and θ_i parameters, and that averaging across time produces estimates consistent with the true underlying parameters.[20]

Ideally we would run our regressions with 27 individual dummy variables and estimate member-specific θ and σ parameters, but we do not have enough observations per member to allow for this approach. Instead, we split the committee using several indicator variables, and explore average differences across groups. In all of our specifications, we take X_i to be a dummy variable that divides MPC voters into two groups A and B for which we recover estimates of the parameters θ^A, σ^A, θ^B, and σ^B.

4.1 Quasi-Bayesian Confidence Intervals

We use a Quasi-Bayesian approach for the computation of confidence intervals. For each of 500 iterations:

1. We take a random draw of α, β, and γ from a multivariate normal distribution centred on the first-stage coefficient point estimates and variance given by the inverse of the negative Hessian of the MLE estimates.

2. We use these new coefficient estimates to calculate a new set of estimated structural parameters $\widehat{\theta}_t^A$, $\widehat{\sigma}_t^A$, $\widehat{\theta}_t^B$, and $\widehat{\sigma}_t^B$.

3. For each relevant meeting,[21] we generated an estimate of the difference between the two groups $\widehat{\theta}_t^{\text{Diff}} = \widehat{\theta}_t^A - \widehat{\theta}_t^B$ and $\widehat{\sigma}_t^{\text{Diff}} = \widehat{\sigma}_t^A - \widehat{\sigma}_t^B$.

4. For each series in $\left\{\widehat{\theta}_t^A, \widehat{\theta}_t^B, \widehat{\theta}_t^{\text{Diff}}, \widehat{\sigma}_t^A, \widehat{\sigma}_t^B, \widehat{\sigma}_t^{\text{Diff}}\right\}$ we derive a time-invariant estimate by taking the mean (and, as a robustness check, the median).

[20] The full discussion of these Monte Carlo exercises is presented in a web appendix for this paper.

[21] We only compute the difference between A and B in the subset of meetings in which both are present, which in most cases is identical to the full set of 137 meetings for which we can construct our proxies for the prior. Also, when we recover θ parameter estimates in the strategic model, we only use the 117 (out of 137) meetings with nine voters for computational simplicity.

This process yields a distribution over structural parameters and their differences, from which we extract the quantiles of interest to construct confidence intervals.[22]

5 The Data

In this section we describe how we construct our voting data and priors for the proxy. In terms of the former, in periods with two unique votes by MPC members (64% of the meetings) we simply say $v_{it} = 1$ if member i is observed to vote for the higher of the two rates.[23] A complication arises in meetings with unanimous votes since we do not directly observe which alternative was under consideration. Below we describe how we use Reuters survey data both to address this issue, and to construct our first proxy of the prior q_t.

5.1 Reuters survey data

In the days leading up to the MPC meeting, Reuters surveys around 30-50 market economists from financial institutions in London and asks them to predict the outcome of MPC voting by writing a probability distribution over possible interest rate choices.[24] Because of the fairly large cross-sectional sample size and the prominence of the participating institutions, the average beliefs in the survey data can be taken as a good measure of conventional wisdom regarding inflationary pressures.

[22] As a robustness check on the procedure outlined in this section, we also compute differences across individuals rather than within meetings. First, we divide each of the 27 into groups A and B. Then, for each member i of group A (B), we compute the mean value of $\widehat{\theta}^A_{i,t}$ and $\widehat{\sigma}^A_{i,t}$ ($\widehat{\theta}^B_{i,t}$ and $\widehat{\sigma}^B_{i,t}$) for the meetings on which i served. This gives us a distribution of individual θ and σ estimates for groups A and B. Finally, we take the difference in means across these two distributions. To obtain confidence intervals under this specification, we sample 500 draws of first stage parameters from the multivariate normal distribution described in step 1., and for each iteration compute the quantities of interest as outlined in the previous sentences. The computation of confidence of intervals then is performed by extracting from this empirical distribution the quantiles corresponding to a given confidence level.

[23] We observe votes for nine unique interest rate changes in our data (-150bps, -100bps, -75bps, -50bps, -40bps, -25bps, no change, +25bps and +50bps). Depending on the set of votes we observe, a particular vote can be mapped into either $v_{it} = 0$ or $v_{it} = 1$. For example, if we observe votes for no change and +25bps, then a vote for +25bps maps into $v_{it} = 1$, while if we observe votes for +25bps and +50bps, it maps into $v_{it} = 0$.

[24] In a web appendix accompanying this paper, available from the authors, we provide the full details of the construction of q^R_t in all periods, including how we treated anomalies in the data. For instance, there are somewhat different formats for different sub-samples within our data for which we follow a slightly different methodology. Also, as Reuters did not have the survey results stored in their database, they were unable to provide the data to us. Instead, we have been able to collate copies of the survey results for most periods in the sample; the two exceptions are February 2000 and March 2000. In addition, we are unable to use the data for periods April 2000, August 2008, and November 2008 (details of why are in the appendix). This leaves 137 out of the 142 months in our sample for which we can construct q^R_t.

In periods with two unique votes by the MPC members we set q_t^R equal to the average probability placed on the higher observed rate over the total average probability placed on both observed rates. In periods with one observed vote, we use the survey to identify the two rates on which the market places the highest average probability and then set $v_{it} = 1$ if and only if i votes for the higher of these two rates.[25] We then set q_t^R equal to the average probability placed on the higher rate over the total average probability placed on both rates. Since the Reuters data provides a full probability mass function over voting alternatives, it is a natural choice for selecting the two most likely outcomes in periods with unanimous voting.

Table 2 illustrates a hypothetical example of the survey and how we use it. The two outcomes with the highest average probability are a rise of 50 basis points and a rise of 25 basis points. So, if we observed a unanimous vote of +25, our proxy measure for the prior would be $q_t^R = \frac{23.75}{23.75+71.25} = 0.25$ and we would set $v_{it} = 0$ for all members. Following this procedure we are in a position to construct the voting data for all periods regardless of whether the vote was unanimous. Figure 4 shows this data for MPC members classified by whether they are internal or external; this figure illustrates that both internal and external members vote high ($v_{it} = 1$) and low ($v_{it} = 0$) across the whole sample.

Table 2: Example of Survey Data

	+50bps	+25bps	0	-25bps	-50bps
UBS	15%	80%	5%		
Goldman Sachs	20%	75%	5%		
JP Morgan	45%	45%	10%		
AIB	15%	85%			
Average	23.75%	71.25%	5%		

Notes: This table shows an example of the survey we use and how we calculate the proxy measure of q_t using these data. First, we average the probability attached to each possible decision across the surveyed banks (average down the columns in this table to get the final row labelled "Average"). We then choose the two most likely decisions based on this average; +50bps and +25bps in this case. Finally, we calculate q_t^R equal to the average probability placed on the higher rate over the total average probability placed on both rates; in the example, $q_t^R = \frac{23.75}{23.75+71.25} = 0.25$.

Of course, q_t^R is not a perfect measure of the unobservable q_t. For example, the data on which respondents form their beliefs is a subset of that available to the MPC since the committee is regularly given advance access to data that will only be released subsequently to the wider public.[26] Also, q_t^R predicts the outcome of MPC voting, not the probability

[25] We confirm that the unanimous decision reached by the MPC is one of the interest rates on which the market puts highest probability, which is itself an important test of the quality of the Reuters survey.

[26] We address this concern in section 6.2.

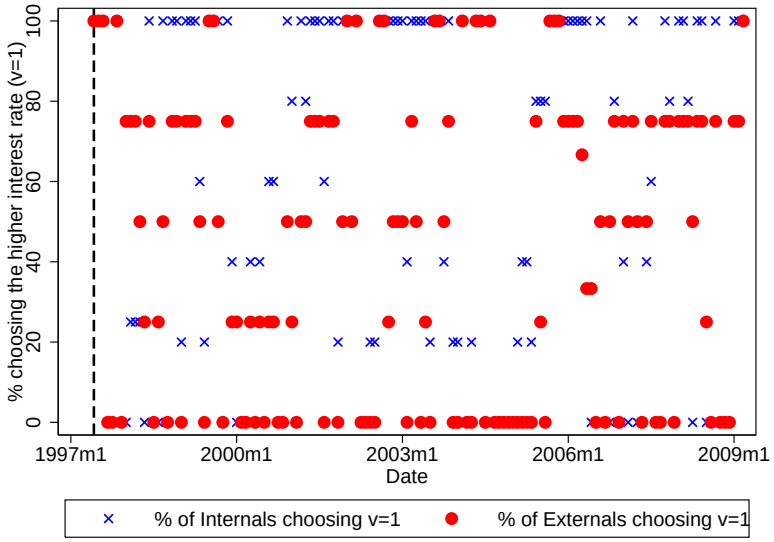


Figure 4: Percentage of Internal and External Members who choose the higher interest rate

Notes: This figure shows the percentage of internal (blue X) and external (red dot) members within a given MPC meeting who vote for the higher interest rate calculated using the empirical data corresponding to the model variable v_{it}.

of the realization of the underlying state variable. It is important to emphasize that we do not take q_t^R to be the actual q_t, but we do argue that it is correlated with it.

5.2 Option price data

The second data source on which we draw comes from the cross-section of prices for short sterling futures options the first day (Wednesday) of the MPC meeting.[27] Short sterling futures contracts are standardized futures contracts which settle on the 3 month London Interbank Offered Rate (LIBOR) on the contract delivery date. Short sterling futures options are a European option (it only settles on the delivery date and not before) on the short sterling futures contract but since the futures contract settles on 3 month LIBOR, the option is effectively an option on 3 month LIBOR. The Bank of England computes the expected value of 3 month LIBOR consistent with a risk neutral trader being willing to hold the option at each observed price; this yields a distribution over risk-neutral traders' beliefs on 3 month LIBOR. The Bank then publishes the $0.05, 0.15, \ldots, 0.95$ percentiles of

[27]Full details about these data, as well as the data itself, are provided by the Bank of England (see Bank of England (2011a), Bank of England (2011b) and Lynch and Panigirtzoglou (2008)); here we simply outline the assumptions underlying these data, why they provide useful information for our needs and the weaknesses of the data for our use.

this CDF. Figure 5 displays the spot 3 month LIBOR rate as well as various percentiles of this CDF. We subtract the actual value of LIBOR on the Wednesday of the MPC meeting (before the decision is made on the Thursday) to express the CDF in terms of traders' beliefs on changes in 3 month LIBOR. We denote this transformed CDF as F, and an individual belief about a change x.

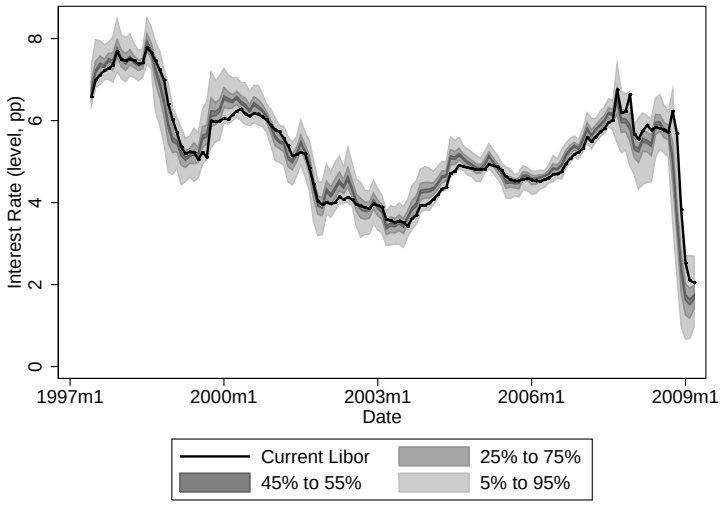


Figure 5: Short-Sterling Implied PDF and 3 Month LIBOR

Notes: This figure shows the spot 3 month LIBOR rate (black line) and the shaded areas represent various percentiles of the risk neutral CDF derived from short sterling (3 month LIBOR) futures contracts.

Since base rate changes are made in discrete 25 point movements while traders' beliefs are continuous, we consider beliefs that lie within 12.5 basis points on either side of the corresponding change to be beliefs associated with that change being more likely. So, for example, our ideal proxy measure for q_t in a period in which no change and a 25 point rise are on the agenda would be

$$\frac{\Pr\left[\,12.5 \leq x \leq 37.5\,\right]}{\Pr\left[\,-12.5 \leq x \leq 37.5\,\right]} = \frac{F(37.5) - F(12.5)}{F(37.5) - F(-12.5)}.$$

Unfortunately we only observe certain percentiles of F. To correct for this, we linearly interpolate between the two percentiles in which a rate change falls. So, for example, suppose that we observe that $F(10) = 0.1$ and $F(20) = 0.3$; then we would construct $F(12.5) = 0.15$. Using this method we are able to build q_t^M for all but four time periods, meaning that we observe the markets data for 138 meetings out of 142 possible meetings in our sample.[28]

[28]The missing periods are February and March 2000, August 2008, and November 2008. These data

Like q_t^R, q_t^M has weaknesses. First, the sterling options that go into the constructed probabilities are based on LIBOR rather than the interest rate that MPC members choose (Bank of England base rate). Second, it is based on beliefs about the 3-month interest rate and as such reflects expected changes over the next three meetings not simply the one immediately following. Third, the beliefs are associated with risk-neutral traders; to the extent that actual traders are risk averse the beliefs backed out from option price data will be biased by the presence of a risk-premium in the observed market data. Finally, as with the Reuters data, q_t^M captures predictions about LIBOR, not underlying inflation states. Despite these problems it is a useful measure because it aggregates the opinions of a large number of agents (all traders in the sterling options market) and, unlike with the Reuters data, these opinions are backed by real money and so potentially less subjective and manipulable. Also, as with q_t^R, we will estimate rather than assume the relationship between q_t and q_t^M.

6 Results

In this section we present the results of the estimation strategy laid out above. We first present results for the split between internal and external members before examining, as a robustness check, differences between other splits.

6.1 Differences between internal and external members

In our baseline specification we take $X_i = 1$ if member i is an internal member and $X_i = 0$ if he or she is an external member (this is the group dummy). To control for members' potentially having different disutilities from errors in states 0 and 1 depending on the agenda, we take $Z_t = 1$ if meeting t had at least one choice on the agenda to hike interest rates - the most common such meetings are those that have a choice of no change and a choice of raising by 25 basis points.

Table 3 contains point estimates and p-values for the first stage parameters in the baseline specification under the "Internal Baseline" heading. The main point of interest is the coefficients on our proxies for the prior. We estimate a large and highly significant relationship between the prior q_t and the Reuter's proxy q_t^R - see coefficient α_1 in the table - while the relationship between the q_t and the proxy derived from market data q_t^M is small and insignificant. This indicates that our Reuter's survey data is a good predictor of members' prior beliefs to which market price data adds little. As indicated by the

are missing due to thin or illiquid short-sterling options markets which mean that no options pdf data is available on the days in the run up to MPC meeting.

positive and significant estimates for β_1 and γ_1, higher values of q_t^R are also associated with a higher probability that members vote high in both states of the world; higher values of q_t^M are only associated with members voting high more often in state 0.

Table 3: First Stage Estimates

	(1) Internal Baseline		**(2) Insider Baseline**		**(3) Internal Alternative 1**		**(4) Internal Alternative 2**	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
α_0 (constant)	-2.35	0.01	-3.41	0.00	-2.50	0.01	-2.43	0.01
α_1 (Reuter's)	5.75	0.00	5.54	0.00	5.23	0.00	4.83	0.00
α_1 (market)	-0.55	0.39	1.85	0.18	0.31	0.44	0.47	0.40
β_0 (constant)	-6.89	0.00	-5.01	0.00	-6.18	0.00	-6.14	0.00
β_1 (Reuter's)	-1.02	0.26	-2.01	0.10	-0.92	0.28	-1.29	0.21
β_2 (market)	2.18	0.02	2.14	0.02	3.38	0.01	3.63	0.00
β_3 (group dummy)	4.77	0.01	2.6	0.09	3.61	0.05	3.21	0.05
β_4 (Reuter's int.)	2.58	0.02	1.9	0.07	2.05	0.07	1.97	0.05
β_5 (market int.)	0.48	0.43	2.53	0.17	0.71	0.40	1.36	0.30
β_{61} (hike)	1.69	0.00	0.83	0.06	1.14	0.07	1.00	0.10
β_{62} (status quo H)					-0.63	0.11	-0.75	0.08
β_{63} (Reuter's x IR)							0.73	0.06
γ_0 (constant)	-1.03	0.09	-0.63	0.20	-2.26	0.01	-2.09	0.01
γ_3 (group dummy)	-4.1	0.00	-1.74	0.07	-3.22	0.00	-3.32	0.00
γ_1 (Reuter's)	2.54	0.00	2.1	0.01	2.82	0.00	2.77	0.00
γ_2 (market)	-0.33	0.40	0.29	0.41	-0.82	0.26	-1.13	0.20
γ_4 (Reuter's int.)	2.74	0.02	6.13	0.00	3.91	0.00	4.39	0.00
γ_5 (market int.)	8.57	0.00	1.44	0.30	5.40	0.02	5.2	0.01
γ_{61} (hike)	1.46	0.00	0.55	0.12	2.68	0.00	2.7	0.00
γ_{62} (status quo H)					1.10	0.00	1.16	0.00
γ_{63} (Reuter's x IR)							-0.21	0.24

Notes: This table shows the results of the first stage estimation of (8). Each pair of columns represents a different specification. The first are the baseline results with members split according to whether they are internal or external. The second instead uses the split of insiders and outsider, but the baseline specification in terms of other regressors. The last two specifications again use the internal-external split, but consider additional covariates in the first stage regression. Significance of coefficient estimates (first column of each pair) is reported using p-values (second column of each pair).

Table 4 and figure 6 present the results of the second stage using the "Internal Baseline" specification. Looking at the estimates of σ, which do not depend on specifying sincere or strategic behavior, it is clear that internal and external members are estimated to form precise (though not perfect) private assessments of economic conditions. For instance, these results imply that a individual internal member has on average a 92% probability of making a correct rate choice; the corresponding number for externals is 86%.[29] These figures represent an average gain of about 20 (for internals) and 14 (for

[29]The probability that an individual banker makes the correct decision is given by the following expression: $q_t \times \left[1 - \Phi\left(\frac{s^*_{it}(\cdot)-1}{\sigma_i}\right)\right] + (1-q_t) \times \Phi\left(\frac{s^*_{it}(\cdot)}{\sigma_i}\right)$. For a given set of structural parameters θ_i and

externals) percentage points in the probability of making the right choice relative to a framework in which private signals play no role.[30] This means that heterogeneity in views is an important driver of heterogeneity in observed votes even after the committee has met and discussed current conditions at length. For even if two members share the same preferences and same precision of signals, they will receive difference signals that may lead them to choose for different rates. Finally, as can be seen from the difference entry, we also find, taking the model literally, that internal members have more expertise in assessing economic conditions than externals.

Table 4: Baseline Estimates of Structural Parameters

	Internal		**External**		**Difference**	
$\boldsymbol{\theta(SIN)}$	0.65		0.34		0.30	
95% Range	*0.52*	*0.76*	*0.25*	*0.44*	*0.18*	*0.4*
$\boldsymbol{\theta(STR)}$	0.54		0.51		0.02	
95% Range	*0.42*	*0.48*	*0.39*	*0.61*	*0.01*	*0.05*
$\boldsymbol{\sigma}$	0.39		0.54		-0.15	
95% Range	*0.35*	*0.48*	*0.45*	*0.7*	*-0.29*	*-0.04*

Notes: This table shows the structural estimates for internal (column 1) and external (column 2) members, as well as the difference between them (column 3). The rows report the estimates for preferences under sincere voting ($\theta(SIN)$) and strategic voting $\theta(STR)$, as well as the precision parameter (σ). The Quasi-Bayesian confidence ranges are reported below each point estimate.

The baseline results for the preference/bias term requires us to specify whether the members vote sincerely or strategically. In the sincere case, we estimate a preference difference that is large in magnitude and significant, with external members systematically more dovish than internals. This finding is in line with the existing literature. With strategic voting, however, external and internal members are estimated to have nearly identical preferences; although the difference remains significant, the point estimates are very close together - the difference falls from 0.3 under sincere voting to 0.02 if voting is strategic.

These results suggest that members of the committee differ along a dimension that corresponds precisely to a variable that the government (or, more generally, the committee designer) controls directly - whether to appoint external members. Our estimates show that this institutional design feature has measurable consequences that affect decision-making (we will quantify the size of the effects below). Unfortunately we cannot

σ_i, we computed this probability for values of q_t ranging from 0.01 to 0.99 (increasing by steps of 0.01). The quantity we are reporting is a simple average of the probability of making the correct decision over the 99 values of q_t.

[30] In a model where private signals play no role, a banker chooses the high rate if and only if $\theta_i \geq 1 - q_t$ and chooses the lower rate otherwise. So when $q_t < 1 - \theta_i$ the probability of a correct decision is $1 - q_t$ and otherwise is q_t.

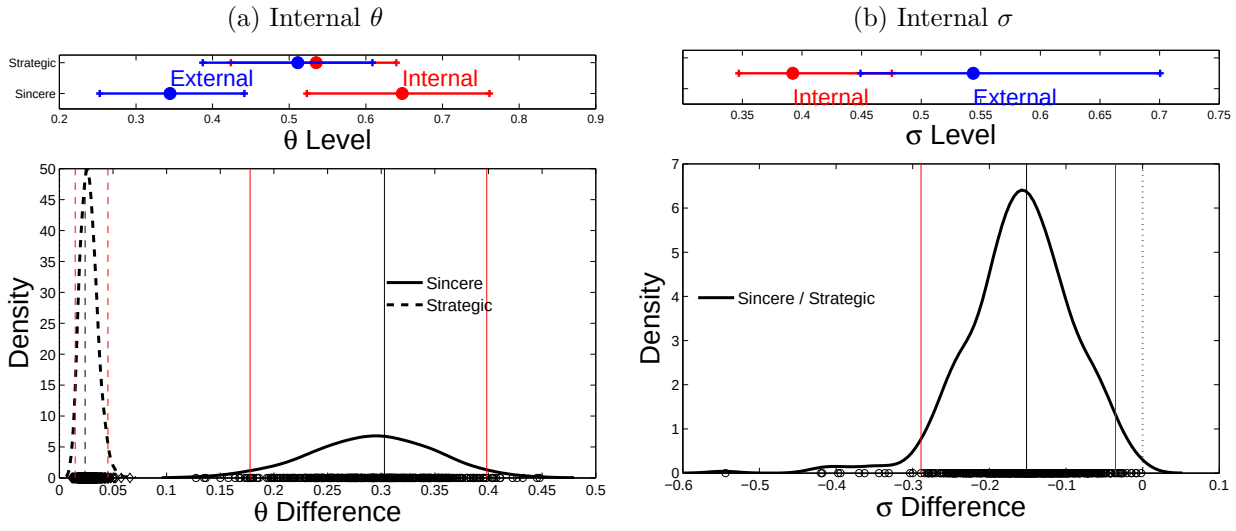


Figure 6: Internal vs External - Baseline Estimates

Notes: The top panel shows the point estimates (represented by a dot) and Quasi-Bayesian 95% confidence range for the estimates of the level of θ and σ by Internal/External and, in the case of the preference parameter, by whether members are assumed to vote sincerely or strategically. The bottom panel shows the estimated distribution of the difference in the parameters for internal and external members. The kernel density is estimated using the diffusion method of Botev, Grotowski, and Kroese (2010) and the vertical lines mark zero, the point estimate of the difference and the 95% confidence bounds. The circles along the lower x-axis represent the estimated differences in each of the 500 simulations.

determine whether internal and external members behave differently because they have fundamentally different characteristics or because there is something about serving in an internal or external capacity that changes preferences and belief formation. It could be that internal members become more inflation-averse, or develop greater expertise, via their experience in central banks, and that they take this with them onto the MPC. Alternatively, it could be driven by the nature of their position; internals might have more expertise because of more direct control of the work streams (as the internal members are also senior management of the Bank), while external members, who typically serve as part-time monetary policymakers, are hindered because they have less time to spend getting on top of the large amounts of analysis that is provided.

One way to shed some light on the relevance of these channels is to use the fact that some newly-appointed internals have come from careers in central banking (especially within the Bank of England), while others have come from other backgrounds, so that their tenure on the MPC coincides with their first central bank job. Analogously, one external member is a former Bank of England central banker. We redefine our internal group to instead be a group of central bank "insiders"; that is, we set $X_i = 1$ if member

i had previously worked in the Bank of England or another central bank prior to taking their position on the MPC. The insider group pools insider-externals (former central bankers serving as externals) and insider-internals (career central bankers); the outsider group consists entirely of people who are coming to the MPC from something other than central banking. As can be seen in table 1, this converts one external members (Charles Goodhart) into an insider and about half the internal members (such as Charlie Bean) to outsiders.

The second column of table 3 presents the first stage estimates for this specification and figure 7 shows the distribution of the difference in parameters between insider and outsider members recovered from the second stage (internal and external member differences are shown for ease of comparison). Given that the groups are closely over-lapping, it is no surprise that comparisons between insiders and outsiders in terms of structural parameters are similar to those between internal and external members. Of more interest is the difference-in-differences. Insiders seem to be even more hawkish relative to their outsider colleagues than internals are relative to externals. This can only be explained by the fact that insider-externals are more hawkish than outsider-internals, which suggests that it is the experience of central banking rather than the institutional responsibilities of being an internal that lead to hawkishness.[31] On the expertise side, the two alternative ways of splitting the data lead to almost exactly the same difference; this means that outsider-internals have as much expertise as insider-externals. If there is increased expertise from prior experience of central banking, this is offset by being an external member. This might be because it is a part-time position, or because these members have less control over the development of work and less information about other areas of the Bank's business such as financial stability.

6.2 Robustness of the baseline results

In order to test the robustness of the baseline results, we also examine alternative meeting controls in the first stage regression. Here we discuss two alternative specifications though we have tried many others with no change in the results; to save on space, we simply discuss the results and present the figures in a web appendix available from the authors. In the first we introduce a second agenda indicator variable to capture whether the high interest rate also corresponds to the status quo decision of no change in rates. While this second agenda variable is indeed a significant predictor of individual votes along with the first (see estimates of β_{61}, β_{62}, γ_{61}, and γ_{62} in table 3), the values of the structural

[31] It might be that long periods of work in central banks make economists more hawkish, or that those who are inflation-averse self-select to careers in central banking (or thrive in them to the point of becoming expert enough to be selected to the MPC).

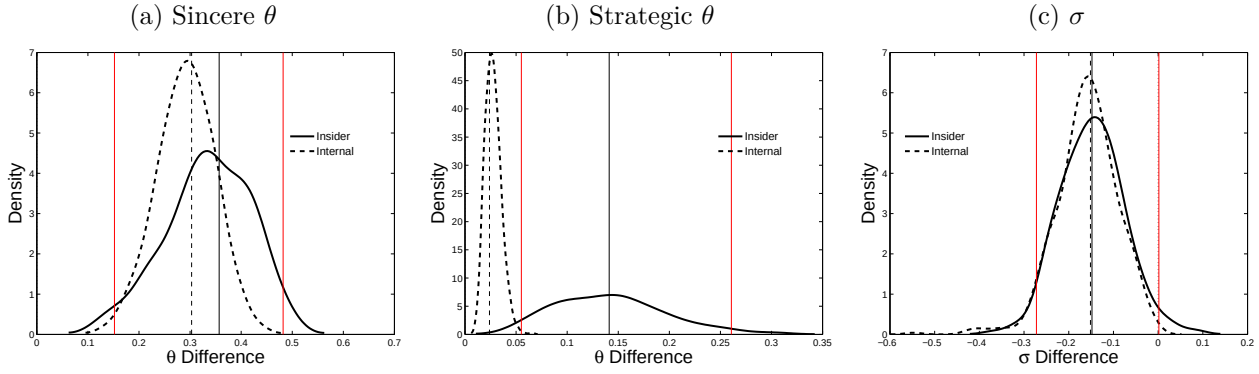


Figure 7: Internal vs External or Insider vs Outsider?

Notes: These figures show, for each structural parameter, the estimated distribution of the difference in the parameters for insiders and outsiders (solid distribution line); for reference, the estimated distribution for internal and external members is reported as the dashed line. The kernel density is estimated as in figure 6.

parameters and relevant differences are unchanged.

In the second alternative we attempt to address a concern about our q^R proxy, the one with the most predictive power in the first stage regressions. In every meeting, members have access to information that is also available to the entire market, as well as proprietary information from within the Bank that market participants do not have. The former information is reflected in our proxies, while the latter is not. If the Bank's information is the main driver of voters' beliefs, our estimation approach might be problematic. In meetings that coincide with the preparation of a quarterly Inflation Report (IR), voters have a particularly large amount of information available before voting (updated staff forecasts of macro variables) that the market does not see until after the meeting. So, if Bank information is the main source of information from which voters derive their prior beliefs, one would expect our proxies to be less correlated with voting high in IR months. To test this idea, we introduce an interaction between q^R and an IR month dummy into the κ_{i0} and κ_{i1} terms. In fact we find that the coefficient on the interaction term is estimated to be *positive* and significant in the κ_{i0} equation - meaning members that economists' predictions on the MPC decision are even more correlated with votes in the low state in IR months - while the equivalent coefficient in the κ_{i1} equation is estimated negative but insignificant. Regardless, the values of the structural differences are unchanged.

To conclude our robustness exercises, we take medians of the structural parameter distributions (rather than means as described in section 4.1), and also take means across members (rather than across time). These are done using the first stage estimates from

the "Internal Baseline" specification. The qualitative features of the second stage results are identical.

6.3 Differences between other groups

We also examine various other splits of the MPC rather than internal and external; these include whether the member worked in the private sector prior to joining the committee, or whether the member was an academic prior to their appointment. In no case do we find significant preference (both sincere and strategic) or expertise differences, although in all cases members' signals are estimated to be drawn from precise distributions.

We then examine whether members with PhDs, or members who were relatively younger[32] when they joined the MPC behave differently. As before, all splits are found to have precise private signals. Across the different groups we examine, the probability of a representative individual making the right rate choice and the gain relative to a model where private information plays no role is similar to that reported in the results section for our main specification. However, there are no statistically significant differences between the different splits in terms of preference or expertise parameters.

These results highlight three interesting messages. First, the main driver of voting differences between most splits of the MPC is differences in beliefs on economic conditions, not differences in preferences or biases. This is notable given that preference differences (probably) receive more attention in the monetary literature. Second, for the splits considered in this subsection, members are ex-ante identical in terms of both preferences and expertise. This means, for example, that replacing older members with younger members or vice versa might have little effect on decision-making. Third, as already discussed, the one split on which members *do* differ in terms of expertise and preferences corresponds to a committee design feature - the appointment, or not, of external members. We now quantify the impact of adding external members to the MPC in terms of the impact on the likelihood the MPC makes the correct decision.

7 Counterfactual Exercises

Our finding that members have imperfect private beliefs on economic conditions suggests that the MPC adds value compared to individual decision making by aggregating dispersed knowledge. The first goal of this section is to measure the extent to which this is the case given our estimates of the underlying structural parameters. Second, our finding that internals and externals have different preferences in the sincere voting

[32]The median age of new MPC members is 49.

specification allows us to explore whether mixing them on the same committee improves decision making despite externals having less expertise.

Our measure of the quality of decision making is the probability that the interest rate matches the state. This quantity is given by the mixture of the summation over the probability of obtaining different decisive coalitions needed for the adoption of a low rate when the state is $\omega_t = 0$ and high rate when the state is $\omega_t = 1$. Thus, for example, in a committee with $n = 5$ internal members and $x = 4$ external members, and where decisions are made by simple majority rule, the probability that the interest rate matches the state is given by the following expression:

$$\begin{aligned} q_t \sum_{m=5}^{9} \sum_{i=m-n}^{x} \left\{ \binom{n}{m-i} \binom{x}{i} (1-\Phi_I(\cdot))^{m-i} \Phi_I(\cdot)^{n-m+i} (1-\Phi_E(\cdot))^{i} \Phi_E(\cdot)^{x-i} \right\} + \\ (1-q_t) \sum_{m=5}^{9} \sum_{i=m-n}^{x} \left\{ \binom{n}{m-i} \binom{x}{i} (1-\Phi_I(\cdot))^{n-m+i} \Phi_I(\cdot)^{m-i} (1-\Phi_E(\cdot))^{x-i} \Phi_E(\cdot)^{i} \right\} \end{aligned} \tag{13}$$

where $\Phi_I(\cdot)$ and $\Phi_E(\cdot)$ denote the probability that an internal and an external member vote for the low rate respectively.[33] This corresponds to the utility function of a committee designer who weighs voting $r_t \neq \omega_t$ equally for $\omega_t \in \{0, 1\}$, which appears to correspond to the Bank's explicitly stated preferences. When we compare different groups of members in terms of this criterion, an important caveat is in order. We cannot measure the effect that a member's presence had on other members' voting behavior. If peer effects are important, the counterfactual simulations we run can be thought of as removing the voting rights from various subsets of members but allowing them to participate in other committee activities, as is the case on advisory committees.

To begin, we calculate the performance of a single internal policymaker endowed with the preferences and expertise reported in table 4. Figure 8 presents the estimates for the sincere voting parameters ($\theta = 0.6$ and $\sigma = 0.39$) with the dashed blue line and for the strategic parameters ($\theta = 0.54$ and $\sigma = 0.39$) with the solid red line.[34] The lines marked with + symbols correspond to the 95% quasi-Bayesian confidence intervals around the probability of getting the decision correct using the sincere voting parameters. The probability that the decision matches the state is different for each value of the prior, and the figure presents estimates disaggregated by the prior. The single decision maker

[33] To compute the individual voting probabilities on which this measure is based, we use the structural parameter estimates σ_i and θ_i to back out the equilibrium thresholds s^*_{it}(SIN) (or, alternatively, s^*_{it}(STR)), according to equations (3) [5] in the text, and compute the quantity of interest for different values of q_t.

[34] Here the single decision maker is assumed to use the sincere voting rule under both parameter estimates since there are no other voters determining the outcome.

has a high probability of getting the decision correct; even when the state of the economy is most uncertain ($q = 0.5$), she gets the decision right about 90% of the time (though the range of estimates is 84% to 93%). The bottom panel shows the estimated distribution of the prior from our data; about 40% of the meetings in our sample are in the range 0.3-0.7 where there is rather large ex ante uncertainty.

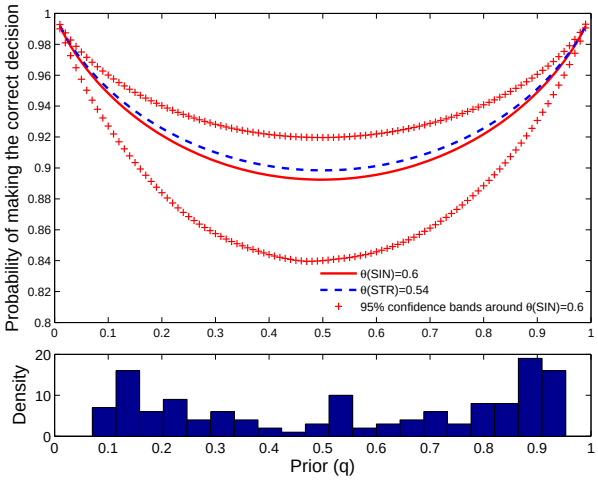


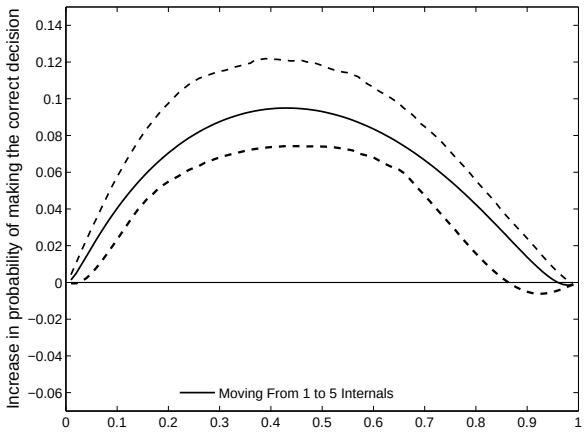
Figure 8: Probability that a single policymaker selects the right policy

Notes: This figure shows the probability that a single policymaker with $\sigma = 0.39$ and $\theta(SIN) = 0.6$ (blue, dashed line) or $\theta(STR) = 0.54$ (red, solid line) would choose a correct interest rate for different values of the prior q_t. The + symbols denote the 95% confidence bounds around the $\theta(SIN) = 0.6$ line; the confidence bounds for the $\theta(STR) = 0.54$ are almost identical and so are omitted.

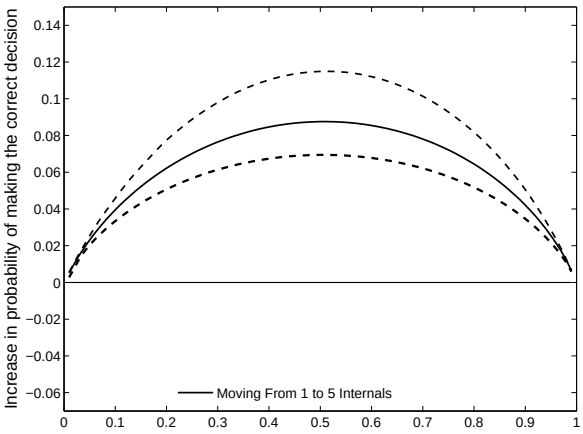
We then repeat the exercise assuming there are five internal members on the MPC. The solid curve in figure 9a (9b) represents the difference in the probability that this committee gets the decision right relative to the single member case under sincere (strategic) voting. In both cases, there is little gain from adding more members if the prior is very high or very low; these are periods when the right decision is relatively easy to predict ex ante. Nevertheless, apart from the most extreme values of the prior, there is a statistically significant improvement in decision quality. The improvement is more substantial for intermediate values of the prior: when the prior is 0.5, the gain from additional members is about nine percentage points (the 95% confidence interval ranges from seven to twelve percentage points).

Condorcet's Jury Theorem (Condorcet (1785)) suggests that further expansions in the size of the committee should lead to ever higher gains, but as a practical matter larger committees also entail additional coordination and infrastructure costs. Therefore an important question is at what rate do the gains to extra members decline. The next committee we construct is one with nine internal members; figures 9c and 9d show the

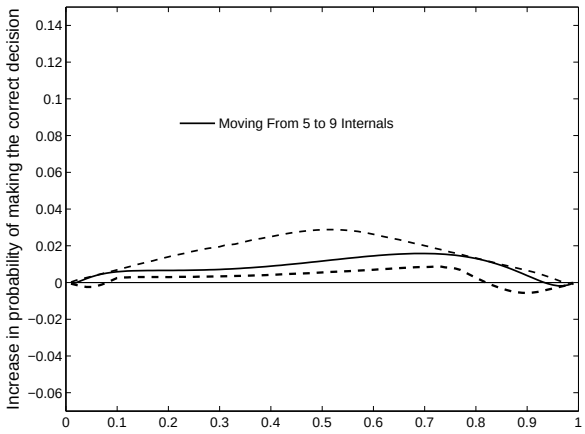
(a) Sincere: 1 to 5 Internals



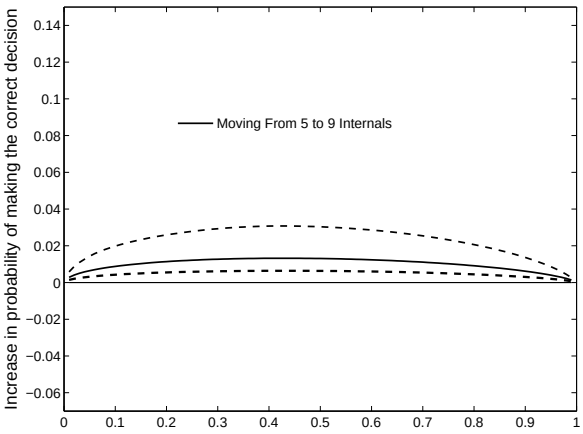
(b) Strategic: 1 to 5 Internals



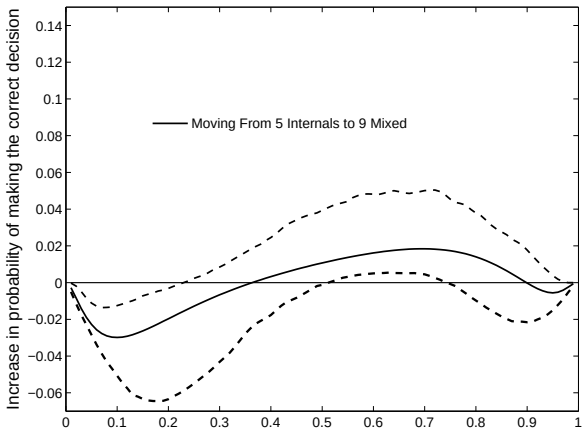
(c) Sincere: 5 to 9 Internals



(d) Strategic: 5 to 9 Internals



(e) Sincere: 5 Internals to 9 Member Mixed



(f) Strategic: 5 Internals to 9 Member Mixed

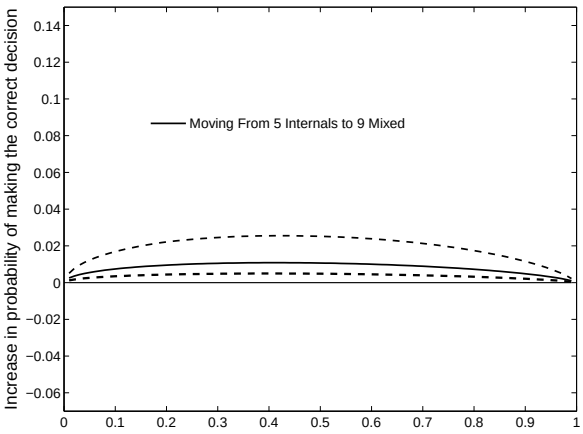


Figure 9: The Gains From Changing the MPC Composition

Notes: These figures show the gains, for different values of the prior (q_t), of changing the committee structure. The gains are calculated using the estimated structural parameters presented in table 4 and are measured in units such that 0.01 represents a 1 basis point increase in the probability that the correct decision is achieved. The left column represent the situation of sincere voting while the left assumes strategic voting. The rows capture the gains from adding more or different members; we examine moving from a single internal decision maker to a committee of five internals (top row), five internals to nine internals (middle row), and five internals to five internals and four externals (nine person mixed committee).

added gain from moving to this committee from the one with five internal members in the sincere and strategic cases, respectively. While the gains are again statistically significant, they are quite small in magnitude, on the order of 1 percentage point. The gains from information aggregation are thus much less marked with this further expansion, and further expansions beyond nine produce even more marginal gains. While we do not wish to propose a theory of "optimal" committee size, given that increasing the number of members is known to make deliberation more difficult and increase the costs associated with member free-riding in terms of information acquisition discussed in Sibert (2006),[35] these results suggest that a smaller committee may be better. In particular, our counterfactual results suggest that a group of five members has a very high probability of getting the decision right, and over the 142 meetings in our sample would be predicted to make just a few errors; this is in with Napier and Gershenfeld (1999) who argue that a group size of five is optimal (or close to optimal) in most situations.

Our last question is whether there are gains to adding an additional four external members to the five-member internal committee, in particular when voting is sincere so that there are meaningful preference differences.[36] Figures 9e and 9f present the results in both cases. As expected, when voting is strategic, there is again simply the gain from aggregating over additional noisy individual votes. Under sincere voting the results are more subtle. For low values of the prior, the addition of external members makes decision-making worse because external members are more likely to vote with their (low) bias, while the situation is reversed for high values of the prior. In this sense, preference diversity can both improve and impede performance from meeting to meeting. On average, though, the gains cancel the losses, so that external members do not add value in expected terms. Rather than assert that external members literally add no value, we believe our estimates show that the justification for their inclusion needs more careful thinking.

8 Conclusion

While theoretical models of decision making claim monetary policymakers can differ in terms of preferences and their expertise in assessing economic conditions, earlier empirical work focused on differences in hawkishness (preferences). Using an adapted version of the estimator of Iaryczower and Shum (2012), we are able to identify the role that these

[35]Furnham (1997) argues that interaction becomes more difficult when the committee size reaches twelve.

[36]This is related to the work of Karotkin and Paroush (2003) who discuss theoretically the necessary conditions for adding members of different skills to a committee that ensure the new committee has a higher probability of a correct decision.

separate factors play in the decisions of monetary policymakers. This allows us to answer a number of important committee design questions and, taken together, our results give an empirically novel view of monetary policymaking by committee.

Across all splits of the committee, diverging assessments of the economy appear to be an important source of voting heterogeneity; this points to the committee structure adding value through pooling private knowledge. Given that we find that differences in economic assessment persist after the deliberation of the committee, it appears that voting is an important mechanism to fully incorporate individual members' views in the final decision. This suggests that a voting committee has advantages over a single policymaker with an advisory committee.

Focusing on the composition question of whether to include externals, two new insights emerge. First, the hawk-dove difference between internals and externals that the previous literature has estimated may simply be a result of strategic voting rather than innate preference or bias differences. Second, fundamental differences *do* appear to exist in terms of expertise at assessing economic conditions.

We also show that adding more members, by increasing the number of signals to average over, can improve the committee decision. However, the returns to more and more members seems to decrease. Moreover, additional members who form more precise assessments of the economic situation are to be preferred to members with less accurate views, though there is some benefit to off-setting extreme preferences in some cases.

Ours is not the final word on these issues. Further work remains to be done on whether members vote strategically or not. Also, a note of caution is that additional members or a more diverse committee structure may endogenously affect the amount of common information members have each period, and, in a more subjective sense, one might imagine that changing the group composition might affect each member's "thinking" in ways that are hard to model and quantify. One point is worth mentioning on this dimension. Adding more diverse members, even where their views are perhaps incorrect, could potentially increase the amount of discussion and deliberation and, therefore, help to draw out the information of individual policymakers. More work needs to be done to explore how deliberation works in committees and what factors might improve, or worsen, it. We leave this to future research. Nonetheless, to our knowledge the paper is the first to decompose voting heterogeneity on a monetary policy committee into distinct preference and signal components, and as such provides potentially valuable facts for moving the debate on monetary policymaking by committee forward.

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A Threshold voting rule in a New-Keynesian model

Here we show that a basic version of Clarida, Galí, and Gertler's (1999) New-Keynesian model of monetary policy leads to a threshold interest rate rule similar to that derived in the simple model in section 3. Following Galí (2008), the economy is characterized by a dynamic IS curve and a New Keynesian Phillips Curve (NKPC):

$$x_t = \mathbb{E}_t[\, x_{t+1}\,] - \phi(i_t - \mathbb{E}_t[\,\pi_{t+1}\,] - r_t^e) \tag{A.1}$$

$$\pi_t = \beta \mathbb{E}_t[\,\pi_{t+1}\,] + \kappa x_t + u_t \tag{A.2}$$

where $x_t \equiv y_t - y_t^e$ is the welfare-relevant output gap, y_t is the log of the stochastic component of output, y_t^e is (log) efficient level of output, π_t as the deviation of period t inflation from its long-run level and i_t is the nominal interest rate.

For simplicity we allow only for a shock to the NKPC, u_t; this shock is generally called a cost-push shock in the literature.[37] We assume this shock follows an AR(1) process:

$$u_t = \rho_u u_{t-1} + \epsilon_t^s \text{ where } \epsilon_t^s \sim N(0, \sigma_{\epsilon^s}^2) \tag{A.3}$$

The social loss to the representative household is, to a second-order approximation, proportional to a function that is quadratic in inflation and output. As the policymaker has discretion to choose the interest rate at time t, based on information available at the end of time $t-1$, so as to minimize the discounted future losses, there is no way that they can credibly commit to any pre-specified path of future policy; this reduces the problem to a series of static problems in which the central bank takes private sector expectations as given. The discretionary problem to determine optimal monetary policy is:

$$\begin{aligned} \underset{i_t}{\text{minimize}} \quad & \frac{\pi_t^2}{2} + \lambda \frac{y_t^2}{2} + \mathbb{E}_t\left[\sum_{\tau=1}^{\infty} \frac{\pi_{t+\tau}^2}{2} + \lambda \frac{y_{t+\tau}^2}{2} \right] \\ \text{subject to} \quad & \pi_t = \kappa x_t + \beta \mathbb{E}_t[\,\pi_{t+1}\,] + u_t \end{aligned}$$

where λ is $\frac{\kappa}{\varepsilon}$, and ε is the substitutability between goods in the consumption aggregator.[38]

The optimal interest rate is:

$$i_t = r_t^e + \frac{1}{\phi}\left(\frac{1}{\kappa^2 + \lambda(1 - \beta\rho_u)} \right)(\kappa + \lambda\phi)\, u_t \tag{A.4}$$

Forcing the MPC member must choose between two interest rates $\bar{i}_t > \underline{i}_t$ (as we do in

[37] We can also include a shock to the IS curve, g_t, which will enter the optimal interest rate linearly.

[38] We can also allow for an interest rate smoothing term.

our main model and show is the case for most MPC meetings), the vote is given by:

$$v_{it} = \begin{cases} \bar{i}_t & \text{if } i_{jt} \geq \bar{i}_t - 12.5\text{bps} \\ \underline{i}_t & \text{otherwise} \end{cases} \tag{A.5}$$

To move to a situation of imperfect information of economic conditions, we use the the certainty equivalent version of the decision rule.[39] Therefore, under uncertainty about the state of the economy, where Ω_t is the information set at time t, the decision rule is as that the policymaker will vote for the higher interest rate ($\bar{i}_t$) if and only if:

$$\mathbb{E}[\, u_t \mid \Omega_t \,] \geq \phi \left(\frac{\kappa^2 + \lambda(1 - \beta\rho_u)}{(\kappa + \lambda\phi)} \right) \left[\bar{i}_t - r^e_{jt} - 12.5\text{bps} \right] \tag{A.6}$$

This is analogous to the decision rule in our main model; the member votes high when their belief about the economic shock exceeds their member-specific cut-off which depends on the structural parameters of the economy.

[39] As Clarida, Galí, and Gertler (1999) Result 9 states: "With imperfect information, stemming either from data problems or lags in the effect of policy, the optimal policy rules are the certainty equivalent versions of the perfect information case. Policy rules must be expressed in terms of the forecasts of target variables as opposed to the ex post behavior."