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Central Banks' Voting Records and Future Policy

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Abstract:

We assess whether the voting records of central bank boards are informative about future monetary policy. First, we specify a theoretical model of central bank board decision-making and simulate the voting outcomes. Three different versions of model are estimated with simulated data: 1) democratic, 2) consensual and 3) opportunistic. These versions differ in the degree of informational influence between the chairman and other board members influence prior to the voting. The model shows that the voting pattern is informative about future monetary policy provided that the signals about the optimal policy rate are noisy and that there is sufficient independence in voting across the board members, which is in line with the democratic version. Next, the model predictions are tested on real data on five inflation targeting countries (the Czech Republic, Hungary, Poland, Sweden and the United Kingdom). Subject to various sensitivity tests, it is found that the democratic version of the model corresponds best to the real data and that in all countries the voting records are informative about future monetary policy, making a case for publishing the records.

Keywords: monetary policy, voting record, transparency, collective decision-making.

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1 Introduction

Monetary policy transparency has increased dramatically over the last two decades (Geraats, 2009; Posen, 2003). Nowadays, central banks typically communicate effectively with the public and explain their policies in great detail. Every monetary policy decision is accompanied by minutes or press releases that outline the arguments that central bankers expressed during the monetary policy meeting. The most transparent central banks where bank boards[1] decide by majority vote also release attributed voting records, typically together with the minutes.[2] In this paper we aim to examine whether voting records are informative about future policy. From the voting records, we are able to calculate an indicator called $skew$, defined as the difference between the average policy rate voted for by the individual board members and the policy rate that is the outcome of the majority vote. Our theoretical model examines under which conditions it is more likely that there will be a rate hike (reduction) in the future when there is a minority vote for higher (lower) rates than the decided-on rate. In addition, an extended empirical model tests whether the skew conveys new information in addition to all the other information already incorporated into financial market expectations prior to the monetary policy meeting.

While some previous research has extensively examined the information content of voting records in the case of the UK (Gerlach-Kristen, 2004), many other central banks' voting records have not been examined empirically yet. Similarly, there is also a lack of theoretical studies examining whether voting results are useful for understanding future monetary policy.

On the theoretical side, we fully specify a model of the central bank committee decision-making process, simulate the decisions taken by the model committee and assess the informative power of the voting pattern for future monetary policy. The basic version of our model is similar to the model of Riboni and Ruge-Murcia (2008a) in acknowledging the endogenous nature of the status-quo decision in the central bank decision-making process. Besides the endogenous status quo, our model also incorporates uncertainty and time dependence in optimal monetary policy as well as the private information of individual committee members (Gerlach-Kristen, 2008). We use several alternative models of monetary policy committee decision-making that differ (among other things) in the degree of informational influence among its members and that are related to the models already found in the relevant literature (Gerlach-Kristen, 2008; Riboni and Ruge-Murcia, 2010; Weber, 2008).

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[1] The decision-making bodies in central banks are typically called either monetary policy committees or bank boards. We use the two terms interchangeably in our paper.

[2] Fry et al. (2000) reports that approximately 90% of central banks around the world make decisions in committees.

What distinguishes our model from the already existing ones is combination of endogeneity of the status-quo policy with time varying heterogeneity of preferences of the monetary policy committee members. The first feature allows us to talk about the $skew$ variable in the first place as the committee decisions are made by vote between two alternatives. Second feature then ensures that typical outcome of such vote will not be unanimous or in other words that the $skew$ variable will attain non-zero values.

Our theoretical model shows that the voting record contains important information about future monetary policy provided that the signals about the optimal policy rate are noisy and a sufficient degree of information independence exists among the committee members. Even if both of those conditions hold, the informative power of the voting record can be overridden by high volatility of the economic environment or by enough noise in the committee members' information, with a larger committee size counteracting both of those effects.

In the empirical part, this paper examines the informative power of voting results in five inflation-targeting countries – the Czech Republic, Hungary, Poland, Sweden and the UK, where monetary policy is decided by a majority vote of at least formally independent committee or board members. In consequence, our research gives a greater international perspective than previously published case studies and is able to draw conclusions that are not country-specific.

Our empirical results confirm the theoretical conclusions. The voting record is informative of future monetary policy changes in all the sample countries. It adds news to the information set used in financial market expectations prior to the voting record announcement. This result is robust to various sensitivity checks such as to different sample periods or to the timing and style of the voting record announcement. Our dataset provides two 'natural experiment' setups, where we can quantify the effect of publicly unavailable voting results (for the case of Poland) and the effect of publicly unavailable names of voting members (for the Czech case). The voting record is informative about future policy in these two setups as well. This implies that that releasing the names themselves is less important for transparency than releasing the voting outcome itself, but releasing voting record in a timely fashion is beneficial for greater monetary policy predictability.

The paper is organized as follows. Section 2 contains the related literature. Section 3 introduces a theoretical model of central bank board decision-making. Section 4 presents the institutional background of monetary policy decision-making in our sample countries. The empirical methodology is discussed in section 5. Section 6 gives the results. Section 7 offers concluding remarks. Appendices containing details of the theoretical model (Appendix A1), details of the institutional background of monetary policy decision-making (Appendix A2) and a data description (Appendix A3) follow.

2 Related Literature

On the most general level the question of whether the voting records of central bank boards and monetary policy committees (MPCs) reveal information about future changes in monetary policy is related to the literature on central bank communication and central bank transparency, surveyed by Blinder et al. (2008) and Geraats (2002, 2009) respectively. The general conclusion of both strands of literature is that the way central banks communicate to the public and their degree of transparency matters for monetary policy. Most of the theoretical and empirical studies also indicate the benefits of more open and more transparent central bank behaviour. However, not all the studies reach unequivocal conclusions. For example, the model in Morris and Shin (2002) leaves open the possibility that more information provided by a central bank is welfare reducing, while Meade and Stasavage (2008) show that the Federal Reserve's decision to release full transcripts of Federal Open Market Committee (FOMC) meetings decreased the incentives of its participants to voice dissenting opinions. Swank et al. (2008) analyze the reputational issues in expert committees and disincentive to dissent. Winkler (2000) draws similar conclusions and puts forward a conceptual framework to distinguish different aspects of transparency.

From the theoretical side, the question of whether the voting records of bank board members are informative about future monetary policy is virtually untouched. One of the reasons is the difficulty of modelling committee decision-making with members who hold possibly different beliefs and objectives in the uncertain monetary environment. Another difficulty is the dynamic nature of central bank decision-making, as a policy rate adopted today becomes the status-quo policy for the next meeting.

Furthermore, it is not entirely clear what is the appropriate assumption to be made about the way bank boards reach decisions. While in reality the chairman usually holds most of the proposal power, empirical evidence in Riboni and Ruge-Murcia (2010) suggests that the real-world features are better captured by what they call a consensus model in which the adopted policy is equal to the most preferred policy of the next-to-median member.

Riboni and Ruge-Murcia (2008a) try to model central bank decision-making taking into account its dynamic nature. They show that even in periods in which policy-makers' preferences do not differ, policy-makers may fail to reach a consensus and change the policy from the status quo, due to the possibility of future disagreement. However, it is not clear whether their model can support the information content of voting behaviour, despite the fact that it produces persistence and strong autocorrelation of policy rates.

Disregarding the dynamic nature of central bank policy-making, Gerlach-Kristen (2008) investigates the role of the MPC chairman in committee decision-making in a model that generates real-world-like dissenting frequencies. The possibility of dissent arising is due to the fact that individual policy-makers receive private information about the unobserved optimal interest rate. Differences in private information sets among the MPC members then give rise to different votes by the time the policy decision is made. In a similar vein, Farvaque et al. (2009) examines how different decision rules in monetary policy committees affect the volatility of interest rates.

The model in Weber (2010) then supports the basic intuition that the publication of voting records reveals the bank board's opinion heterogeneity and thus provides more information to the financial markets than the publication of the final decision only. Better informed financial markets are then able to better predict the central bank's future behaviour, providing a rationale for the publication of voting records.

Similarly, the empirical literature investigating the informative power of voting records is rather scant. This is mainly due to the fact that the practice of publishing the voting records of board members has been adopted relatively recently and several central banks make their voting records public only in the transcripts of their monetary policy meetings, published with a several-year lag.

For the MPC of the Bank of England, Gerlach-Kristen (2004) shows that for the period 1997–2002 the difference between the average voted-for and actually implemented policy rate is informative about changes in the policy rate in the future, a conclusion robust to the inclusion of different measures of market expectations. In a similar spirit and using the same measure of dissent in the MPC, Fujiki (2005) reaches a similar conclusion for the Bank of Japan, and Andersson, Dillen and Sellin (2006) do likewise for the Riksbank.

The empirical literature trying to estimate the reaction functions of individual bank board members using information about their voting behaviour is closely related. In this case, information about the individual members' votes is used to predict their preferred policy rate given the state of the economy and hence to better forecast future monetary policy decisions. For the Federal Reserve, Chappell, McGregor and Vermilyea (2005) estimate the individual reaction functions of FOMC members. For the Bank of England MPC, Bhattacharjee and Holly (2006, 2010), Brooks, Harris and Spencer (2008), Besley, Meads and Surico (2008) and Riboni and Ruge-Murcia (2008b) conduct a similar exercise.

The general conclusion emerging from these studies is that there is often significant evidence of heterogeneity among bank board members. In combination with the assumption that monetary policy is better conducted in an environment with no information asymmetry between the central bank and the markets, the publication of voting records revealing the heterogeneity of the bank board members is desirable.

3 A Model of Central Bank Board Decision-Making

In this section we introduce a theoretical model of the central bank board decision-making process and investigate under which conditions the voting pattern can be informative about future policy. The general objective is to fully specify the model, simulate the path of the decisions, recording the preferences of the individual committee members, and use those in a regression similar to our benchmark study Gerlach-Kristen (2004), which is also the starting point of our empirical analysis. In this regression, we test whether the skew indicator is informative about future interest rate changes.

3.1 Model setup

The model is set in an infinite horizon with discrete periods denoted by $t = 0, 1, \ldots$, in each of which the monetary policy committee or board takes a decision about the policy instrument with a policy adopted at t denoted by p_t. Although we call p_t the interest rate, it can stand for any standard monetary policy instrument.

There are N (N being an even number) 'normal' board members P (each referred to as 'he') and one proposer or chairman C (referred to as 'she'). Therefore, the committee size is odd. In each period t, decision-making is done by a standard majority rule with two alternatives pitched against each other. The first alternative is the current status-quo policy x_t, which is equal to the policy adopted at $t-1$, i.e. $x_t = p_{t-1}$. The second alternative is the policy proposed by the chairman, which we denote by y_t.[3] The alternative that gains a majority of the votes then becomes the new policy p_t. For mathematical convenience we assume that a C who cannot propose anything better than x_t indeed proposes x_t (instead of proposing a policy that would be rejected for certain).

The committee tries to set policy p_t so as to match the uncertain 'state of the world' denoted by i_t^*, where for inflation-targeting central banks i_t^* can be interpreted as the interest rate that is compatible with achieving the inflation target over time. We assume that the per-period utility function of all committee members is quadratic around i_t^* and is given by $-(p_t - i_t^*)^2$. Note that even though the board members share an equal goal embedded in a common utility function, their behaviour can (and will) depend on their private information, which is not necessarily homogeneous.

We assume that the unobserved state of the world follows an $AR(1)$ process given by $i_t^* = \rho i_{t-1}^* + u_t$, where $\rho \in (0,1)$, with u_t being an $i.i.d.$ shock with distribution $N(0, \sigma_u^2)$. That is, the optimal monetary policy changes over time, with the current optimal interest rate being influenced by the previous-period optimal interest rate and eventually converging to some long-run value compatible with a stable state of the economy. With our interpretation of i_t^* as the optimal interest rate it might seem unrealistic to assume that it can attain negative values, but the whole model and all the results are invariant to adding a constant to the optimal interest rate. In Appendix A1, we provide a robustness check to show that the $AR(1)$ assumption can be changed into AR(2) without altering the conclusions.

To generate non-homogeneous votes among the committee members we assume that each member j has an imperfect signal i_t^j about i_t^* given by $i_t^j = i_t^* + v_t^j$, where the noise v_t^j is $i.i.d.$ with distribution $N(0, \sigma_j^2)$. The assumption of non-homogeneous views of the individual committee members about the state of the economy is perfectly in line with the observed practice. Individual committee members often rely both on a staff forecast and on their privately formed views about which risks should be attached to the staff forecast and additional privately collected information about the state of the economy (Budd, 1998). It is assumed that for all Ps

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[3] Chairman's proposal can in principle be equal to status-quo. Meetings with no change in policy then can be result of either chairman proposing policy equal to the status-quo or chairman's proposal being rejected.

$\sigma_j = \sigma_P$ and that C has $\sigma_j = \sigma_C$. We assume that the chairman has the same or a higher capacity to collect private information compared to the other committee members and hence the same or a higher capacity to reduce noise. It follows that $\sigma_C \leq \sigma_P$.[4]

The proposal power of chairman along with heterogeneous preferences among the committee members generated by different signals implies that interpretation of our model fits best final stage of a typical monetary policy meeting. Common practice in many central banks is to start with a free format discussion of economic developments after which, typically the chairman, proposes policy which is then approved or rejected in a formal vote.

Next we make some assumptions in order to make the model tractable. We assume that the whole committee learns the previous state of the world at the beginning of each period before making its next decision, i.e. i^*_{t-1} is known by the time the t-period decision is being made. The alternative to this assumption would be not to reveal i^*_{t-1} and have the board members use Kalman filtering to update their beliefs about the optimal interest rate. While this extension is possible, we think it would add no substantive insight while greatly complicating the analysis.

The timing of events in period t is as follows: i) the last-period state of the world i^*_{t-1} is revealed, ii) nature determines all the random variables in the model, hence setting i^*_t and all the signals of the board members, iii) the signals about the current state of the world i^j_ts are revealed to all the members and remain their private information, iv) C makes proposal y_t, v) voting takes place between y_t and the status quo (i.e. the last-period policy) $x_t = p_{t-1}$ and the winning alternative becomes the new policy p_t, and finally, vi) the players collect their utilities and the decision-making process moves to $t+1$.

We will focus on a Stationary Markov Perfect equilibrium in which strategies are measurable only with respect to payoff-relevant variables (histories) and do not depend on time (Maskin and Tirole, 2001). This allows us to drop the time subscripts and the notation becomes x for the status quo, y for the proposal, i^* for the previous-period optimal interest rate, and i^j for signals about the current optimal interest rate. The current optimal interest rate will be denoted by $\bar{i}^*$, with the bar denoting variables that will become known in the next period (the same applies to

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[4] We could have generated heterogeneous preferences among the committee member by assuming fixed innate differences in their preferences. But with fixed pattern of heterogeneity, there is no reason why voting record should predict future decisions. On the other hand our assumption of private signals generating heterogeneous preferences can be alternatively viewed as an assumption of different innate preferences among the committee members, but one following stochastic pattern.

the other variables, i.e. $\bar{i}^j$ is the signal about the next-period optimal interest rate player j receives at the beginning of the next period). With this notation the $AR(1)$ process for the optimal interest rate becomes $\bar{i}^* = \rho i^* + \bar{u}$ and the signals are determined according to $i^j = \bar{i}^* + \bar{v}^j$. The information set of each player j is thus $I_j = \{i^*, i^j\}$.

C's strategy in this game is to offer the proposal, depending on information set variables and denoted by $y(x, I_C)$, that maximizes her expected utility. It will be a solution to

$$U_C(x, I_C) = \max_{y \in Y} \mathbb{E}_M \left[-(p(x,y) - \bar{i}^*)^2 + \delta U_C(p(x,y), \bar{i}^*, \bar{i}^C) | I_C \right] \qquad (1)$$

where δ is a discount factor common to all board members and $p(x,y)$ denotes the policy adopted, depending on the status quo x and proposal y. Set Y is assumed to be a set of discrete values in which the interest rate can be set, i.e. Y is a set of integer multiples of some value $\bar{s}$. The notation for the expectation operator $\mathbb{E}_M[\cdot]$ captures the idea that C will calculate her expectations differently based on a model of the committee members' behaviour, which we specify below. Finally, $U_C(x, I_C) = U_C(x, i^*, i^C)$ is C's continuation value utility from a game starting with the status quo x, the last-period optimal interest rate i^* and a signal about the current optimal interest rate i^C.

The strategy of each P member j is a simple binary decision to vote for or reject C's proposal given the status quo x and all the remaining variables in information set I_j. We restrict our attention to stage-undominated strategies (Baron and Kalai, 1993) in which player j simply votes for an alternative providing higher expected utility. This avoids equilibria in which players vote for an alternative they do not prefer simply because their vote cannot change the final decision. Along with the assumption above, this implies that j, given the status quo x, C's proposal y and j's signal i^j, votes for y if and only if

$$\mathbb{E}_M \left[-(y - \bar{i}^*)^2 + \delta U_j(y, \bar{i}^*, \bar{i}^j) | I_j \right] \geq \mathbb{E}_M \left[-(x - \bar{i}^*)^2 + \delta U_j(x, \bar{i}^*, \bar{i}^j) | I_j \right] \qquad (2)$$

where again $U_j(y, i^*, i^j)$ is the continuation value utility of player j from a game starting with the status quo y, with the previous-period optimal interest rate i^* and signal i^j. Notice that the voting rule specifies that an indifferent j votes for C's proposal. Hence, when C's offer y equals the current status quo x, pro-forma voting takes place within the committee and C's proposal is unanimously approved.

3.2 Committee members' behaviour

One way to proceed would be to assume full rationality on the part of all the committee members in the standard sense, solve for the model equilibrium (which would involve complicated expectation updating and signal extraction problems) and then simulate the path of the decisions for a random draw of model stochastic variables. However, the presence of information asymmetry among the board members, along with the infinite horizon framework, makes derivation of a full solution unfeasible.

Besides technical complexity, such a model does not capture the different modes or codes of conduct found among real-world central bank committees (see Blinder, 2004, or Chappell, McGregor and Vermilyea, 2005, for a discussion) and the possible degrees of informational influence among their members. A purely rational model also implicitly assumes a lack of other motives on the part of central bank committee members, such as acknowledgement of the chairman's authority and better expertise or career concerns manifested by a willingness to adopt the chairman's opinion. In effect we view the fully rational model as an unrealistic description of reality.

For this reason we specify four different models of committee behaviour, for which we solve for equilibrium and then proceed with the simulations. The first three models, which we label as *democratic*, *consensual* and *opportunistic* based on C's behaviour, assume that the committee members do not take into account the impact of their actions on their future decisions. Formally, this is achieved by assuming $\delta = 0$.[5] By making this assumption we break the first intertemporal link in the committee decision-making mentioned above. Current policy still determines the future status quo, but the committee members do not take this fact into account. This assumption, for environments with $\sigma_C = \sigma_P$, implies that the policy proposal could in fact come from a different board member at each meeting, so that the role of the chairman is not institutional. When $\sigma_C < \sigma_P$, that is, when chairman C is better informed, her proposal power reflects her position as the best-informed board member. The fourth and last model, which we label *intertemporal democratic*, maintains the first intertemporal link but breaks the second one, i.e. it assumes that the optimal monetary policy is independent across periods. Formally, this is achieved by assuming

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[5] Assumption that policy-makers ignore effect of their current actions on their future decisions is common (Gerlach-Kristen 2008; Riboni and Ruge-Murcia 2008b, Riboni and Ruge-Murcia 2010, Weber 2010) although it manifests through the $\delta = 0$ assumption only in the first paper. In Riboni and Ruge Murcia 200b and in Weber 2010 there is no decision making between status-quo and proposed alternative. And in Riboni and Ruge-Murcia 2010 even though policy-makers are forward looking when determining their most preferred interest rate, their do not take into account effect of their vote on future status-quo.

$\rho = 0$ in the $AR(1)$ process determining the optimal monetary policy rate i^*. Below we describe the models, relegating the formal details to Appendix A1.

Notice that the first three models, described below, embed different degrees of informational influence among chairman C and the remaining P members. In the democratic model there is little or no influence, as C is not influenced by the information that the P members have, and they are not influenced by C's proposal. In the consensual model, C is informationally independent, while the P members are influenced by her proposal. Finally, in the opportunistic model it is C who is influenced by the other P members by basing her proposal on their preferences and disregarding her own preference to a certain extent. Note that the degree of informational influence is not related to how intense communication is prior to voting. The board members may in principle communicate a lot with each other prior to policy meeting but with low degree of informational influence and *vice versa*.

Democratic model

In this model of committee behaviour, chairman C plays the role of a democratic leader whose only special power is a proposal-making one. The proposal is based solely on C's own information set. The other committee members are free to express their own will by voting on her proposal, and C's behaviour has no effect on their own. In the language of our model, each P member j is assumed to vote based on the voting rule (2) using information set $I_j = \{i^*, i^j\}$ and extracting no information content from C's proposal. Given this behaviour, C solves her optimization problem (1) using information $I_C = \{i^*, i^C\}$ and forming her expectation in a standard rational manner, i.e. $\mathbb{E}_M[\cdot] = \mathbb{E}[\cdot]$, where $\mathbb{E}[\cdot]$ is a standard expectation operator. Notice that this does not mean C offers her expected optimal policy rate $\mathbb{E}[\,\bar{i}^*|i^*, i^C]$ given her information set; she offers her proposal y taking into account the fact that its eventual acceptance (as opposed to the acceptance of the status quo x) reveals information about the unobserved $\bar{i}^*$.

Consensual model

In this model, chairman C is assumed to have a dominant position beyond her proposal-making power. Her dominant position makes the other P members too keen to adopt her point of view, since they assume that the information available to the chairman is superior. In the language of our model, C's proposal is a solution to (1) given information $I_C = \{i^*, i^C\}$, but with the expectation operator $\mathbb{E}_M[\cdot]$ not taking into account the fact that possible rejection or acceptance of y contains information about unknown $\bar{i}^*$. In other words, C's proposal is the policy in Y

closest to C's expectation of $\bar{i}^*$, i.e. closest to $\mathbb{E}[\ \bar{i}^*|i^*, i^C]$. While not fully rational, this specification of the way in which C forms her expectations captures the notion that because she knows that the other committee members' voting behaviour is strongly influenced by her own proposal she disregards the possible information content of that behaviour and proposes her optimal policy.

To capture the notion that the P members adopt C's point of view, we assume that each P member j votes based on voting rule (2), but when calculating the expected value of $\bar{i}^*$, j extracts information from C's proposal. It is easy to see that the expectation can be written as $\mathbb{E}[\ \bar{i}^*|i^*, i^j, i^C \in \langle i_l^C, i_u^C \rangle]$, where i_l^C and i_u^C are, respectively, the lower and upper bounds on C's signal, as revealed by her proposal. We have decided to label this model consensual, since the extraction of information from C's proposal considerably reduces the level of heterogeneity of opinions within the committee.

Opportunistic model

In this model, we assume that C is opportunistic in consulting the other P members before the actual committee meeting. Once at the meeting, C then knows the most preferred policies of the other members and offers the policy she knows will be adopted by a supermajority of $\frac{N}{2} + 2$ of them. In the appendix, we provide a robustness check for a mere majority case to illustrate that this assumption is not binding for our results. In terms of our model, we assume that C knows the most preferred policy of each member j, which is the policy in Y closest to $\mathbb{E}[\ \bar{i}^*|i^*, i^j]$. Ordering those policies such that $y_1 \leq \ldots \leq y_m \leq \ldots \leq y_{N+1}$, where y_m is the policy preferred by the median committee member, offering the policy adopted by a supermajority of $\frac{N}{2} + 2$ amounts to, for the $x \leq y_m$ case, offering y_{m-1} if $x \leq y_{m-1}$ and offering x if $x \geq y_{m-1}$. The $x \geq y_m$ case is analogous. An implicit assumption about the behaviour of each P member j is that his voting is given by voting rule (2) with the expectation computed using information set $I_j = \{i^*, i^j\}$ and ignoring the information content of C's proposal.

This model is inspired by Riboni and Ruge-Murcia (2010), who in their empirical investigation of several descriptive monetary policy committee decision-making models show that their 'consensual' model fits the real world data best. In their model, the adopted policy is equal to the most preferred policy of the next-to-median member (the side depending on the position of the status quo) when this policy is sufficiently far away from the status quo. When this policy is close to the status quo, the adopted policy is indeed the status quo. This is what our opportunistic model does, except that we label it differently, as in our model it captures the idea that the chairman's objective is to offer a policy which would never be rejected and she achieves this by using her authority to consult individual committee members or, in an alternative interpretation, to speak last during the committee discussion, after the remaining members have expressed their preferred policies.

The results from the experiments with the opportunistic model in which C offers the policy accepted by a mere majority $\frac{N}{2}+1$ of the members are reported only for completeness in Appendix A1 (Tables 15 and 16). They are largely similar to the results of the opportunistic model presented above. Notice that a mere majority model is often used in the literature, as the accepted policy is equal to the policy most preferred by the median committee member.

The three models just explained are also related to some of the models found in the existing literature. As already noted, our opportunistic model is similar to the 'consensual' model of Riboni and Ruge-Murcia (2010). Our simple majority version of the opportunistic model mentioned above is similar to the 'frictionless' model in Riboni and Ruge-Murcia (2010), to the 'individualistic' model in Gerlach-Kristen (2008) and to the model in Weber (2010). In all those models, the adopted policy is equal to the policy preferred by the median committee member. Furthermore, our democratic model is similar to the 'agenda-setting' model of Riboni and Ruge-Murcia (2010) in that the chairman proposes the policy that maximizes her expected utility among the policies she knows would be accepted. The key difference in our democratic model is that the acceptance is only probabilistic, as C does not know the signals of the other committee members. Finally, our consensual model is similar to the 'autocratically collegial' model in Gerlach-Kristen (2008) in that chairman proposes her most preferred policy and her authority makes the other committee members vote for her proposal. In the autocratically collegial model this is modelled as the other committee members having a 'tolerance interval' around their preferred policy, but in our model it is modelled as the other members considering the chairman's point of view by extracting information from her signal.

Intertemporal democratic model

The fourth model is similar to the democratic model specified above in that each P committee member votes based on his private information only and does not extract any information from C's proposal, with C solving her optimization problem in a fully rational manner. As opposed to the democratic model, this model maintains the intertemporal link in the committee decision by assuming that all the committee members take into account the effect of their current behaviour on their future decisions. This effect works through current policy determining the future status quo. Formally, this is achieved by setting $\delta > 0$.

A key problematic aspect in simulating the equilibrium of this model is the fact that C's proposal strategy maps $\mathbb{R}^2 \times Y$ into Y, and we would have to estimate the value functions $U_C(\cdot)$ at each point of this space. With standard value function iteration on the discrete version of $\mathbb{R}^2 \times Y$ the computational costs are prohibitive. To overcome this complication we set $\rho = 0$, breaking the intertemporal link in the optimal monetary policy. As a result, C's proposal strategies will be a function of the current status quo x along with her signal i^C mapping $\mathbb{R} \times Y$ into Y, which is considerably easier to simulate. We still have to derive the equilibrium value function $U_j(\cdot)$ for all the board members, but we only need to know $U_j(\cdot)$ at a discrete and rather coarse set of points sufficient for numerical integration over $\mathbb{R}$, as the Y set is already discrete.

3.3 Model simulations

For each version of the model of committee behaviour we generate 101 different random 100-period-long paths. These are chosen so as to gain insights into the results and avoid inference based either on a low number or on short paths while still keeping the simulations manageable. With the simulation of one path in the (intertemporal) democratic model taking approximately one hour for $N = 4$ on a standard desktop computer (twice as much for $N = 6$) we see the choice of the number and length of paths as an appropriate trade-off between validity and manageability (simulations of the other models take considerably less time, while simulations of the intertemporal democratic model require an additional several days for estimation of the continuation value function).[6]

Along each path for every period we record the status quo x_t, the proposal y_t and the final policy p_t and calculate the $skew_t$ variable as defined in the introductory part. It is given by

$$skew_t = \frac{\#(\text{voting for } y_t) \cdot y_t + \#(\text{voting for } x_t) \cdot x_t}{N+1} - p_t \qquad (3)$$

and allows us to run an ordered probit regression analogous to the one from the benchmark study Gerlach-Kirsten (2004), which we use later in our empirical part, in which the estimate of a_1 shows the informative power of the $skew$ variable for future policy changes

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[6] We also tested stability of our results across sub-samples of the 101 paths with satisfactory results. For example, if we split the 101 paths into two halves, out of 292 p-values reported for the simulation exercise, only 13 cross the 10 percent significance level in either of the two halves, relative to the results reported. Full results are available upon request.

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}. \tag{4}$$

In order to make the results more comparable among the different models, we keep the values of the random variables fixed across the simulations of those models. That is, when simulating, say, the first path in the democratic model, the random values in the model are the same as when simulating the first path in the consensual, opportunistic or democratic intertemporal model.

Following the discussion above, the simulation values of the parameters in the models are $\rho = 0.95$ and $\delta = 0$ for the democratic, consensual and opportunistic models (however, see the simulation robustness checks in Appendix A1 for the results with different values of ρ) and $\rho = 0$ with $\delta = 0.95$ for the intertemporal democratic model. In all the models, we assume that the interest rate is set in steps of a quarter of a percentage point, that is, in all the models $\bar{s} = 0.25$.

Next, we need to specify values for the distributions of random shocks. The choice of σ_u is driven by our attempt to match the standard deviation of the changes in the monetary policy rate in our empirical data. As p_t in our model eventually follows a similar process as i_t^*, Δp_t will follow a similar process as Δi_t^*. With the standard deviation of Δi_t^* equal to $\sqrt{2/(1+\rho)}\sigma_u$ and the empirically observed standard deviation of changes in the monetary policy rate between 0.25 and 0.5, we set σ_u to those two values.

For the standard deviation of the board members' signals σ_P and σ_C, we assume those to be either 0.25 or 0.5, implying that approximately 70% of the board members' signals are within 25 or 50 basis points of the optimal interest rate.

From the values above we construct several scenarios. Our baseline scenario assumes $\sigma_u = 0.25$, $\sigma_C = 0.25$ and $\sigma_P = 0.25$. Interested in the comparative static properties, we further take $\sigma_u = 0.5$, $\sigma_C = 0.25$ and $\sigma_P = 0.25$ in a 'high volatility' scenario, $\sigma_u = 0.25$, $\sigma_C = 0.5$ and $\sigma_P = 0.5$ in a 'bad information' scenario, and finally $\sigma_u = 0.25$, $\sigma_C = 0.25$ and $\sigma_P = 0.5$ in a 'P bad information' scenario. Note that we could call this 'P bad information' scenario also 'C superior information' scenario, since we consider the relative noise in the C and P information sets. For the four scenarios just explained, we simulate the models for both $N = 4$ and $N = 6$ in order to see the effect of increasing committee size on the results. We have chosen committee sizes of 5 and 7, as those are the most common central bank monetary policy committee sizes (Mahadeva and Sterne, 2000).

3.4 Simulation results

Tables 1–3 show the results of our simulation exercise. Besides estimates of coefficients a_1 and a_2 from (4) averaged over the 101 paths, we include average standard errors and average p-values. The row labelled *MSE* is the average mean squared error between the enacted and optimal monetary policy, *Votes proposal* is the average number of votes for C's proposal, and *No change* is the average fraction of meetings resulting in no change in policy. Tables 1 and 2 show the results for the democratic, consensual, opportunistic and mechanical (see below) models for $N = 4$ and $N = 6$ respectively. Table 3 shows the results for the intertemporal democratic model.

Before proceeding to the discussion of our results, we were interested to see whether we could generate the informative power of $skew$ with a purely mechanical model. In this model, policy p in each period is equal to the policy in Y closest to the optimal policy $\bar{i}^*$ and we calculate $skew$ assuming that there are $d \in \{1, \ldots, N/2\}$ dissenting members voting for the status quo x. We take d to be a random variable drawn anew for each committee meeting, with each value from $\{1, \ldots, N/2\}$ being equally likely.

What is apparent from this mechanical model is that it cannot generate data in which $skew$ holds information about future monetary policy changes. This is because there is no uncertainty about the optimal policy in this model, and there is nearly no difficulty in deciding where to set interest rates (the only difficulty being the fixed size of the minimum policy rate change). What the row MSE also shows is the benchmark or minimum error in monetary policy stemming from the fact that the monetary policy rate is set in discrete steps.

Looking at the democratic model results for the baseline scenario and $N = 4$ in Table 1, the average estimate of a_1 shows the informative power of the $skew$ variable for future policy changes. The intuition for this result is the following. Assume that the optimal policy rate i^* has been constant for several periods at some value i_1^* and that the committee has been setting its policy p_1 at the same level. Assume now that the optimal policy rate increases to some value i_2^*. The committee members receive imperfect information about this shock and several courses of action follow. If C's signal does not prompt her to offer a policy different from the current status quo p_1, the new policy p_2 will be equal to the current status quo and hence the $skew$ variable will be equal to zero.

If, on the other hand, C offers proposal y_2 close to the new optimal policy rate i_2^*, her proposal will be higher than the current status quo p_1. Depending on the votes of the other committee members, two possibilities arise. The first one is that C's proposal is approved. The new policy p_2 will then be approximately equal to the optimal rate i_2^* and the $skew$ variable will be negative. But due to the fact that the optimal policy rate is an $AR(1)$ process with relatively large ρ, it is approximately equally likely that the optimal rate will increase or decrease in the future. With monetary policy eventually following the optimal rate, it is then equally likely that the policy will increase or decrease in the future. The second possibility is that C's proposal is rejected. The new policy p_2 will then be equal to the status quo p_1 and the $skew$ variable will be positive. It is also more likely than not that the interest rate will increase in the future if it follows the optimal rate. The combination of an equal probability of increase and decrease in policy when $skew < 0$ and a higher probability of increase when $skew > 0$ is what gives the positive estimate of a_1 (see also Figure 1 below and the surrounding text).

The intuition just explained also reveals two conditions under which $skew$ holds information about future policy changes. The first condition is that monetary policy cannot follow the optimal rate precisely. This is apparent from the estimates for the mechanical model. The second condition is that there has to be a certain minimum degree of dissent in the committee. If all the committee members vote in the same way, the $skew$ variable will always be zero and hence cannot be informative about future policy changes. This is revealed by the estimates for the consensual and opportunistic models. In both of those models, information is shared among the committee members and hence their decision-making shows a low degree of dissent. This is also apparent from the high average votes for the proposal, which for both models is around 4.5 in a five-member committee.

Nevertheless, the two conditions just explained are not enough for $skew$ to be informative about future policy changes. Inspecting the first column of Table 1 for the democratic model across the different scenarios, the informative power of $skew$ can disappear either in a volatile economic environment (the high volatility scenario) or in an environment in which central bankers possess imprecise information (the bad information scenario). Comparing the results for the bad information and P bad information scenarios then suggests that it is the precision in C's signal that is important for the informative power of $skew$.

As already noted, the results for the other two models in Table 1 – the consensual and opportunistic ones – do not show any informational content in the $skew$ variable, despite the fact that some of the estimates for the consensual model come close to statistical significance on average. This holds despite the fact that the policy in these models is on average further away from its optimum than in the democratic model, or, in other words, the first condition for $skew$ to be informative explained above holds. What both of these models lack is the second condition – independence in the behaviour of the committee members.

We have already mentioned that high volatility of the economic environment or a lot of noise in the information of committee members can render $skew$ uninformative about future monetary policy changes even in the democratic model. However, turning our attention to Table 2, it is apparent that both effects can be overcome by increasing the committee size. The estimates of a_1 for the democratic model now become significant on average even in the high volatility and bad information scenarios. At the same time, an increase in the committee size does not change the insignificance of the estimates of a_1 in the consensual and opportunistic models despite the fact that the average p-values increase for both models and all scenarios.

Finally, with one exception the average estimates of a_2 are not significant in Tables 1 and 2, suggesting that past changes in the interest rate do not predict future change in the interest rate in our model, despite the fact that some of the estimates for the opportunistic models, and for two scenarios also for the democratic model, come close to statistical significance. As further discussed in the empirical part, a significant estimate of a_2 suggests an interest rate smoothing motive on the part of the monetary policy committee. It is then not surprising that the estimates are not significant, as the interest rate smoothing motive is not built into any of the theoretical models. An alternative explanation of the lagged policy change insignificance is that it is driven by the $AR(1)$ assumption for the optimal policy rate. This is what the results of our simulation robustness checks suggest, as the lagged policy change becomes significant when the $AR(1)$ assumption is changed to $AR(2)$. Whether, both in theory and in reality, the significance of the lagged policy change is driven by the smoothing motive or by the structure of the underlying economic environment is beyond the scope of this study.

Table 1 – Does the Voting Record Predict Policy Rate Changes?
Estimates Using Simulated Data with $N = 4$ and $\rho = 0.95$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	4.10 *	5.93	5.25	0.60
	[1.63] (0.089)	[3.29] (0.175)	[6.40] (0.418)	[3.99] (0.435)
Lagged policy change (a_2)	0.75	0.07	1.63	-0.14
	[0.53] (0.259)	[0.45] (0.520)	[0.74] (0.108)	[1.26] (0.451)
MSE	0.027	0.033	0.033	0.005
Votes proposal/No change	2.92/0.43	4.64/0.41	4.83/0.59	---/0.36
High volatility scenario ($\sigma_u = 0.5$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	2.19	2.59	0.69	0.21
	[1.04] (0.124)	[2.43] (0.364)	[3.65] (0.585)	[2.05] (0.444)
Lagged policy change (a_2)	0.24	0.01	0.60	0.00
	[0.24] (0.362)	[0.21] (0.515)	[0.29] (0.112)	[0.64] (0.462)
MSE	0.043	0.049	0.044	0.005
Votes proposal/No change	3.46/0.28	4.62/0.24	4.78/0.37	---/0.19
Bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.5$, $\sigma_P = 0.5$)				
Skew (a_1)	3.43	6.84	6.05	---
	[1.50] (0.106)	[3.59] (0.148)	[6.47] (0.385)	---
Lagged policy change (a_2)	0.29	0.08	1.04	---
	[0.48] (0.435)	[0.46] (0.507)	[0.64] (0.203)	---
MSE	0.048	0.052	0.053	---
Votes proposal/No change	3.00/0.43	4.69/0.41	4.85/0.56	---
P bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.5$)				
Skew (a_1)	4.97 *	9.98	6.53	---
	[1.79] (0.055)	[6.24] (0.228)	[6.43] (0.356)	---
Lagged policy change (a_2)	0.82	-0.19	1.25	---
	[0.54] (0.228)	[0.42] (0.490)	[0.67] (0.128)	---
MSE	0.041	0.036	0.049	---
Votes proposal/No change	2.74/0.50	4.88/0.38	4.84/0.57	---

Note: Average ordered probit estimates over 101 random 100-period-long paths. [Average standard errors] and (average p-value). * statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level based on average p-value. MSE is average mean squared difference between adopted and optimal policy. Votes proposal is average number of votes for chairman's proposal. No change is proportion of committee meetings with no policy change.

Table 2 – Does the Voting Record Predict Policy Rate Changes?
Estimates Using Simulated Data with $N = 6$ and $\rho = 0.95$

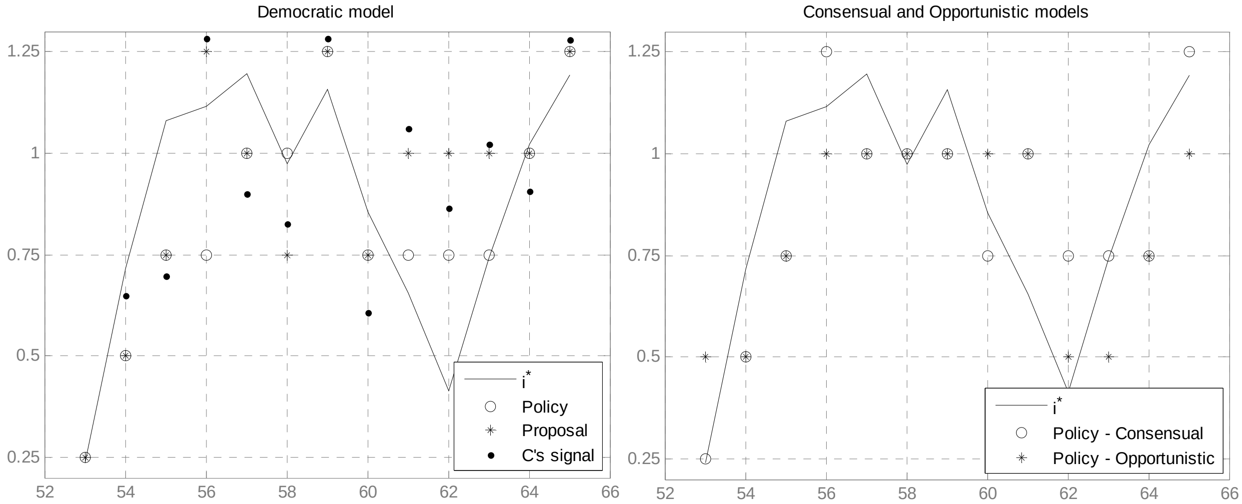
$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	5.15 **	6.57	7.41	0.01
	[1.66] (0.025)	[3.30] (0.156)	[5.30] (0.256)	[3.45] (0.510)
Lagged policy change (a_2)	1.08	0.14	2.05 *	-0.30
	[0.56] (0.125)	[0.46] (0.490)	[0.81] (0.065)	[1.06] (0.541)
MSE	0.026	0.032	0.030	0.005
Votes proposal/No change	3.90/0.45	6.46/0.42	6.62/0.57	---/0.36
High volatility scenario ($\sigma_u = 0.5$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	2.37 *	3.01	1.69	-0.03
	[1.02] (0.085)	[2.43] (0.328)	[2.99] (0.449)	[1.76] (0.521)
Lagged policy change (a_2)	0.28	0.02	0.63	-0.07
	[0.24] (0.311)	[0.21] (0.499)	[0.30] (0.115)	[0.54] (0.551)
MSE	0.040	0.049	0.036	0.005
Votes proposal/No change	4.66/0.31	6.42/0.24	6.52/0.33	---/0.19
Bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.5$, $\sigma_P = 0.5$)				
Skew (a_1)	3.57 *	7.60	7.44	---
	[1.47] (0.079)	[3.67] (0.140)	[5.09] (0.261)	---
Lagged policy change (a_2)	0.40	0.15	1.16	---
	[0.49] (0.421)	[0.47] (0.460)	[0.65] (0.184)	---
MSE	0.047	0.052	0.051	---
Votes proposal/No change	4.04/0.44	6.54/0.41	6.67/0.52	---
P bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.5$)				
Skew (a_1)	5.31 **	12.42	7.86	---
	[1.71] (0.032)	[6.61] (0.174)	[5.08] (0.231)	---
Lagged policy change (a_2)	1.00	-0.13	1.36	---
	[0.55] (0.147)	[0.42] (0.517)	[0.68] (0.128)	---
MSE	0.041	0.036	0.048	---
Votes proposal/No change	3.66/0.51	6.82/0.37	6.66/0.54	---

Notes: See Table 1.

To provide further intuition behind our results, Figure 1 shows a fraction of a typical simulated policy path for the three models from Tables 1 and 2. The solid line in both figures is the optimal monetary policy rate unknown to the central bank committee. The left figure then shows enacted policy in the democratic model along with C's proposals, and the right figure shows enacted policy in the consensual and opportunistic models. We do not show the proposals for the two latter models, as they are always accepted in the opportunistic model and very often accepted in the consensual model (always accepted for the particular policies We choose this particular path as it produces the estimates closest to the average estimates shown for the democratic model in Table 1 for the baseline scenario.

Figure 1 – Simulated Policy Paths



Focusing first on the left figure shows why the $skew$ variable is informative about future changes of monetary policy in the democratic model. For periods 53–55 the enacted policy closely follows the optimal one, but then in period 56 the committee fails to increase the policy further to C's proposal of 1.25 because the proposed step seems too large to the other committee members. This generates a positive value for $skew$ in this period and suggests an increase of policy to 1.00 in period 57. The right figure then shows why the $skew$ variable is not informative about future policy changes in the consensual and opportunistic models. In the consensual model chairman C gets her proposal of 1.25 in period 56 approved, as her proposal reveals her high signal to the other committee members, who are influenced by it, so that the policy does not need to 'catch up' in the period 57. In the opportunistic model a similar thing happens, but with a policy of 1.00 adopted instead.

Intuitively, it might seem that the democratic model generates an informative value of $skew$ due to the failure of the committee to adopt higher policy in the period 56. While this is certainly true, notice that the other two models err in different situations. The consensual model errs in that C's proposals are too often accepted and hence the enacted policy reflects too much noise in C's signals. This is evident from C's failure to propose higher policy in period 59 or the eventually accepted proposal for higher policy in period 61. The democratic model, on the other hand, guards against strong influence of the chairman, as evident by the rejection of the proposals in periods 58 and 61–63, all of which would have taken the policy further away from the optimal one.

The opportunistic model errs in that it takes too long to form the super-majority of the committee needed to change the policy. This is evident from the no policy change in period 59 and then the maintenance of policy at the 1.00 level until period 61 before changing it to 0.50 in period 62, with a smoother transition being more appropriate.

What the figure also shows is that both the democratic and the consensual models generate policy paths that are somewhat more volatile than the policy path generated by the opportunistic model. From Tables 1 and 2, the democratic and consensual models on average, excluding the high volatility scenario, generate somewhere between 40 and 50 per cent of no policy change meetings, while the opportunistic model generates somewhere between 50 and 60 per cent of no policy change meetings. However, with the fraction of no policy change meetings in our data being 61% for Poland, 62% for Sweden, 65% for Hungary, 66% for the Czech Republic and 69% for the United Kingdom, this does not seem to be significant weakness of either of the two models.

What the figure does not show, however, is the source of the no policy change meetings. As already noted in both consensual and opportunistic models, C's proposal is often accepted, implying that the source of no changes in policy is C's proposal being equal to the status quo. This, along with the voting behaviour, implies a high percentage (equal to the fraction of no change meetings for the opportunistic model and very close to the fraction of no change meetings for the consensual model in Tables 1 and 2) of meetings with no change in the policy rate with the decision being reached unanimously. On the other hand, in the democratic model C's proposal is almost never equal to the status quo policy and hence almost all the no change meetings are a result of C's proposal being rejected. As at least she votes for her proposal, none of the no change meetings reach this decision unanimously, which more closely resembles the empirically observed stylized facts.

Source of meetings with no policy change in the three models also reveals another intuition for the explanatory power of the $skew$ variable. Any meeting with unanimous decision generates zero $skew$ and as a result consensual and democratic models are associated with $skew$ variable with less variance relative to the democratic model.

To check how robust our simulation results are, we repeated the simulations for the democratic, consensual, opportunistic and mechanical models either for different values of ρ compared to the benchmark results or changing the $AR(1)$ process to an $AR(2)$ process. The results are given in Tables 9–14 in Appendix A1. To summarize, the results change very little when we change $\rho = 0.95$ from the benchmark results to either $\rho = 0.90$ (Tables 9 and 10) or $\rho = 0.99$ (Tables 11 and 12). When we change the benchmark $AR(1)$ process to an $AR(2)$ process (Tables 13 and 14), the most notable change is that the average estimate of the lagged policy change becomes significant in most cases. Nevertheless, $skew$ still is informative about future policy changes only in the democratic model.

Table 3 – Does the Voting Record Predict Policy Rate Changes?
Estimates Using Simulated Data

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Intertemporal Democratic	
	$N = 4$	$N = 6$
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)		
Skew (a_1)	1.98	2.36
	[1.64] (0.338)	[1.66] (0.271)
Lagged policy change (a_2)	-2.31 ***	-2.23 ***
	[0.56] (0.002)	[0.58] (0.008)
MSE	0.028	0.027
Votes proposal	2.89	3.89

Notes: See Table 1.

Before we conclude the theoretical section, we turn our attention to the results for the intertemporal democratic model. Table 3 shows the simulation results for this model and the baseline scenario for both $N = 4$ and $N = 6$. We decided not to include more results, as those come with considerable time costs and even the estimates for the baseline scenario show the main weakness of this model, which is a negative estimate of a_2. Intuitively, this result is driven by the fact that $\rho = 0$. When the optimal rate increases to some value and monetary policy follows it, giving a positive policy change, it is highly likely that in the next period monetary policy will have to be reversed, as the optimal rate is normally distributed around zero for $\rho = 0$. Additionally, the average estimate of a_1 in Table 3 is not significant, showing that breaking the intertemporal link in the optimal interest rate renders the $skew$ variable uninformative about future monetary policy.

Overall, the model delivers several interesting policy implications. First, publishing the voting pattern of the monetary policy committee members is important if monetary policy is not always at its optimal level. This allows other economic agents to gain information about the future course of monetary policy in the form of the $skew$ variable.

Second, the informative power of the $skew$ variable is not guaranteed automatically. What is needed is informational independence of the committee members. If all the committee members behave based on the same information or one of the committee members has enough authority for the other committee members to adopt his or her point of view, a high degree of consensus ensues and the $skew$ variable is rarely different from zero.

Third, even with independently behaving central bankers, the $skew$ variable might not be informative. In a volatile economic environment, or when the monetary policy committee members possess imprecise information, it is important for the committee to have a sufficient number of members, as every additional committee member brings new information.

4 Institutional Background

This section gives information on the background of central bank committees' decision-making about monetary policy. The bank boards typically meet on a monthly frequency and decide on the level of the repo rate. The frequency of monetary policy meetings varies. For example, the Bank of England and the Hungarian and Polish central banks meet monthly. The Czech National Bank used to meet monthly up to 2007 but has met eight times a year since 2008, the same as the Riksbank for the large part of our sample period. Occasionally, the central banks hold extraordinary policy meetings.

The boards take decisions based on a majority vote. In the event of a tie, the chairperson (the governor, if present at the meeting) has the casting vote. The policy decision is announced on the same day. Minutes explaining the monetary policy decision, i.e. the voting of central bankers, are published approximately one or two weeks later. Except for Poland, the voting record is an integral part of the minutes and summarizes the qualitative information contained in the minutes. In the case of Poland, the voting record appears no sooner than 6 weeks (and no later than 12 weeks) after the policy meeting.[7] Polish case documents that the informative power of the voting records does not depend on the ex ante known publishing time lag. An in-depth study on voting records in Poland is provided by Sirchenko (2010).

The voting results are typically attributed, but not always. For example, the voting ratio was released without an explicit statement on how the individual board members voted for the monetary policy decisions in the Czech Republic in 2000–2007. From mid-2000 to January 2006 the (unattributed) voting record was published in the minutes only, while since February 2006 the voting record has been released at the press conference held about 3 hours after the announcement of the interest rate decision. In addition, the Czech National Bank has recently published the transcripts of its monetary policy meetings in 1998–2001, which include the voting record as well. Hence, the Czech case offers us a second natural experiment set-up in which we can test whether the voting ratio has a similar informative power to the full voting record. The results show that this is the case. The lesson learnt from the Czech case is therefore to publish at least the voting ratio if there are serious concerns about naming names.

Disagreement among central bankers is common. The voting was not unanimous in 46% of cases for the Czech central bank, 70% for the Hungarian central bank, 46% for the Polish central bank, 19% for the Swedish central bank and 59% for the Bank of England during our sample period. The frequency of unanimous voting depends to a certain extent on the size of the bank board, with Hungary having more than 10 members in the board during our sample. The typical magnitude of monetary policy rate change is 25 basis points. Other magnitudes are less common, although central banks decreased policy rates quite aggressively during the recent financial crisis, often by 50 or even 100 basis points at the meeting. Substantial policy rate changes of similar magnitude were also observed in the Czech Republic, Hungary and Poland during the period of transition to a market economy, which was characterized by more volatile macroeconomic development. The data are further described in Appendices A2 and A3.

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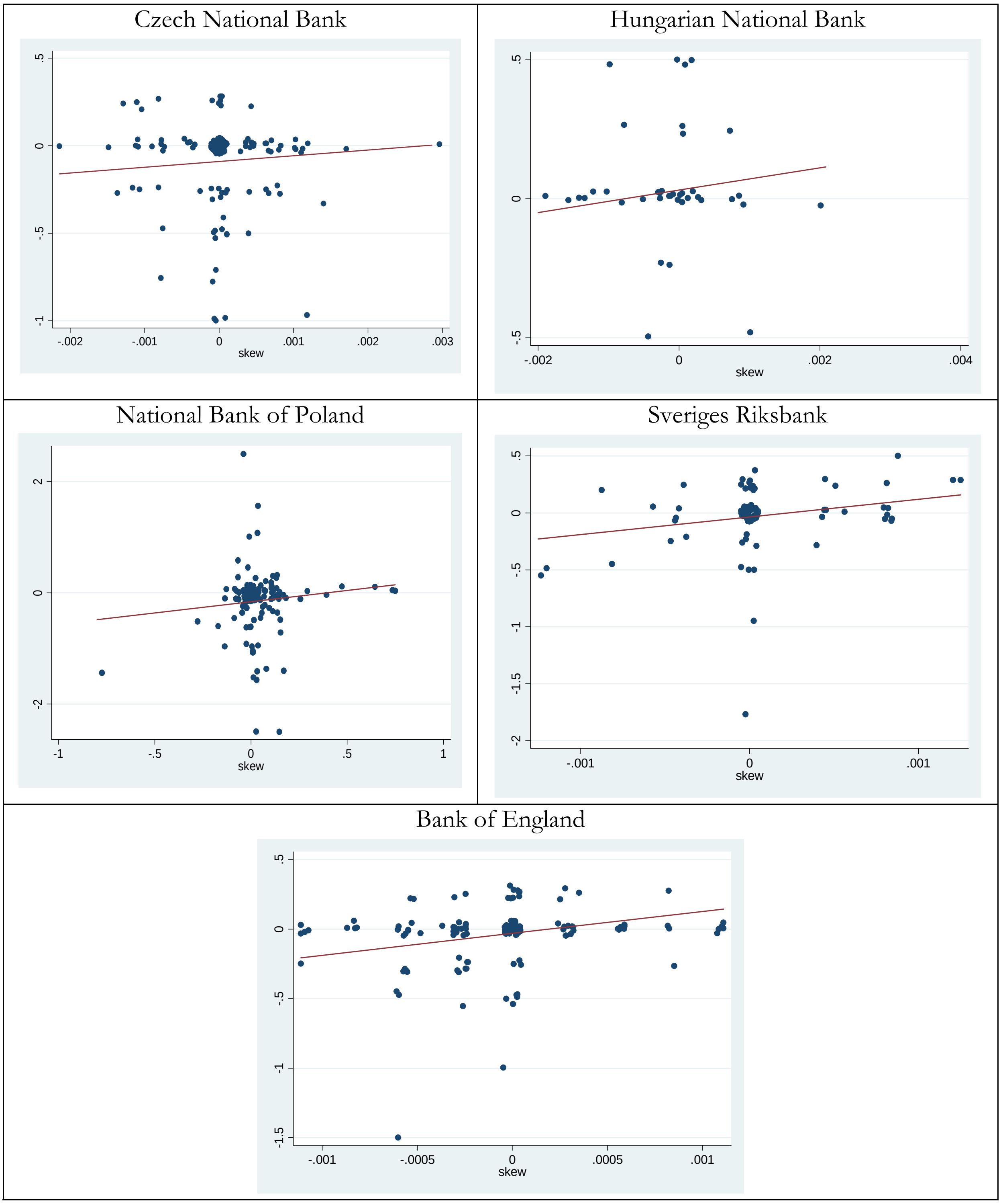
[7] More specifically, if the repo rate was changed, the voting record is first published in the Court and Economic Gazette of the Ministry of Justice and only after that in the inflation report. Voting records have to be published in the Court and Economic Gazette no sooner than 6 weeks and no later than 12 weeks after the voting took place.

Figure 2 – Actual Voting Record Skew and Future Policy Rate Change



Note: Skew, plotted on the x-axis, is calculated as the difference between the average repo rate voted for by the individual board members and the actual repo rate at the next meeting. The future monetary policy rate change is plotted on the y-axis. Jitter is used for overlapping observations for expositional purposes.

Figure 2 presents the link between the actual voting record skew and the future policy rate change. In all countries, the link seems to be positive, although there are cases where skew can give a noisy signal about future policy, for example when the rates are not changed and one board member dissents. When we look at the various signal-to-noise ratios, we see that there is a certain level of noise in an individual member's voting record, but when more than one member dissents at the same policy meeting, the level of noise declines and is typically well above 50%.[8] We perform a regression analysis in the following section to shed light on the extent to which the voting record gives systematic information for future policy. For the regression analysis, the future policy rate change is stacked in fewer categories, as large-magnitude policy changes happen rarely (more on this below).

5 Empirical Methodology

Our theoretical model shows when the voting record is likely to be informative for future policy changes. As regards the empirical methodology we follow the approach developed by Gerlach-Kirsten (2004) to assess the predictions of our model. Gerlach-Kirsten (2004) analyses the voting record of the MPC of the Bank of England over the period 1997–2002, while we provide a more comprehensive international comparison. More specifically, we focus on the following five countries that conduct their policies within an inflation-targeting regime: the Czech Republic, the United Kingdom, Hungary, Poland and Sweden.

Following our benchmark study Gerlach-Kirsten (2004), we define a measure of disagreement in the bank board, the variable $skew$, as

$$skew_t = average(i_{j,t}) - i_t \tag{5}$$

where $i_{j,t}$ is the interest rate voted for by bank board member j at a monetary policy meeting at time t, and i_t denotes the monetary policy rate. This is an identical definition to equation (3) used in our theoretical models. However, for the sake of comparability with the benchmark study, we use here the benchmark notation for the policy interest rate i_t, while in the theoretical models we kept the notation typical for that stream of literature, where the policy tool is denoted p_t. We follow the benchmark study and assess whether the voting record reveals information on future monetary policy by estimating the following baseline regression model for each country separately.

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[8] More specifically, we calculate the signal-to-noise ratio as follows. When at least 25% of board members dissent – for example at least two members out of seven vote for higher rates – at a particular meeting and the rates are not changed, we classify the skew variable as giving the correct signal when the rates are increased at the next policy meeting. Calculating the signal-to-noise ratio in this way, the ratio is 71% for the Czech Republic, 67% for Hungary, 64% for Poland, 80% for Sweden and 54% for the UK. The ratio is above 50%, indicating that the voting record gives more often a correct, rather than noisy, signal.

$$\Delta i_{t+1} = a_0 + a_1 skew_{\tau(t)} + a_2 \Delta i_t + u_{t+1} \quad (6)$$

This equation is identical to equation (4) used in the theoretical part. Again, for the sake of comparability, we altered the notation for the policy interest rate. It is assumed in (6) that the interest rate decision is taken at time t. The votes are released at time $\tau(t)$, i.e. in the period between the interest rate decisions at t and $t+1$ (often together with the minutes, typically about two weeks after the interest rate decision at t; it is worth emphasizing that we focus on the voting record, as this is the only quantitative information in the minutes; alternatively, one would have to classify the qualitative information contained in the minutes). Analogously to the theoretical models, we estimate (6) by an ordered probit technique to reflect the discrete nature of monetary policy rate changes. It is important to emphasize that the discrete dependent variable has been stacked in fewer categories, as some policy change magnitudes, such as 75 basis points, happened rarely. Therefore, the dependent variable was coded in four to five categories depending on the country and defined as follows: large decrease, decrease, no change, hike and large hike (-50, -25, 0, +25 and +50 basis point changes respectively).[9]

According to our theoretical model, the coefficients a_1 and a_2 are expected to take positive values. As regards the sign of a_1, if some bank board members favour higher rates, $skew$ is positive and a future interest rate hike is more likely, conditional upon the voting record being informative for future policy. As regards the coefficient a_2, it reflects interest rate smoothing and the attempt of central bankers to avoid sudden policy reversals. If a_1 is significant, we can infer that the voting record improves the explanatory power of a 'naïve' model which assumes only smoothing and reactions to shocks. We can also infer that the conditions identified by our theoretical model have been fulfilled and that the voting mechanism has been democratic.

Our second baseline model extends this naive model by considering the information set available to the financial markets. We approximate their information set from the yield curve. While the naive model is directly comparable to the outcomes from our theoretical models, the second baseline model should be viewed as its extension. In this extension, we can test whether the information set available to the financial markets contains all the information sets available to the individual committee members. If the financial markets have an identical information set and evaluate the information at least as effectively as the central bank, the information content of the

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[9] The number of categories is set according to the log-likelihood of competing models. An alternative way would be to test whether the thresholds estimated within the ordered probit model differ significantly from each other. Note that the coding of the dependent variable substantially lowers the potential impact of vertical outliers. As concerns the potential impact of horizontal outliers, we estimate the regressions based on various sub-samples, with the results being affected minimally.

skew indicator should be built into the slope of the term structure of interest rates. In that case, parameter b_1 would be insignificant in our second baseline model (as would b_2 if interest rate smoothing is fully priced into the term structure). In the opposite case, the voting record reveals additional information to the financial markets. Our theoretical models also suggest other situations when $skew$ could be insignificant. Specifically, in periods of high volatility or under certain voting mechanisms the skew may be insignificant despite the fact that individual board members have valuable information sets. To assess these considerations formally, we estimate a regression of the following form:

$$\Delta i_{t+1} = b_0 + b_1 skew_{\tau(t)} + b_2 \Delta i_t + b_3 (i_{\chi(t),L} - i_{\chi(t),S}) + u_{t+1} \qquad (7)$$

As compared to (6), equation (7) now includes an additional term to control for financial market expectations. $i_{\chi(t),L)-i_{\chi(t),S}}$ represents the slope of the term structure, where L and S denote the respective money market maturities[10] and it is assumed that $L > S$ (following Gerlach-Kirsten, 2004, we will consider various maturities). $\chi(t)$ denotes the time period between the interest rate decisions, and the data on $i_{\chi(t),L}$ and $i_{\chi(t),S}$ will be from the day before the release of the voting record (thus, $\chi(t) < \tau(t)$).

Regarding our two natural experiment set-ups, we can test whether $skew$ is informative in the period when voting records are disclosed with a considerable time lag, as in the aforementioned case of Poland. We can also test whether the voting ratio is informative when only unattributed voting records are available, as in the aforementioned case of the Czech Republic.

We add two robustness checks to our baseline models. First, we extend the empirical specification by Gerlach-Kirsten (2004) to include a measure of dispersion in the voting records, which can serve as an indicator of the degree of uncertainty the board members face. We measure the dispersion of the voting results by the standard deviation of the individual votes.[11]

$$\Delta i_{t+1} = b_0 + b_1 skew_{\tau(t)} + b_2 \Delta i_t + b_3 (i_{\chi(t),L} - i_{\chi(t),S}) + b_4 dispersion_t + u_{t+1} \qquad (8)$$

The sign of b_4 is not clear-cut, although more uncertainty may trigger looser monetary policy (Soderstrom, 2002; Bekaert et al., 2010). Second, we also estimate Eq. (7) based on the data before the 2008–2009 financial crisis in order to test the sensitivity of the results.

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[10] An alternative would be to include interest rate futures or forwards, but these were not available for all the sample countries.

[11] The share of the largest minority could serve as an alternative measure.

6 Empirical Results

This section gives the empirical results on whether the voting record is informative about future monetary policy. We first present our baseline estimates (Eqs. (6) and (7)) for all countries. Alternative specifications follow.

Table 4 – Does the Voting Record Predict Repo Rate Changes?
Baseline Estimates

$$\Delta i_{t+1} = b_0 + b_1 skew_{\tau(t)} + b_2 \Delta i_t + b_3 (i_{\chi(t),L} - i_{\chi(t),S}) + u_{t+1}$$

Country	Czech Rep.		Hungary		Poland		Sweden		UK	
Sample	2000:7–2008:12		2005:10–2009:2		1998:2–2009:12		1999:1–2009:2		1997:6–2009:2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lagged repo changes (b_2)	1.34***	0.46	1.44***	0.97***	0.73***	0.66***	1.03***	0.87***	0.87***	0.99***
	(0.27)	(0.42)	(0.32)	(0.38)	(0.12)	(0.17)	(0.19)	(0.21)	(0.23)	(0.19)
Skew (b_1)	1.74***	1.14***	0.62*	0.62*	0.33***	0.63***	1.58***	1.27***	1.22***	1.58***
	(0.33)	(0.40)	(0.33)	(0.33)	(0.08)	(0.14)	(0.36)	(0.39)	(0.39)	(0.29)
Term structure (b_3)		2.53**		3.92***		1.97***		1.26*		1.52***
		(1.15)		(1.36)		(0.36)		(0.74)		(0.49)
Adj. pseudo R-squared	0.24	0.20	0.34	0.49	0.13	0.33	0.24	0.25	0.20	0.32
Observations	100	75	40	40	142	108	90	90	142	142

Note: * statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level. Standard errors in parentheses. Ordered probit estimation. Term structure stands for difference between 1Y and 3M interbank rate in given country. Data for Czech Republic in column 2 until 2006:7 only. Data on 12M interbank rate in Poland is available only from 2001 onwards, therefore number of observations in column (6) is smaller than that in (5).

The results reported in Table 4 suggest that the voting record is indeed informative about future policy rate changes. The lagged repo rate change is typically significant, suggesting that the central banks smooth interest rates to a certain extent and try to avoid sudden reversals in their policies. The variable $skew$ is statistically significant at conventional levels in all countries in the first baseline 'naïve' model as well as in the second baseline model with financial market expectations. The pseudo R-squared – the measure of regression fit – varies from 0.13 to 0.49. Our results for the UK confirm the previous empirical findings by Gerlach-Kirsten (2004). The significance of $skew$ indicates that the conditions identified by our theoretical model have been fulfilled. First, the chairmen in these central banks probably act as democratic leaders whose only special power is the proposal-making one and other committee members are free to express their own will by voting on the proposals of the chairmen, and the chairmen consider the voting of the other committee members informative. In other words, although we do not want to overemphasize our results it suggests that the democratic version of our theoretical model describes the real world data most closely. Second, it is likely that in our sample period there was enough noise in the signals, and at the same time the committee members' information sets were not distorted by excessively high economic volatility, given the size of the committee.

In the case of Poland, where the voting record is published with a significant lag separately from the minutes and is not available before the next policy meeting, $skew$ carries additional information available only to board members, not to the financial markets. The adjusted pseudo R-squared increases from 0.23 in the specification with lagged policy rate changes and term structure to 0.33 in the specification with lagged policy rate changes, term structure and $skew$. We therefore conclude that despite the time lag the skew indicator contains additional information that can be used by board members. Releasing voting records faster would be beneficial for transparency of monetary policy.

The results for the Czech Republic use the data until 2006:7 in the specification with financial market expectations (column 2 in Table 4). The reason is that from this period onwards the voting record was released only about 3 hours after the monetary policy decision was announced. The monetary policy decision was typically announced at around 1 p.m. and the voting ratio was released at around 3.30 p.m. at a press conference. In principle, we could collect the interbank rates at say 2 p.m. and therefore use more recent data as well, but it has to be emphasized that the interbank market was not very liquid during the financial crisis. Therefore, we preferred to restrict the sample to 2006:7. The results for the Czech Republic also suggest that publishing the voting ratio (without an attributed voting record) may be sufficient to foster a better understanding of the future course of monetary policy.

Table 5 – Does the Voting Record Predict Repo Rate Changes? Alternative Specifications – Different Maturities in Term Structure and Uncertainty

$$\Delta i_{t+1} = b_0 + b_1 skew_{\tau(t)} + b_2 \Delta i_t + b_3 (i_{\chi(t),L} - i_{\chi(t),S}) + b_4 dispersion_t + u_{t+1}$$

Country	Czech Rep.		Hungary		Poland		Sweden		UK	
Sample	2000:7–2006:7		2005:10–2009:2		1998:2:2–2009:12		1999:1–2009:2		1997:6–2009:2	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lagged repo changes (*b_2*)	0.08	0.45	1.22***	0.88**	0.63***	0.69***	0.92***	0.87***	1.15***	0.99***
	(0.43)	(0.42)	(0.37)	(0.40)	(0.13)	(0.18)	(0.19)	(0.21)	(0.18)	(0.19)
Skew (*b_1*)	0.89**	1.14***	0.50*	0.48	0.35***	0.60***	1.48***	1.29***	1.70***	1.54***
	(0.41)	(0.40)	(0.28)	(0.36)	(0.09)	(0.14)	(0.37)	(0.41)	(0.29)	(0.31)
Term structure (*b_3*)	10.24***	2.48**	2.10	4.67***	1.61***	1.75***	3.23**	1.24*	0.41***	1.58***
	(2.87)	(1.15)	(1.96)	(1.73)	(0.30)	(0.41)	(1.45)	(0.74)	(0.67)	(0.50)
Dispersion (*b_4*)		-0.93		-7.88*		-1.03		0.93		-3.99*
		(2.54)		(4.51)		(0.88)		(2.85)		(2.28)
Adj. pseudo R-squared	0.27	0.20	0.35	0.54	0.24	0.41	0.27	0.25	0.29	0.33
Observations	75	75	40	40	142	60	90	90	142	142

Note: * statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level. Standard errors in parentheses. Ordered probit estimation. Term structure stands for difference between 3M and 1M (1Y and 3M) interbank rate in odd (even) columns in given country. Data for Czech Republic in columns 1 and 2 until 2006:7 only. Uncertainty stands for standard deviation of individual votes in bank board. Data on 12M interbank rate in Poland is available only from 2001 onwards, therefore number of observations in column (6) is smaller than that in (5).

We also carried out a number of robustness checks. In the baseline specifications, the term structure was defined as the difference between the 12-month and 3-month interbank rate. Alternatively, the term structure is based on different maturities, defined in the regressions presented in Table 5 as the difference between the 3-month and 1-month interbank rate. The results remain largely unchanged. $skew$ remains statistically significant and its estimated size is largely similar. Similarly, introducing dispersion – a measure of disagreement in the board – as an additional explanatory variable does not change the interpretation of the baseline estimates. The dispersion is statistically significant at 10% level in Hungary and the UK. This suggests that a more dispersed opinion about policy rates is associated with a loosening of policy in these two countries. The dispersion in the other countries is insignificant. Table 6 reports the results based on the sample excluding the financial crisis period (up to 2007:7). Again, the results remain largely stable. Finally, we included the level of interest rates as additional regressor to tackle the issue that the increase in the policy rate by 0.25 if the rate is at, for example, 1% or when it is at 5% can give different message to the public. Even after the inclusion of the level of interest rate, $skew$ remains statistically significant (these results are available upon request).

Table 6 – Does the Voting Record Predict Repo Rate Changes?
Alternative Specifications – Data until Financial Crisis Only

$$\Delta i_{t+1} = b_0 + b_1 skew_{\tau(t)} + b_2 \Delta i_t + b_3 (i_{\chi(t),L} - i_{\chi(t),S}) + u_{t+1}$$

Country	Czech Rep.		Hungary		Poland		Sweden		UK	
Sample	2000:7–2007:7		2005:10–2007:7		1998:2–2007:7		1999:1–2007:7		1997:6–2007:7	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lagged repo changes (b_2)	1.24***	0.46	1.50***	1.22	0.64***	0.49**	1.01***	0.67***	0.99***	0.46*
	(0.31)	(0.42)	(0.47)	(0.80)	(0.13)	(0.20)	(0.23)	(0.27)	(0.21)	(0.25)
Skew (b_1)	1.66***	1.14***	0.47	1.94**	0.28***	0.62***	1.39***	0.84*	1.57***	1.28***
	(0.35)	(0.40)	(0.47)	(0.92)	(0.08)	(0.15)	(0.28)	(0.44)	(0.29)	(0.32)
Term structure (b_3)		2.53**		8.08**		2.44***		2.24**		2.99***
		(1.15)		(3.19)		(0.47)		(0.88)		(0.68)
Adj. pseudo R-squared	0.19	0.20	0.35	0.71	0.11	0.37	0.24	0.25	0.23	0.33
Observations	87	75	22	22	114	80	79	79	123	123

Note: * statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level. Standard errors in parentheses. Ordered probit estimation. Term structure stands for difference between 1Y and 3M interbank rate in given country. Data until 2007:7 exclude global financial crisis period. Data for Czech Republic in column 2 until 2006:7 only. Data on 12M interbank rate in Poland is available only from 2001 onwards, therefore number of observations in column (6) is smaller than that in (5).

All in all, the results suggest that the voting record bears relevant information about future monetary policy for all the countries in our sample and, in consequence, serves as a useful tool for improving the transparency of monetary policy.

7 Concluding Remarks

In this paper, we examine whether the voting records of central bank boards or monetary policy committees are informative about future monetary policy. We approach this issue from two angles. First, we develop a theoretical model of central bank decision-making where board members have non-homogeneous information sets and try to set policies so as to match the uncertain 'state of the world'. The model contains an intertemporal link between decisions taken at different board meetings to reflect the nature of monetary policy-making in which the interest rate adopted at one board meeting becomes the status quo for the next board meeting. The model also assumes an intertemporal link in optimal policies that change only slowly over time. We investigate whether the voting pattern is informative about changes in the interest rate based on data simulated from this model. Three different versions of model are estimated with the simulated data: 1) democratic, 2) consensual and 3) opportunistic. In essence, these versions differ in the extent to which the chairman influences the voting of the other board members. In version 1, the chairman allows the other board members to express their opinions democratically, and there is sufficient independence in the voting across the board members. In version 2, the chairman has a dominant enough position to bring about a consensus. And in version 3, the chairman votes opportunistically according to the majority of the other board members. The results show that only the democratic version of our model is able to generate significant correlations between the voting pattern and future policy changes. The results also show that the voting pattern resulting from democratic voting is informative only if there is sufficient noise in the signals.

Second, the model predictions are tested on real data. For this reason, data on five inflation targeters (the Czech Republic, Hungary, Poland, Sweden and the United Kingdom) that release voting records are collected. It is found that in all these countries the voting records are indeed informative about future monetary policy and thus in principle improve monetary policy transparency. More specifically, it is found that if a minority votes for higher rates than the majority, it is more likely that there will be a rate hike at the following meeting. This result is robust to controlling for financial market expectations as well as different sample periods. The result for Poland suggest that committee members tend to put the same effort into forming their views no matter whether their voting is published soon after the meeting or after a longer period of time. Hence, releasing voting records faster would be beneficial for both the public and the central bank, which could gain credibility.

Similarly to Gerlach-Kristen (2004) the results in this paper hold regardless of whether the voting record is attributed or not. In consequence, where there are concerns that attributed voting records might expose individual board members to some external pressure (such as in the case of a monetary union with board members not voting for national interests), the voting results can be published as non-attributed and still contribute to a better understanding of monetary policy. All in all, monetary policy transparency can be improved by releasing the voting record in a timely fashion.

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APPENDIX

A1 Derivation of Central Bank Board Decision-Making Model and Simulation Robustness Checks

In this appendix we explain the models from the third part of the paper in more detail so that it becomes apparent how to generate C's proposals and Ps' voting behaviour. We further explain several aspects of our simulation exercise and the methods we used.

First note that for all the models, equilibrium exists. This can be established for the three models with $\delta = 0$ using the simple backward induction argument. As there is no intertemporal link in the decisions, we can focus on a single period. Within this period, the P members move last and their behaviour is given by the specified voting condition. Knowing this, C derives her proposal y as a solution to her optimization problem. Finally, for the intertemporal democratic model, note that the policy space is finite and the existence of a Stationary Markov Perfect equilibrium follows from the arguments in Maskin and Tirole (2001).

Throughout the explanation we will often work with a vector of random variables in our model. All those variables form a random vector $r = \{\bar{i}^*, i^{P1}, \dots, i^{PN}, i^C\}'$ that has a multivariate normal distribution with – conditional on the information embedded in i^* – a mean equal to ρi^* and a variance-covariance matrix equal to a matrix with the vector $\{\sigma_u^2, \sigma_u^2 + \sigma_P^2, \dots, \sigma_u^2 + \sigma_P^2, \sigma_u^2 + \sigma_C^2\}$ on the main diagonal and all the off-diagonal elements equal to σ_u^2. Often we will need to compute the conditional expectation of r given the specific value of one or more of its elements. For this we use the well known result for the multivariate normal distribution that states that for a vector of (possibly more than two) random variables $\{x_1, x_2\}'$ distributed according to $N(\mu, \Sigma)$ with $\mu = \{\mu_1, \mu_2\}'$ and $\Sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix}$, where the partitioning of μ and Σ conforms to the partition of $\{x_1, x_2\}'$, the conditional distribution of x_1 given a specific value of x_2 is $N(\mu_1', \sigma_{11}')$, where $\mu_1' = \mu_1 + \sigma_{12}\sigma_{22}^{-1}(x_2 - \mu_2)$ and $\sigma_{11}' = \sigma_{11} - \sigma_{12}\sigma_{22}^{-1}\sigma_{21}$.

To simulate each of the models, we start in the first period, with the previous optimal interest rate and monetary policy rate being zero. In the simulations of the democratic, consensual and opportunistic models we restrict the policy space to be in the interval $\langle -10, 10 \rangle$ so that with our choice of $\bar{s}$ the policy space is equal to $Y = \{-10, -9.75, \ldots, 9.75, 10\}'$. For the intertemporal democratic mode we restrict the policy space to be in $\langle -3.5, 3.5 \rangle$ for the baseline scenario. We do not need to look at a larger policy space, as the optimal interest rate and players' signals stay well away from its border. As explained in the text, it is also inconsequential that we allow the optimal interest rate and the monetary policy rate to attain negative values, as all the results and estimates are invariant to adding a constant to the optimal interest rate.

The values of the random variables used in the simulations are kept constant across the different models. That is, when we simulate, say, the first path for the baseline scenario of the democratic model, the random variables used are the same as when simulating the first path of any other scenario for the same model or of any other model for the same scenario. This holds even across the $N = 4$ and $N = 6$ simulations, where we naturally have to add two more random variables for the two extra players, but the remaining random variables are kept the same.

In the democratic model with $\rho = 0.95$, $\delta = 0$ and $\bar{s} = 0.25$, at the beginning of each period with status quo x, last-period optimal interest rate i^* and fresh draw of $r = \{\bar{i}^*, i^{P1}, \ldots, i^{PN}, i^C\}'$, we first need to derive C's proposal y. This will be given as a solution to the optimization problem

$$\max_{y \in Y} \mathbb{E}\left[-(p(x,y) - \bar{i}^*)^2 | i^*, i^C\right] \tag{A1}$$

where $p(x, y)$ is the policy adopted given proposal y and status quo x. The optimization problem can be rewritten as

$$\max_{y \in Y} p_a \mathbb{E}[-(y - \bar{i}^*)^2 | i^*, i^C, a] + (1 - p_a)\mathbb{E}[-(x - \bar{i}^*)^2 | i^*, i^C, \hat{a}] \tag{A2}$$

where a is the event of y being accepted, $\hat{a}$ is the event of y being rejected and p_a is the probability of event a.

Next, we will need to calculate the probability of offer y being accepted against status quo x, p_a. In order to do so, chairman C knows, and we show below, that the remaining players will vote for y if and only if their signal is above (or below, but this case is symmetric) a certain cut-off that we denote here by k. The other relevant information that C has is her own signal i^C and the previous optimal interest rate i^*, hence we need to calculate the probability of at least $\frac{N}{2}$ P members voting for y given i^C and i^*. The probability of, say, the first N' members voting for y is equal to $P(\#|i^P \geq k| = N', \#|i^P < k| = N - N' | i^*, i^C)$ and is straightforward to calculate, as we know the distribution of the random vector $\{i^{P1}, \ldots, i^{PN}\}'$ and can always transform it into a problem of calculating $\mathbb{P}(\#|i^P \leq k| = N|i^*, i^C)$ by multiplying the whole problem (that is the mean and variance-covariance matrix) by $\{-1, \ldots, -1, 1, \ldots, 1\}'$, where there are N' negative ones and $N - N'$ positive ones. The probability can then be calculated using the standard cumulative distribution function of the multivariate normal distribution. Denoting the probability of the first N' members accepting by $\mathbb{P}_{N'}$, the probability of accepting becomes $\sum_{i=N/2}^{N} \mathbb{P}_i \begin{pmatrix} N \\ i \end{pmatrix}$.

The key computational problem in simulating the democratic model is computing the expected value of $\bar{i}^*$ given C's signal i^C, i^* and the event of y being accepted, as the event of accepting y means that the signals i^P of $\frac{N}{2}$ or more P members must have been above (or below) a certain threshold k. There are two results we use to make the computation simpler that are straightforward to prove. First, for random variable X and two mutually exclusive and exhaustive events A and B we have

$$\mathbb{E}[X] = \mathbb{E}[X|A]\mathbb{P}(A) + \mathbb{E}[X|B]\mathbb{P}(B)$$

and the similar result for variance states that

$$\begin{aligned} var(X) = \ & var(X|A)\mathbb{P}(A) + var(X|B)\mathbb{P}(B) \\ & +(\mathbb{E}[X|A] - \mathbb{E}[X])^2\mathbb{P}(A) + (\mathbb{E}[X|B] - \mathbb{E}[X])^2\mathbb{P}(B) \end{aligned}$$

which greatly simplifies the calculation of some of the expressions below.

Nevertheless, the key problem remains, as we need to calculate an expectation of the form $\mathbb{E}[\ \bar{i}^*|i^*, i^C, \#|i^P \geq k| = N', \#|i^P < k| = N - N']$. The first step is simple and amounts to calculating the distribution of $\{\bar{i}^*, i^{P1}, \ldots, i^{PN}\}'$ given i^* and i^C, which is $N(\mu, \Sigma)$, with each element of μ being equal to $\frac{\rho i^* \sigma_C^2 + i^C \sigma_u^2}{\sigma_u^2 + \sigma_C^2}$ and Σ being a matrix with the vector $\{\sigma', \sigma' + \sigma_P^2, \ldots, \sigma' + \sigma_P^2\}'$ on the main diagonal and $\sigma' = \frac{\sigma_u^2 \sigma_C^2}{\sigma_u^2 + \sigma_C^2}$ off the main diagonal. We then convert the problem into one of finding $\mathbb{E}[\ \bar{i}^*|\#|i^P \geq k| = N]$ using the technique just explained for the calculation of p_a. This leaves us with a multivariate truncated normal random vector with known mean and variance. To calculate the expectation we used the results in Tallis (1961) and Lee (1979) and wrote our own MATLAB function which calculates the expectation. We checked its correctness using the 'tmvtnorm' R-software package (see Wilhelm, 2010).

With those results, we can expand the maximand in (A2) and use the rules for conditional expectations and variance given above, then we determine the value of the objective function for each $y \in Y$ using the function for the expectation of the truncated multivariate normal, finally determining the solution to C's optimization problem and hence her proposal.

With C's proposal y determined, we can determine the voting behaviour of the remaining P committee members. For each member j we use the voting rule (2) from the text adapted to the democratic model

$$\mathbb{E}\left[-(y-\bar{i}^*)^2|i^*,i^j\right] \geq \mathbb{E}\left[-(x-\bar{i}^*)^2|i^*,i^j\right] \tag{A3}$$

which rewrites as

$$x^2-y^2 \geq 2(y-x)\mathbb{E}[\ \bar{i}^*|i^*,i^j] \tag{A4}$$

with $\mathbb{E}[\ \bar{i}^*|i^*,i^j] = \frac{\rho i^*\sigma_j^2+i^j\sigma_u^2}{\sigma_u^2+\sigma_j^2}$. This result also proves that each P member votes for y if and only if his signal is above (or below, depending on the position of the status quo) a certain cut-off. With the voting pattern determined, we can calculate the $skew$ variable and proceed to the next period.

In the consensual model with $\rho = 0.95$, $\delta = 0$ and $\bar{s} = 0.25$, at the beginning of each period with status quo x, last-period optimal interest rate i^* and fresh draw of $r = \{\bar{i}^*, i^{P1}, \ldots, i^{PN}, i^C\}'$, proposal y will be the policy most preferred by C. This is equal to the policy in Y that is closest to C's expectation of $\bar{i}^*$ given her signal i^C and the previous optimal policy rate i^*. This expectation is equal to $\mathbb{E}[\ \bar{i}^*|i^*,i^C] = \frac{\rho i^*\sigma_C^2+i^C\sigma_u^2}{\sigma_u^2+\sigma_C^2}$.

Next, we need to determine the behaviour of the P committee members. In the consensual model, each P member j will vote based on the voting rule (2) using his information about the previous optimal interest rate i^*, his private signal i^j and the information embedded in C's proposal y, hence the voting rule rewrites as

$$x^2-y^2 \geq 2(y-x)\mathbb{E}[\ \bar{i}^*|i^*,i^j,y] \qquad \text{(A5).}$$

It is easy to confirm that the information embedded in C's proposal is equal to an event of $i^C \in \langle i_l^C, i_u^C \rangle$, where the lower bound of the interval is $i_l^C = \frac{1}{\sigma_u^2}\left[(y-\frac{\bar{s}}{2})(\sigma_u^2+\sigma_C^2)-\sigma_C^2\rho i^*\right]$ and the upper bound of the interval is $i_u^C = \frac{1}{\sigma_u^2}\left[(y+\frac{\bar{s}}{2})(\sigma_u^2+\sigma_C^2)-\sigma_C^2\rho i^*\right]$. Calculation of $\mathbb{E}[\bar{i}^*|i^*,i^j,i^C \in \langle i_l^C, i_u^C \rangle]$ is then easy using the law of iterated expectations, which allows us to rewrite the expression to $\mathbb{E}[\mathbb{E}[\bar{i}^*|i^*,i^j,i^C]|i^*,i^j,i^C \in \langle i_l^C, i_u^C \rangle]$. The inner expectations are equal to $\frac{\rho i^*\sigma_j^2\sigma_C^2+i^j\sigma_u^2\sigma_C^2+i^C\sigma_u^2\sigma_j^2}{\sigma_u^2\sigma_j^2+\sigma_u^2\sigma_C^2+\sigma_C^2\sigma_j^2}$. Moreover, we know that the distribution of i^C given i^* and i^j is normal, with mean $\frac{\rho i^* \sigma_j^2 + i^j \sigma_u^2}{\sigma_u^2 + \sigma_j^2}$ and variance $\frac{\sigma_u^2 \sigma_j^2}{\sigma_u^2 + \sigma_j^2} + \sigma_C^2$. The last result we use to calculate the expectations is that for random variable x_1 distributed according to $N(\mu, \sigma^2)$. The conditional expectation of x_1 given that $x_1 \in \langle a_l, a_u \rangle$ is given by $\mathbb{E}[x_1 | x_1 \in \langle a_l, a_u \rangle] = \mu + \sigma \frac{\phi(\frac{a_l - \mu}{\sigma}) - \phi(\frac{a_u - \mu}{\sigma})}{\Phi(\frac{a_u - \mu}{\sigma}) - \Phi(\frac{a_l - \mu}{\sigma})}$, where $\phi(\cdot)$ and $\Phi(\cdot)$ are, respectively, the probability density and cumulative distribution functions of the univariate standard normal distribution. With the voting pattern determined, we can calculate the $skew$ variable and proceed to the next period.

In the opportunistic model with $\rho = 0.95$, $\delta = 0$ and $\bar{s} = 0.25$, the chairman C knows the most preferred policies of all the committee members. For each player j, this policy will be the policy in Y closest to j's expectation of $\bar{i}^*$ given i^* and i^j, i.e. closest to $\mathbb{E}[\bar{i}^* | i^*, i^j] = \frac{\rho i^* \sigma_j^2 + i^j \sigma_u^2}{\sigma_u^2 + \sigma_j^2}$. At the beginning of each period with status quo x and last-period optimal interest rate i^*, given a fresh drawn of $r = \{\bar{i}^*, i^{P1}, \ldots, i^{PN}, i^C\}'$, we will then have the vector of most preferred policies $\{p_1^*, \ldots, p_{N+1}^*\}$, which we order so that $p_j^* \leq p_{j+1}^*$ for $j \in \{1, \ldots, N\}$, where we denote the policy most preferred by the median member by $p_m^* = p_{N/2+1}^*$.

In the opportunistic model, C's proposal will be the policy which receives a super-majority of at least $\frac{N}{2} + 2$ members. It is easy to see that this will be the policy in the interval (x, p_m^*) (where the order is reversed if the status quo x is larger than p_m^*) that is closest to p_m^* if such policy exists. Otherwise, the proposal will be equal to the status quo x.

Next, we need to calculate the $skew$ variable. For this, we again use the voting rule (2) along with the assumption that player j does not extract any information content from proposal y and votes for y as opposed to voting for the status quo x if and only if

$$x^2 - y^2 \geq 2(x - y)\mathbb{E}[\ \bar{i}^* | i^*, i^j] \tag{A6}$$

with $\mathbb{E}[\ \bar{i}^* | i^*, i^j] = \frac{\rho i^* \sigma_j^2 + i^j \sigma_u^2}{\sigma_u^2 + \sigma_j^2}$. By construction, C's proposal is always accepted, with the number of votes for y being at least $\frac{N}{2} + 2$. With the voting pattern and hence $skew$ determined, we move to the next period.

Finally, in the intertemporal democratic model with $\bar{s} = 0.25$, $\rho = 0$ and $\delta = 0.95$, the previous-period optimal interest rate i^* plays no role and hence the only relevant information is the current status quo x. We again start each period of the simulation by drawing fresh values for $r = \{\bar{i}^*, i^{P1}, \dots, i^{PN}, i^C\}'$. Next, we need to determine C's proposal. This will again be the solution to the optimization problem

$$\max_{y \in \mathbb{X}} \mathbb{E}\left[-(p(x,y) - \bar{i}^*)^2 + \delta U_C(p(x,y), \bar{i}^C) | i^C\right] \tag{A7}$$

where $U_C(\cdot)$ is the continuation value function of a game starting with the status quo $p(x,y)$ and C's signal $\bar{i}^C$. The expression can again be rewritten as

$$\max_{y \in \mathbb{X}} \left[\begin{array}{l} p_a \mathbb{E}[-(y - \bar{i}^*)^2 | i^C, a] + (1 - p_a)\mathbb{E}[-(x - \bar{i}^*)^2 | i^C, \hat{a}] \\ +\delta p_a V_C(y) + \delta(1 - p_a) V_C(x) \end{array} \right] \tag{A8}$$

where $V_C(x) = \int U_C(x,z) f(z) dz$, with $f(z)$ being a probability distribution function of univariate normal distribution with mean zero and variance equal to $\sigma_u^2 + \sigma_C^2$. With $V_C(\cdot)$ known (we explain its estimation below) we proceed similarly as in the democratic model, calculating the probability of y being accepted and the expected values in the maximand. The distribution of the random variables $\{\bar{i}^*, i^{P1}, \dots, i^{PN}\}$ given i^C is again $N(\mu, \Sigma)$, with each element of μ being equal to $\frac{i^C \sigma_u^2}{\sigma_u^2 + \sigma_C^2}$ and Σ being a matrix with vector $\{\sigma', \sigma' + \sigma_P^2, \dots, \sigma' + \sigma_P^2\}'$ on the main diagonal and $\sigma' = \frac{\sigma_u^2 \sigma_C^2}{\sigma_u^2 + \sigma_C^2}$ off the main diagonal.

The voting behaviour of P member j given status quo x, proposal y and signal i^j is again given by the voting rule (2), which for the intertemporal democratic model becomes

$$\mathbb{E}\left[-(y - \bar{i}^*)^2 + \delta U_P(y, \bar{i}^j) | i^j\right] \geq \mathbb{E}\left[-(x - \bar{i}^*)^2 + \delta U_P(x, \bar{i}^j) | i^j\right] \tag{A9}$$

where $U_P(\cdot)$ is the continuation value function of the P member from a game starting with the given status quo and signal. Note that this function is equal for all P players. This condition can be rewritten as

$$x^2 - y^2 + \delta(V_P(y) - V_P(x)) \geq 2(y - x)E[\ \bar{i}^* | i^j] \tag{A10}$$

with $\mathbb{E}[\ \bar{i}^* | i^j] = \frac{i^j \sigma_u^2}{\sigma_u^2 + \sigma_j^2}$ and $V_P(x) = \int U_P(x,z) f(z) dz$, with $f(z)$ being a probability distribution function of univariate normal distribution with mean zero and variance equal to $\sigma_u^2 + \sigma_P^2$. With the voting pattern determined, we can calculate the $skew$ variable and proceed to the next period.

It remains to explain how we determine the continuation value functions. Prior to running the simulations, we estimate the $V_C(\cdot)$ and $V_P(\cdot)$ functions by standard value function iteration. We start with $V_{C,0}(\cdot) = 0$ and $V_{P,0}(\cdot) = 0$ and determine both functions $V_{C,s}(\cdot)$ and $V_{P,s}(\cdot)$ in a general step s as follows.

For $V_{C,s}(\cdot)$ we use numerical integration via the standard Gaussian quadrature method using the 'compecon' toolbox described in Miranda and Fackler (2002). To determine $V_{C,s}(x)$ for a specific value of x, we determine the set of nodes for C's signals $\{i^1, \ldots, i^H\}$ (using $H = 9$ in practice) and for each signal $i^h \in \{i^1, \ldots, i^H\}$ calculate

$$U_{C,s}(x, i^h) = \max_{y \in \mathbb{X}} \left[\begin{array}{l} p_a \mathbb{E}[-(y - \bar{i}^*)^2 | i^h, a] + (1 - p_a)\mathbb{E}[-(x - \bar{i}^*)^2 | i^h, \hat{a}] \\ +\delta p_a V_{C,s-1}(y) + \delta(1 - p_a) V_{C,s-1}(x) \end{array} \right] \tag{A11}$$

using the approach described above. The cut-off values for the calculation of the probability of acceptance are derived from the voting rule, which uses the $V_{P,s-1}(\cdot)$ function.

For $V_{P,s}(\cdot)$ we use the same numerical integration approach, generating the set of P's signals and numerically integrating $V_{P,s}(x) = \int U_{P,s}(x, z) f(z) dz$. The only complication is that we need to determine the $U_{P,s}(\cdot)$ function. For the specific status quo x and signal i^j of P player j, $U_{P,s}(x, i^j)$ gives the continuation value from the game starting with x and i^j and hence can be written as

$$U_{P,s}(x, i^j) = \mathbb{E}\left[-(p - \bar{i}^*)^2 + \delta U_{P,s-1}(p, \bar{i}^j) | i^j\right] \tag{A12}$$

but the expectation operator hides considerable complexity. First, j does not know C's signal and hence her proposal. Second, j does not know whether the proposal will be accepted or not, and third, j does not know the next-period signal. Reconciling the third source of uncertainty is straightforward and the whole expression can be rewritten as

$$U_{P,s}(x, i^j) = \mathbb{E}\left[-(p - \bar{i}^*)^2 + \delta V_{P,s-1}(p) | i^j\right] \tag{A13}$$

with only the first two sources of uncertainty remaining.

To resolve those we need to take expectations over C's signal, which will determine her proposal as well. Expanding the expectations operator thus gives

$$U_{P,s}(x, i^j) = \int \left[\begin{array}{l} p_a(z)[\mathbb{E}[-(y(z) - \bar{i}^*)^2 | i^j, z, a] + \delta V_{P,s-1}(y(z))] \\ +(1 - p_a(z))[\mathbb{E}[-(x - \bar{i}^*)^2 | i^j, z, \hat{a}] + \delta V_{P,s-1}(x)] \end{array} \right] f(z) dz \tag{A14}$$

where the variable of integration is C's signal, $y(z)$ is C's proposal given her signal, $p_a(z)$ is the probability of this proposal being accepted, and $f(z)$ is the probability distribution function of C 's signal.

Hence, in order to get $V_{P,s}(\cdot)$ we need to integrate twice, once over the distribution of j's signal (which will be normal, with mean zero and variance $\sigma_u^2 + \sigma_P^2$) and once over the distribution of

C's signal (which for a given value of i^j will be normal, with mean equal to $\frac{i^j\sigma_u^2}{\sigma_u^2+\sigma_P^2}$ and variance equal to $\frac{\sigma_u^2\sigma_P^2}{\sigma_u^2+\sigma_P^2}+\sigma_C^2$). Integrating numerically then amounts to generating a grid of discrete nodes in $\mathbb{R}^2$ with one dimension for j's signals and nodes $\{i^1,\dots,i^M\}$ and the second dimension for C's signal and nodes $\{i^1,\dots,i^H\}$ (again we use $H=M=9$ in practice).

For each node in $\mathbb{R}^2$ consisting of $\{i^m,i^h\}$ we calculate

$$\begin{aligned}&p_a(i^h)[\mathbb{E}[-(y(i^h)-\bar{i}^*)^2|i^m,i^h,a]+\delta V_{P,s-1}(y(i^h))]\\&+(1-p_a(i^h))[\mathbb{E}[-(x-\bar{i}^*)^2|i^m,i^h,\hat{a}]+\delta V_{P,s-1}(x)]\end{aligned} \tag{A15}$$

which then allows us to calculate $V_{P,s}(\cdot)$. To calculate the expression, we first calculate C's proposal $y(i^h)$. Given the proposal, we can calculate the probability of the proposal being accepted (with j taking into account his own voting behaviour) and, finally, the remaining expectations given acceptance or rejection. In the whole expression, j will condition on the information embedded in $\{i^m,i^h\}$ and hence the appropriate conditional distribution of the remaining random variables in the model $\{\bar{i}^*,i^{P1},\dots,i^{PN-1}\}$ is multivariate normal $N(\mu,\Sigma)$, with each element of μ being equal to $\frac{\sigma_u^2(\sigma_C^2 i^m+\sigma_P^2 i^h)}{\sigma_u^2(\sigma_C^2+\sigma_P^2)+\sigma_C^2\sigma_P^2}$ and Σ being a matrix with vector $\{\sigma',\sigma'+\sigma_P^2,\dots,\sigma'+\sigma_P^2\}'$ on the main diagonal and $\sigma'=\frac{\sigma_u^2\sigma_C^2\sigma_P^2}{\sigma_u^2(\sigma_C^2+\sigma_P^2)+\sigma_C^2\sigma_P^2}$ off the main diagonal.

We iterate on s until $\max\{||V_{P,s}-V_{P,s-1}||,||V_{C,s}-V_{C,s-1}||\}\geq 0.001$, where $||\cdot||$ is the usual sup norm. We experienced no problems with convergence, and the typical s needed was around 70 iterations.

Next, we re-run the simulations of the democratic, consensual, opportunistic and mechanical models for different parameter values compared to those in the main part of the paper. First, we changed the benchmark $\rho=0.95$ to $\rho=0.90$, second we changed the benchmark $\rho=0.95$ to $\rho=0.99$, and third we changed the underlying $AR(1)$ process for optimal policy to $AR(2)$. In this specification, it evolves according to $i_t^*=\rho_1 i_{t-1}^*+\rho_2 i_{t-2}^*+u_t$ and we picked $\rho_1=1.95$ and $\rho_2=-0.98$ following Gerlach-Kristen (2008). Note that the model changes only in that ρi_{t-1}^* in the expressions for expectations changes to $\rho_1 i_{t-1}^*+\rho_2 i_{t-2}^*$. With the $AR(2)$ process governing the optimal policy we also had to change the standard deviation of the underlying shocks, but followed the same rationale as in the benchmark model. That is, Δi_t^* has a standard deviation of

$\sqrt{\frac{2}{(1+\rho_2)(1+\rho_1-\rho_2)}}\sigma_u$, hence in order to match the observed standard deviation of the policy changes between 0.25 and 0.50 we set $\sigma_u = 0.05$ in the baseline scenario and correspondingly decreased the noise in the committee signals to $\sigma_C = 0.05$ and $\sigma_P = 0.05$, doubling those values when appropriate for the other scenarios. The results of the simulations are given in Tables 9–14, with the following Tables 15 and 16 showing the results of the simulations for the opportunistic model with a simple majority as opposed to the super-majority used in the benchmark simulations.

Table 9 – Does the Voting Record Predict Policy Rate Changes? Estimates Using Simulated Data with $N = 4$ and $\rho = 0.90$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	4.16 *	5.90	6.22	0.05
	[1.64] (0.074)	[3.24] (0.159)	[6.56] (0.391)	[3.94] (0.438)
Lagged policy change (a_2)	0.65	-0.02	1.62	-0.38
	[0.54] (0.305)	[0.46] (0.548)	[0.77] (0.107)	[1.24] (0.459)
MSE	0.027	0.033	0.034	0.005
Votes proposal/No change	2.91/0.43	4.63/0.41	4.83/0.59	---/0.36
High volatility scenario ($\sigma_u = 0.5$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	2.20	3.05	0.91	0.21
	[1.06] (0.118)	[2.50] (0.303)	[3.65] (0.506)	[2.03] (0.424)
Lagged policy change (a_2)	0.17	-0.04	0.54	-0.04
	[0.24] (0.454)	[0.21] (0.534)	[0.29] (0.155)	[0.64] (0.455)
MSE	0.041	0.050	0.045	0.005
Votes proposal/No change	3.48/0.28	4.62/0.24	4.78/0.37	---/0.19
Bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.5$, $\sigma_P = 0.5$)				
Skew (a_1)	3.43 *	6.79	6.50	---
	[1.52] (0.100)	[3.58] (0.164)	[6.53] (0.349)	---
Lagged policy change (a_2)	0.19	-0.03	1.00	---
	[0.49] (0.514)	[0.47] (0.505)	[0.67] (0.248)	---
MSE	0.048	0.052	0.052	---
Votes proposal/No change	2.97/0.43	4.69/0.42	4.85/0.57	---
P bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.5$)				
Skew (a_1)	4.93 **	8.86	7.36	---
	[1.78] (0.036)	[6.25] (0.250)	[6.57] (0.335)	---
Lagged policy change (a_2)	0.76	-0.28	1.22	---
	[0.56] (0.284)	[0.42] (0.473)	[0.70] (0.181)	---
MSE	0.041	0.036	0.050	---
Votes proposal/No change	2.70/0.51	4.88/0.37	4.84/0.58	---

Note: Average ordered probit estimates over 101 random 100-period-long paths. [Average standard errors] and (average p-value). * statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level based on average p-value. MSE is average mean squared difference between adopted and optimal policy. Votes proposal is average number of votes for chairman's proposal. No change is proportion of committee meetings with no policy change.

Table 10 – Does the Voting Record Predict Policy Rate Changes? Estimates Using Simulated Data with $N = 6$ and $\rho = 0.90$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	5.07 **	6.57	7.65	-0.02
	[1.65] (0.025)	[3.25] (0.130)	[5.40] (0.257)	[3.39] (0.513)
Lagged policy change (a_2)	1.00	0.06	1.98	-0.39
	[0.56] (0.172)	[0.46] (0.516)	[0.85] (0.102)	[1.04] (0.530)
MSE	0.026	0.033	0.030	0.005
Votes proposal/No change	3.85/0.47	6.45/0.41	6.62/0.57	---/0.36
High volatility scenario ($\sigma_u = 0.5$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	2.38 *	3.25	1.86	-0.05
	[1.03] (0.096)	[2.45] (0.302)	[3.04] (0.421)	[1.75] (0.514)
Lagged policy change (a_2)	0.21	-0.03	0.54	-0.12
	[0.24] (0.451)	[0.21] (0.529)	[0.30] (0.164)	[0.54] (0.555)
MSE	0.039	0.049	0.036	0.005
Votes proposal/No change	4.69/0.30	6.42/0.24	6.53/0.34	---/0.19
Bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.5$, $\sigma_P = 0.5$)				
Skew (a_1)	3.62 *	7.53	6.70	---
	[1.49] (0.079)	[3.63] (0.133)	[5.23] (0.305)	---
Lagged policy change (a_2)	0.33	0.05	1.11	---
	[0.51] (0.450)	[0.48] (0.500)	[0.69] (0.218)	---
MSE	0.047	0.052	0.050	---
Votes proposal/No change	3.94/0.46	6.53/0.42	6.67/0.54	---
P bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.5$)				
Skew (a_1)	5.56 **	11.17	7.73	---
	[1.72] (0.017)	[6.57] (0.206)	[5.26] (0.274)	---
Lagged policy change (a_2)	0.94	-0.22	1.28	---
	[0.57] (0.194)	[0.43] (0.518)	[0.72] (0.182)	---
MSE	0.041	0.036	0.048	---
Votes proposal/No change	3.60/0.52	6.82/0.37	6.66/0.55	---

Notes: See Table 9.

Table 11 – Does the Voting Record Predict Policy Rate Changes?
Estimates Using Simulated Data with $N = 4$ and $\rho = 0.99$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	4.30 *	6.33	7.06	0.52
	[1.65] (0.065)	[3.25] (0.152)	[6.31] (0.351)	[4.05] (0.435)
Lagged policy change (a_2)	0.78	0.15	1.86 *	-0.11
	[0.53] (0.237)	[0.45] (0.511)	[0.73] (0.068)	[1.28] (0.485)
MSE	0.027	0.033	0.033	0.005
Votes proposal/No change	2.94/0.42	4.64/0.41	4.83/0.58	---/0.37
High volatility scenario ($\sigma_u = 0.5$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	2.16	2.68	0.77	0.05
	[1.05] (0.140)	[2.48] (0.373)	[3.60] (0.523)	[2.07] (0.438)
Lagged policy change (a_2)	0.29	0.04	0.66 *	-0.01
	[0.24] (0.344)	[0.21] (0.494)	[0.29] (0.090)	[0.65] (0.472)
MSE	0.041	0.050	0.045	0.005
Votes proposal/No change	3.45/0.28	4.61/0.24	4.78/0.37	---/0.19
Bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.5$, $\sigma_P = 0.5$)				
Skew (a_1)	3.58	7.01	5.67	---
	[1.53] (0.103)	[3.67] (0.160)	[6.19] (0.410)	---
Lagged policy change (a_2)	0.38	0.11	1.06	---
	[0.47] (0.390)	[0.45] (0.457)	[0.61] (0.207)	---
MSE	0.049	0.052	0.052	---
Votes proposal/No change	3.05/0.41	4.70/0.39	4.84/0.53	---
P bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.5$)				
Skew (a_1)	4.83 *	8.77	6.46	---
	[1.76] (0.056)	[6.08] (0.279)	[6.16] (0.334)	---
Lagged policy change (a_2)	0.87	-0.14	1.33	---
	[0.53] (0.228)	[0.41] (0.492)	[0.64] (0.134)	---
MSE	0.041	0.036	0.049	---
Votes proposal/No change	2.78/0.49	4.88/0.37	4.83/0.55	---

Notes: See Table 9.

Table 12 – Does the Voting Record Predict Policy Rate Changes? Estimates Using Simulated Data with $N = 6$ and $\rho = 0.99$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	4.94 **	6.70	8.16	0.12
	[1.66] (0.029)	[3.24] (0.128)	[5.21] (0.255)	[3.49] (0.502)
Lagged policy change (a_2)	1.12	0.22	2.20 **	-0.23
	[0.55] (0.128)	[0.45] (0.470)	[0.80] (0.047)	[1.08] (0.504)
MSE	0.026	0.033	0.029	0.005
Votes proposal/No change	3.92/0.45	6.46/0.41	6.61/0.56	---/0.37
High volatility scenario ($\sigma_u = 0.5$, $\sigma_C = 0.25$, $\sigma_P = 0.25$)				
Skew (a_1)	2.35	2.91	1.39	0.06
	[1.02] (0.108)	[2.48] (0.318)	[2.92] (0.466)	[1.78] (0.507)
Lagged policy change (a_2)	0.33	0.05	0.65	-0.01
	[0.25] (0.284)	[0.21] (0.500)	[0.31] (0.111)	[0.54] (0.535)
MSE	0.040	0.049	0.036	0.005
Votes proposal/No change	4.64/0.31	6.41/0.24	6.50/0.33	---/0.19
Bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.5$, $\sigma_P = 0.5$)				
Skew (a_1)	3.59 *	8.24	6.22	---
	[1.48] (0.069)	[3.66] (0.114)	[5.05] (0.292)	---
Lagged policy change (a_2)	0.46	0.21	1.15	---
	[0.48] (0.388)	[0.45] (0.422)	[0.63] (0.166)	---
MSE	0.048	0.039	0.050	---
Votes proposal/No change	4.07/0.44	6.55/0.39	6.67/0.51	---
P bad information scenario ($\sigma_u = 0.25$, $\sigma_C = 0.25$, $\sigma_P = 0.5$)				
Skew (a_1)	5.23 **	11.56	6.69	---
	[1.70] (0.024)	[6.45] (0.174)	[5.04] (0.271)	---
Lagged policy change (a_2)	1.04	-0.07	1.38	---
	[0.54] (0.148)	[0.42] (0.516)	[0.66] (0.108)	---
MSE	0.041	0.036	0.047	---
Votes proposal/No change	3.71/0.51	6.82/0.36	6.65/0.52	---

Notes: See Table 9.

Table 13 – Does the Voting Record Predict Policy Rate Changes?
Estimates Using Simulated Data with $N = 4$ and $\rho_1 = 1.95$, $\rho_2 = -0.98$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.05$, $\sigma_C = 0.05$, $\sigma_P = 0.05$)				
Skew (a_1)	12.88 ***	14.95	19.38	-0.31
	[3.03] (0.002)	[8.37] (0.138)	[11.81] (0.177)	[5.89] (0.550)
Lagged policy change (a_2)	4.40 ***	3.62 **	4.02 **	3.57
	[0.72] (0.008)	[0.85] (0.034)	[0.90] (0.032)	[1.90] (0.186)
MSE	0.006	0.006	0.006	0.005
Votes proposal/No change	3.23/0.47	4.92/0.47	4.95/0.48	---/0.48
High volatility scenario ($\sigma_u = 0.10$, $\sigma_C = 0.05$, $\sigma_P = 0.05$)				
Skew (a_1)	5.96	15.21	19.04	0.14
	[2.50] (0.107)	[8.28] (0.145)	[10.77] (0.173)	[3.23] (0.489)
Lagged policy change (a_2)	4.10 ***	3.77 **	4.18 **	4.09 **
	[0.44] (0.000)	[0.72] (0.030)	[0.65] (0.020)	[1.07] (0.018)
MSE	0.007	0.007	0.007	0.005
Votes proposal/No change	4.18/0.27	4.92/0.28	4.95/0.29	---/0.27
Bad information scenario ($\sigma_u = 0.05$, $\sigma_C = 0.10$, $\sigma_P = 0.10$)				
Skew (a_1)	13.69 ***	16.25	17.35	---
	[3.05] (0.006)	[11.07] (0.155)	[12.60] (0.259)	---
Lagged policy change (a_2)	4.18 ***	3.40 **	3.52 *	---
	[0.70] (0.006)	[0.83] (0.039)	[1.04] (0.053)	---
MSE	0.007	0.007	0.007	---
Votes proposal/No change	3.15/0.46	4.94/0.46	4.96/0.48	---
P bad information scenario ($\sigma_u = 0.05$, $\sigma_C = 0.05$, $\sigma_P = 0.10$)				
Skew (a_1)	16.12 ***	14.59	19.76	---
	[3.68] (0.007)	[138.32] (0.470)	[12.08] (0.174)	---
Lagged policy change (a_2)	4.25 ***	2.63	3.75 **	---
	[0.70] (0.003)	[2.67] (0.239)	[0.77] (0.022)	---
MSE	0.007	0.007	0.007	---
Votes proposal/No change	3.82/0.48	4.98/0.46	4.95/0.48	---

Notes: See Table 9.

Table 14 – Does the Voting Record Predict Policy Rate Changes?
Estimates Using Simulated Data with $N = 6$ and $\rho_1 = 1.95$, $\rho_2 = -0.98$
$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$

Model	Democratic	Consensual	Opportunistic	Mechanical
Baseline scenario ($\sigma_u = 0.05$, $\sigma_C = 0.05$, $\sigma_P = 0.05$)				
Skew (a_1)	17.56 ***	16.49	18.38	0.26
	[3.55] (0.000)	[8.67] (0.106)	[9.53] (0.106)	[5.09] (0.525)
Lagged policy change (a_2)	5.02 ***	3.75 **	4.19 ***	3.71
	[0.79] (0.003)	[0.67] (0.014)	[0.72] (0.009)	[1.61] (0.125)
MSE	0.006	0.006	0.006	0.005
Votes proposal/No change	4.13/0.47	6.88/0.47	6.90/0.48	---/0.48
High volatility scenario ($\sigma_u = 0.10$, $\sigma_C = 0.05$, $\sigma_P = 0.05$)				
Skew (a_1)	10.09 **	15.50	16.70	-0.21
	[3.10] (0.025)	[8.52] (0.142)	[8.74] (0.114)	[2.78] (0.543)
Lagged policy change (a_2)	4.30 ***	3.83 **	4.37 ***	3.98 **
	[0.45] (0.000)	[0.62] (0.020)	[0.46] (0.000)	[0.90] (0.017)
MSE	0.007	0.007	0.006	0.005
Votes proposal/No change	5.33/0.27	6.88/0.28	6.89/0.29	---/0.27
Bad information scenario ($\sigma_u = 0.05$, $\sigma_C = 0.10$, $\sigma_P = 0.10$)				
Skew (a_1)	16.22 ***	17.79	17.53	---
	[3.56] (0.000)	[9.88] (0.129)	[10.26] (0.163)	---
Lagged policy change (a_2)	4.27 ***	3.54 **	3.70 **	---
	[0.70] (0.005)	[0.65] (0.018)	[0.76] (0.023)	---
MSE	0.007	0.007	0.007	---
Votes proposal/No change	4.31/0.46	6.90/0.46	6.92/0.47	---
P bad information scenario ($\sigma_u = 0.05$, $\sigma_C = 0.05$, $\sigma_P = 0.10$)				
Skew (a_1)	17.63 ***	21.99	18.10	---
	[3.95] (0.001)	[192.17] (0.369)	[9.84] (0.153)	---
Lagged policy change (a_2)	4.33 ***	3.05	3.81 **	---
	[0.71] (0.002)	[1.75] (0.139)	[0.78] (0.022)	---
MSE	0.007	0.007	0.007	---
Votes proposal/No change	4.93/0.48	6.97/0.46	6.91/0.47	---

Notes: See Table 9.

Table 15 – Does the Voting Record Predict Policy Rate Changes?
Opportunistic Model with Simple Majority, Estimates Using Simulated Data with $N = 4$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

	$\rho = 0.95$	$\rho = 0.90$	$\rho = 0.99$	$\rho_1 = 1.95$, $\rho_2 = -0.98$
Baseline scenario				
Skew (a_1)	6.58	6.53	6.58	13.65 *
	[3.19] (0.142)	[3.22] (0.135)	[3.14] (0.123)	[6.03] (0.060)
Lagged policy change (a_2)	1.51	1.45	1.65 *	4.19 **
	[0.72] (0.120)	[0.75] (0.133)	[0.72] (0.083)	[0.72] (0.011)
MSE	0.024	0.025	0.025	0.006
Votes proposal/No change	4.46/0.45	4.46/0.46	4.45/0.44	4.87/0.47
High volatility scenario				
Skew (a_1)	1.82	1.77	1.76	12.12 *
	[1.78] (0.365)	[1.78] (0.363)	[1.79] (0.392)	[5.35] (0.075)
Lagged policy change (a_2)	0.37	0.28	0.40	4.33 ***
	[0.27] (0.267)	[0.27] (0.340)	[0.28] (0.236)	[0.46] (0.000)
MSE	0.026	0.026	0.026	0.006
Votes proposal/No change	4.38/0.22	4.38/0.23	4.37/0.22	4.87/0.27
Bad information scenario				
Skew (a_1)	5.11	5.71	5.23	13.22
	[3.11] (0.193)	[3.22] (0.187)	[3.09] (0.197)	[6.65] (0.123)
Lagged policy change (a_2)	0.70	0.72	0.76	3.69 **
	[0.59] (0.317)	[0.62] (0.317)	[0.57] (0.280)	[0.67] (0.015)
MSE	0.048	0.048	0.047	0.007
Votes proposal/No change	4.56/0.43	4.56/0.45	4.56/0.42	4.90/0.46
P bad information scenario				
Skew (a_1)	5.90	5.89	5.65	13.24 *
	[3.13] (0.162)	[3.24] (0.181)	[3.07] (0.148)	[6.36] (0.098)
Lagged policy change (a_2)	0.95	0.95	1.00	3.82 **
	[0.63] (0.237)	[0.66] (0.244)	[0.60] (0.186)	[0.68] (0.014)
MSE	0.044	0.043	0.043	0.007
Votes proposal/No change	4.53/0.44	4.53/0.46	4.53/0.43	4.89/0.46

Note: Average ordered probit estimates over 101 random 100-period-long paths. [Average standard errors] and (average p-value). * statistically significant at 10% level, ** statistically significant at 5% level, *** statistically significant at 1% level based on average p-value. MSE is average mean squared difference between adopted and optimal policy. Votes proposal is average number of votes for chairman's proposal. No change is proportion of committee meetings with no policy change. Values of σ_u, σ_C and σ_P depend on ρ, but correspond to those in previous tables.

Table 16 – Does the Voting Record Predict Policy Rate Changes?
Opportunistic Model with Simple Majority, Estimates Using Simulated Data with $N = 6$

$$\Delta p_{t+1} = a_0 + a_1 skew_t + a_2 \Delta p_t + u_{t+1}$$

	$\rho = 0.95$	$\rho = 0.90$	$\rho = 0.99$	$\rho_1 = 1.95$, $\rho_2 = -0.98$
Baseline scenario				
Skew (a_1)	7.66	7.35 *	7.73	13.51 *
	[3.36] (0.109)	[3.37] (0.090)	[3.34] (0.115)	[5.90] (0.065)
Lagged policy change (a_2)	1.99 *	1.88 *	2.13 **	4.24 **
	[0.79] (0.052)	[0.81] (0.063)	[0.79] (0.047)	[0.73] (0.014)
MSE	0.024	0.024	0.024	0.006
Votes proposal/No change	6.21/0.46	6.21/0.47	6.21/0.46	6.81/0.47
High volatility scenario				
Skew (a_1)	2.11	2.03	2.10	12.43 *
	[1.86] (0.330)	[1.88] (0.333)	[1.88] (0.332)	[5.21] (0.060)
Lagged policy change (a_2)	0.44	0.38	0.50	4.39 ***
	[0.29] (0.237)	[0.29] (0.288)	[0.29] (0.202)	[0.46] (0.000)
MSE	0.023	0.023	0.023	0.006
Votes proposal/No change	6.06/0.22	6.08/0.23	6.06/0.22	6.80/0.27
Bad information scenario				
Skew (a_1)	5.65	6.08	5.58	13.23
	[3.16] (0.170)	[3.28] (0.166)	[3.13] (0.183)	[6.27] (0.104)
Lagged policy change (a_2)	0.85	0.86	0.92	3.76 **
	[0.62] (0.260)	[0.65] (0.305)	[0.59] (0.243)	[0.68] (0.015)
MSE	0.047	0.047	0.047	0.007
Votes proposal/No change	6.34/0.43	6.35/0.45	6.35/0.42	6.85/0.46
P bad information scenario				
Skew (a_1)	6.14	6.51	6.01	13.53 *
	[3.18] (0.156)	[3.30] (0.156)	[3.14] (0.147)	[6.11] (0.083)
Lagged policy change (a_2)	1.04	1.10	1.14	3.86 **
	[0.64] (0.216)	[0.69] (0.218)	[0.63] (0.170)	[0.69] (0.013)
MSE	0.044	0.044	0.044	0.007
Votes proposal/No change	6.31/0.43	6.32/0.46	6.31/0.43	6.83/0.46

Notes: See Table 15.

A2 Data

Voting records

Voting records were collected from the following central banks (start and end dates of the sample in brackets): the Czech Republic (1998:1–2008:12), the United Kingdom (1997:6–2009:2), Hungary (2005:10–2009:2), Poland (2000:2–2008:12) and Sweden (1999:1–2009:2). Typically, voting data are available at a monthly frequency.

As regards the Czech Republic, the 1998:1–2000:4 voting results were available only in transcripts that are published with a 6-year delay. Therefore, the baseline estimates for this country are based on the data from 2000:7 onwards. In addition, the baseline estimates for the Czech Republic are restricted until 2006:7 in the specification with financial market expectations. The reason is that from this period onwards the voting record was released only about 3 hours after the monetary policy decision was announced. The monetary policy decision was typically announced at around 1 p.m. and the voting ratio was released at around 3.30 p.m. at a press conference. In principle, the interbank rates could have been collected at, say, 2 p.m. and therefore more recent data could have been used as well, but it has to be emphasized that the interbank market was not very liquid during the financial crisis. In light of this fact, we restrict the data for the Czech Republic to the period until 2006:7.

Interbank rates

Interbank rates are collected to capture financial market expectations. The source of the data is Datastream. Specifically, we use PRIBOR rates for the Czech Republic, BUBOR rates for Hungary, WIBOR rates for Poland, STIBOR rates for Sweden and LIBOR rates for the UK for the following maturities: 1 month, 3 months and 12 months.

A3 Central Banks' Voting Record Release Schedules

Czech National Bank

The Bank Board meets on Thursdays.[12] A press conference with a presentation containing the voting ratio (without the names) takes place the same day in the early afternoon.

Until 8/2006, the voting ratio was not disclosed at the press conference.

The minutes are released the next Friday (+8 days). They contain the voting ratio, and since 1/2008 have also included the names explicitly.

Until 4/2005, the minutes were released on Tuesdays, two weeks after the meetings (+12 days).

Bank of England

The Monetary Policy Committee decides during a two-day meeting that takes place on Wednesdays and Thursdays. A press release of the decision follows at midday on Thursday.

The minutes are released two weeks later, on Wednesdays (+13 days). They contain the voting record with names.

Magyar Nemzeti Bank

The Monetary Council meets on Mondays. A press release of the decision follows on Monday at 3 p.m.

The minutes are released 2–4 weeks after the decision, usually on Wednesdays. They contain the detailed voting record with names.

National Bank of Poland

The Monetary Policy Council decides during a two-day meeting that takes place on Tuesdays-and Wednesdays. A press release of the decision follows on Wednesday.

The minutes are released on Thursdays in the week before the next MPC meeting, which means 3–4 weeks after the decision.

The MPC meeting minutes do not contain the voting records. The voting records are published only later, in the quarterly inflation reports. If the repo rate was changed, the voting record is first published in the Court and Economic Gazette of the Ministry of Justice and only after that in the inflation report. Voting records have to be published in the Court and Economic Gazette no sooner than 6 weeks and no later than 12 weeks after the voting took place.

Sveriges Riksbank

The Executive Board meets on Mondays or Wednesdays. A press release of the decision follows the same day.

The minutes are released approximately two weeks later (+14, or occasionally +15, days). They contain a detailed voting record with names.

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[12] There are some exceptions to the described organization of monetary policy decision-making processes for all the central banks, typically because of national holidays. For example, in the case of the Czech National Bank, the board usually meets on a Thursday. In exceptional cases, however, it may meet on a Wednesday instead of a Thursday because of holidays. Since 4/2005, the minutes have been published 8 days after the meeting. In the case of holidays, the minutes can be published more than 8 days after the meeting.

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