Monetary Policy Committees and the Benefits of Deliberation

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Abstract

The literature on interest rate setting by Monetary Policy Committees does not model the role of discussions in the decision process even though policymakers deliberate at each meeting. The committee members naturally change their views during these discussions before coming to a decision. We assume that uncertainty about the state and structure of the economy causes MPC members' views about the appropriate stance of monetary policy to differ. Discussions allow policymakers to adjust their views, and we demonstrate that this improves the policy outcome.

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1 Introduction

In the 1990s a number of central banks, among them the Bank of England, the Bank of Japan and the Bank of Sweden, shifted the responsibility for interest rate setting to a Monetary Policy Committee (MPC). These committees as well as the Federal Open Market Committee (FOMC) in the US meet to discuss the state of the economy and to decide in a majority vote on the appropriate level of interest rates.[1] In other economies such as the euro area and Switzerland the decision making organs responsible for monetary policy do not vote but set interest rates by consensus.

There is a growing theoretical literature on decision making in MPCs, which we review in the next section. While these papers provide rationales for why individual MPC members may have different views about the economy and therefore about the appropriate level of interest rates, they do not explain why policymakers meet to discuss the policy options. In principle committee members could simply gather for a vote and set the level of the policy rate equal to the median of these votes. In practice, however, discussions seem to be an important element in the decision process.

This paper provides a first attempt to model the benefits of deliberation. We assume that there is uncertainty about the state and structure of the economy and show that the committee can reduce the resulting uncertainty by exchanging information through discussions. We consider the cases of (a) no deliberation, (b) full information and (c) deliberation. In case (a) the interest rate is set in a vote and monetary policy deviates considerably from the interest rate which would be set under certainty. In case (b) the MPC members pool their information sets fully. A vote is unnecessary since all committee members agree on which level of the interest rate to set. The policy errors committed are smaller and decrease fast as the MPC is enlarged. In case (c), which we think of as the situation in which committee members communicate with each other but are unable to convey their views completely. Voting is necessary to reach a decision and policy outcomes are inferior to those under full information but superior to those achieved if there is no deliberation.

[1] The FOMC arguably deviates from the "one man, one vote" system of MPCs since the Chairman appears to have a larger influence on the interest rate decision than the other committee members.

The paper is organised as follows. Section 2 reviews the literature on MPCs, uncertainty in interest rate setting and common knowledge. Section 3 describes the model of the economy under certainty and derives an optimal interest rate reaction function. It then analyses how a single policymaker sets interest rates if he is subject to data and parameter uncertainty. Section 4 studies the conduct of monetary policy in a committee. We consider in turn the cases of no deliberation, full information and deliberation. Section 5 concludes.

2 Selected Survey of the Literature

This paper provides a theoretical explanation for why MPCs deliberate. Since discussions are necessary only if the individual committee members disagree about the appropriate level of interest rates, we assume as source of these different views uncertainty about the state and structure of the economy. Policymakers improve their judgement of the appropriate stance of policy by pooling their information sets. If communication is perfect, they agree on which level of the interest rate to implement. To set the stage for the subsequent discussion, we here briefly review the literature on MPCs, on uncertainty in the conduct of monetary policy and on common knowledge.

2.1 Monetary Policy Committees

There are three strands of papers on interest rate setting in MPCs, one theoretical, one empirical and one experimental. The theoretical literature focuses on two main questions. The first of these is why policymakers disagree about the level of interest rates. Several arguments have been advanced. Policymakers may disagree because they have different views about the optimal rate of inflation (see Waller [32], Sibert [27] and Mihov and Sibert [23] and the related popular discussion on "hawks" and "doves"). Alternatively, different views about the appropriate stance of policy may arise because MPC members use different measures of inflation (see Aksoy, De Grauwe and Dewachter [1], Von Hagen and Süppel [31] and the discussion on national interests in the ECB). Finally, committee members might disagree because some individuals are more skilled than others and therefore have a better sense of the appropriate level of interest rates (see Gersbach and Hahn [12]).[2]

The second question the theoretical literature on MPCs addresses is how different decision making procedures impact on policy. Gerlach-Kristen [9] studies the performance of different procedures under the assumption that committee members' views of the relevant economic data are subject to uncertainty. One key finding is that voting is desirable if policymakers' ability to judge the state of the economy differs.

The empirical literature on MPCs is rather limited. Gerlach-Kristen [10] and [11] studies the voting record of the MPC at the Bank of England, while Andersson, Dillén and Sillen [2] examine that of the Swedish Riksbank. In both cases the distribution of votes helps forecast interest rate changes. Meade [22] compares the information content of the voting records of the FOMC and of the MPC at the Bank of England and argues that there is evidence that skills differ in the FOMC, but not in the MPC.

Blinder and Morgan [6] and Lombardelli, Proudman and Talbot [19] provide some experimental evidence on decision making in MPCs. Both papers compare the decision making ability of committees to that of individuals and find that policy is better in the former case. Lombardelli, Proudman and Talbot moreover adduce evidence indicating that deliberation improves monetary policy beyond the performance achieved if the participants in the experiment do not discuss their views but merely vote on the interest rate. Their paper provides the starting point for the analysis conducted here. We model the benefits of deliberation by assuming that policymakers are uncertain about the economy but can reduce this uncertainty by discussing. Next we provide a short overview of papers which deal with the effect of uncertainty on policy decisions.

2.2 Uncertainty in Monetary Policy

Both Alan Blinder and Charles Goodhart, after serving on the FOMC and the MPC of the Bank of England, respectively, have emphasised the importance of uncertainty in the conduct of monetary policy (see Blinder [5] and Goodhart [13]). They discuss three kinds

[2] There also is an older literature linking FOMC members' background to their dissents (see e.g. Havrilesky and Gildea [18]).

of uncertainty.[3]

The first and arguably most serious of these is model uncertainty. This notion describes the situation in which it is not clear how monetary policy impacts on the economy. Obviously, model uncertainty renders the interest rate decision extremely difficult.

The second and both from a policy and a modelling perspective most benign kind of uncertainty is data, or additive, uncertainty. This concept captures the situation in which policymakers know the exact impact of the actual variables on each other but observe these variables imprecisely. Certainty equivalence in general implies that policymakers should act as if their perception of the data were correct.[4] Gerlach-Kristen [9] discusses the interest rate setting of an MPC under data uncertainty. It should be noted that deliberation in the MPC is not necessary in that model because it is possible to infer a policymaker's perception of the state of the economy from his preferred level of the interest rate.[5]

The third kind of uncertainty, which does not seem to have been discussed yet in the context of MPCs, concerns the parameters in the model and thus the structure of the economy. It is also referred to as multiplicative uncertainty. Brainard [7] shows that if the impact of an instrument on a goal variable is uncertain, it usually is best to move this instrument cautiously. Applying this framework to monetary policy, Martin [20] and Martin and Salmon [21] establish that interest rates should in general be changed less in response to movements in economic conditions than under certainty if it is not entirely clear how large an effect a change in the stance of monetary policy has. Thus, since the single policymaker should not use his perception of the uncertain parameter in the interest rate decision as if it corresponded to the truth, certainty equivalence does not hold under parameter uncertainty. While the main conclusion of this literature is that monetary policy ought to be less aggressive than otherwise, Sack [26] and Wieland [33], by contrast, argue that a tradeoff exists between caution and experimentation. They

[3] See also Batini, Martin and Salmon [4] and Hall, Salmon, Yates and Batini [16].

[4] See Orphanides [24], Rudebusch [25], Smets [28] and Swanson [30] for examples of additive uncertainty in which certainty equivalence breaks down.

[5] Gerlach-Kristen [9] assumes imprecise observations on only one variable. If there were a second uncertain variable, deliberation would be beneficial also in the case of data uncertainty.

suggest that policymakers should move interest rates by more than implied by economic conditions so as to learn about the structure of the economy. While we below ignore these dynamics of inter-temporal learning, we allow for the individual MPC members to learn from each other through discussions about the state and structure of the economy.

2.3 Common Knowledge

One implication of the model presented below is that all MPC members should favour the same level of the policy interest rate once they have fully pooled their information sets. This finding is related to the literature on common knowledge, which dates back to Aumann [3]. He shows that if two individuals share all information about a variable, they should form the same view of it.[6] For the case of an MPC, consider the situation in which two policymakers are able to communicate perfectly to each other their individual views of the state and structure of the economy. Policymaker 1 then updates his opinion of the economy using his colleague's view of it and vice versa. If both policymakers are rational, have the same goals and do not behave strategically, they should after this updating come to the same view of the economy and therefore of the appropriate level of the interest rate. To use Aumann's phrase, they cannot "agree to disagree."

In practice MPC members disagree even after having exchanged information.[7] Since we assume below that policymakers are rational, have the same goals and do not behave strategically, disagreement must arise because they fail to pool their information sets perfectly. We model this by assuming that committee members have difficulties in communicating in a sense made precise below.

[6] Geanakoplos [8] provides a series of examples.

[7] As noted above policymakers at the European Central Bank and the Swiss National Bank set interest rates by consensus. It could be argued that their discussions allow them to reach common knowledge. Alternatively, they might adopt a common view merely towards the outside while disagreement persists within the policy board.

3 The Basic Model

Next we outline the model. We first solve it assuming no uncertainty about the state and structure of the economy and then go on to show how a single policymaker sets interest rates under uncertainty.

3.1 No Uncertainty

As a starting point for the analysis we discuss how interest rates would be set if there were neither additive nor multiplicative uncertainty. The economy is described as a reduced form of a backward-looking Phillips and a backward-looking IS curve, so that the (demeaned) rate of inflation at time $t+1$ depends on its own lagged value and on the nominal interest rate at time t,

$$\pi_{t+1} = \beta\pi_t - \alpha_t i_t + \varepsilon_{\pi,t+1}, \tag{1}$$

where π_t denotes inflation, i_t the nominal interest rate and $\varepsilon_{\pi,t+1}$ a random shock.[8] We let $0 < \beta < 1$ and $\varepsilon_{\pi,t} \sim N(0, \sigma_\pi^2)$. The coefficient α_t, which we refer to as the impact coefficient, reflects the effect of monetary policy on the economy. It is a combination of underlying structural parameters and varies through time. In particular, we assume that α_t follows the AR(1) process

$$\alpha_t = A + \gamma\alpha_{t-1} + \varepsilon_{\alpha,t}, \tag{2}$$

where $0 < \gamma < 1$ and where the innovation $\varepsilon_{\alpha,t}$ is uncorrelated with $\varepsilon_{\pi,t}$ and normally distributed around zero with variance σ_α^2. Since high interest rates tend to reduce inflation, we let A be a positive number, so that the unconditional mean of α_t equals $A/(1-\gamma) > 0$. Note, however, that α_t also can take negative values. While this conflicts with the conventional wisdom, one can think of situations in which higher interest rates may increase inflation at least in the short run.[9]

[8] Martin and Salmon [21] have the real interest rate enter in equation (1). We replace it with the nominal rate so as to keep the problem compact.

[9] See e.g. Goyal and McKinnon's [14] discussion of the Japanese economy. They argue that higher interest rates would allow banks to restructure their balance sheets. This in turn should increase economic activity and lead to inflation.

The central bank minimises the loss function

$$L_t = E_t \sum_{i=0}^{\infty} \theta^t \pi_{t+i}^2, \tag{3}$$

with θ denoting the discount factor. Expression (3) corresponds to the situation in which the central bank attempts to reach an inflation target of zero.[10] Differentiating L_{t+1} with respect to the current interest rate yields

$$\frac{\partial L_{t+1}}{\partial i_t} = -2E_t \left[(\beta \pi_t - \alpha_t i_t + \varepsilon_{\pi,t+1}) \alpha_t \right].$$

Consequently, under certainty the optimal interest rate reaction function is given by

$$i_t^* = \frac{\beta}{\alpha_t} \pi_t.$$

In the following, we refer to $c_t^* = \beta / \alpha_t$ as the response coefficient and let the asterisk denote the solution in the case of certainty. Having discussed the basic setup, we now introduce uncertainty.

3.2 A Single Policymaker under Uncertainty

It is useful to consider the case of a single policymaker. We assume that policymaker 1 observes π_t and α_t imperfectly. We let these two observations be given by

$$\pi_t^{(1)} = \pi_t + e_t^{(1)} \tag{4}$$

and

$$\alpha_t^{(1)} = \alpha_t + \mu_t^{(1)}, \tag{5}$$

where the superscript (1) denotes variables particular to the single policymaker and where $e_t^{(1)} \sim N(0, \sigma_e^2)$. Policymaker 1's observation error in equation (4) captures the data uncertainty in the model, while in equation (5) $\mu_t^{(1)}$ gives rise to parameter uncertainty.[11] We assume that if policymaker 1 in one period perceives the impact coefficient to be larger than it actually is (so that $\mu_t^{(1)} > 0$), he is likely to do so again in the next period. For the

[10] The assumption of a zero inflation target is not critical for the conclusions below.

[11] It should be noted that we assume for simplicity that inflation at time t is not known with certainty even in the subsequent period.

case of an MPC this assumption allows for two policymakers to disagree repeatedly, one in favour of a higher, the other in favour of a lower interest rate. Repeated disagreements of this kind are found in the actual voting data of MPCs (see Gerlach-Kristen [11]). We model $\mu_t^{(1)}$ as

$$\mu_t^{(1)} = \delta \mu_{t-1}^{(1)} + \varepsilon_{\mu,t}^{(1)}, \tag{6}$$

with $0 < \delta < 1$ and where $\varepsilon_{\mu,t}^{(1)} \sim N(0, \sigma_\mu^2)$ is uncorrelated with $\varepsilon_{\pi,t}$ and $\varepsilon_{\alpha,t}$. Since the mean of $e_t^{(1)}$ and $\mu_t^{(1)}$ are zero, policymaker 1's observations of inflation and the impact of monetary policy are on average correct. We assume that all remaining parameters of the model are known with certainty.

In order to set $i_t^{(1)}$ policymaker 1 uses his best guesses of π_t and α_t to infer the optimal interest rate. Since he is faced with a signal extraction problem, we can apply the Kalman filter to derive his assessment of current inflation and the current impact coefficient.[12] The observation equation is given by

$$\begin{bmatrix} \pi_t^{(1)} \\ \alpha_t^{(1)} \end{bmatrix} = H' \begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(1)} \end{bmatrix} + \begin{bmatrix} e_t^{(1)} \\ 0 \end{bmatrix} \tag{7}$$

with

$$H' = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \end{bmatrix}.$$

Equation (7) is simply a restatement of equations (4) and (5). The processes of actual inflation, α_t and $\mu_t^{(1)}$ are given by equations (1), (2) and (6) and they can be combined into the state equation

$$\begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(1)} \end{bmatrix} = \begin{bmatrix} 0 \\ A \\ 0 \end{bmatrix} + F_t \begin{bmatrix} \pi_{t-1} \\ \alpha_{t-1} \\ \mu_{t-1}^{(1)} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{\alpha,t} \\ \varepsilon_{\mu,t}^{(1)} \end{bmatrix}$$

with

$$F_t = \begin{bmatrix} \beta & -i_{t-1}^{(1)} & 0 \\ 0 & \gamma & 0 \\ 0 & 0 & \delta \end{bmatrix}.$$

[12] See Hamilton [17] for a general discussion of the Kalman filter.

While policymaker 1 does not observe the state variables π_t, α_t and $\mu_t^{(1)}$, he knows the structure of F_t. His information set $\Omega_t^{(1)}$ thus comprises

$$\Omega_t^{(1)} = [\pi_t^{(1)}, \alpha_t^{(1)}, A, \beta, \gamma, \delta, \sigma_e^2, \sigma_\pi^2, \sigma_\alpha^2, \sigma_\mu^2, i_{t-1}^{(1)}, p_{t-1}^{(1)}, a_{t-1}^{(1)}, m_{t-1}^{(1)}],$$

where we let $p_{t-1}^{(1}$, $a_{t-1}^{(1)}$ and $m_{t-1}^{(1)}$ denote the single policymaker's assessment of the state variables at $t-1$. It should be noted that $i_{t-1}^{(1)}$ is predetermined at time t.

Given this information policymaker 1's estimates of π_t, α_t and $\mu_t^{(1)}$ are given by

$$\begin{bmatrix} p_t^{(1)} \\ a_t^{(1)} \\ m_t^{(1)} \end{bmatrix} = \Phi_t \begin{bmatrix} \pi_t^{(1)} \\ \alpha_t^{(1)} \end{bmatrix} + (I - \Phi_t H') \left(\begin{bmatrix} 0 \\ A \\ 0 \end{bmatrix} + F_t \begin{bmatrix} p_{t-1}^{(1)} \\ a_{t-1}^{(1)} \\ m_{t-1}^{(1)} \end{bmatrix} \right).$$

This equation reflects the process in which policymaker 1 updates his view of the economy. His estimates $p_t^{(1}$, $a_t^{(1)}$ and $m_t^{(1)}$ are a linear combination of his current observations $\pi_t^{(1)}$ and $\alpha_t^{(1)}$ and his past estimates of the state variables, $p_{t-1}^{(1}$, $a_{t-1}^{(1)}$ and $m_{t-1}^{(1)}$. For completeness, note that I is a 3×3 identity matrix, that

$$\underset{3\times 2}{\Phi_t} = P_{t|t-1} H (H' P_{t|t-1} H + \begin{bmatrix} \sigma_e^2 & 0 \\ 0 & 0 \end{bmatrix})^{-1}$$

and that $P_{t|t-1}$, the covariance matrix of the forecast errors, equals

$$\underset{3\times 3}{P_{t|t-1}} = F_t (P_{t-1|t-2} - \Phi_{t-1} H' P_{t-1|t-2}) F_t' + \begin{bmatrix} \sigma_\pi^2 & 0 & 0 \\ 0 & \sigma_\alpha^2 & 0 \\ 0 & 0 & \sigma_\mu^2 \end{bmatrix}.$$

We denote the $(2, 2)$ element of $P_{t|t-1}$, which captures the uncertainty attached to $a_t^{(1)}$, as $s_t^{(1)}$.

How does policymaker 1 set interest rates given $p_t^{(1}$, $a_t^{(1)}$ and $m_t^{(1)}$? As under certainty, he minimises the loss function with respect to i_t. However, since he does not observe the true π_t and α_t, he uses his best guesses, $p_t^{(1)}$ and $a_t^{(1)}$, to form his expectation of future inflation. The loss function then is modified to

$$L_t = E_t \sum_{i=0}^{\infty} \theta^t [p_{t+i}^{(1)}]^2.$$

Replacing with policymaker 1's expectation for next period's rate of inflation and differentiating, we obtain

$$\frac{\partial L_{t+1}}{\partial i_t} = -2E_t\left[(\beta p_t^{(1)} - a_t^{(1)} i_t^{(1)} + \varepsilon_{\pi,t+1})a_t^{(1)}\right].$$

Since $a_t^{(1)}$ is a random variable,

$$E_t\{[a_t^{(1)}]^2\} = [a_t^{(1)}]^2 + s_t^{(1)}.$$

Consequently, the single policymaker sets the interest rate as

$$i_t^{(1)} = \frac{\beta a_t^{(1)}}{[a_t^{(1)}]^2 + s_t^{(1)}} p_t^{(1)}, \tag{8}$$

and we denote

$$c_t^{(1)} = \frac{\beta a_t^{(1)}}{[a_t^{(1)}]^2 + s_t^{(1)}}.$$

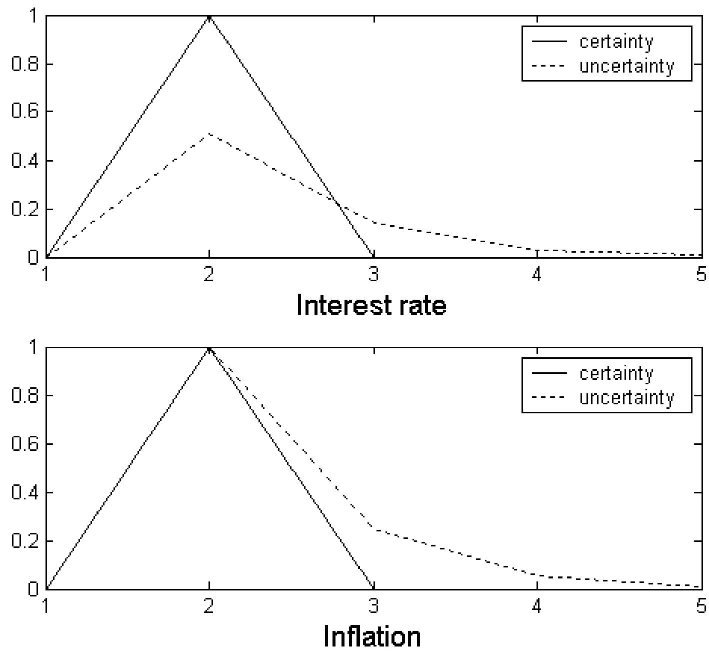
Since $s_t^{(1)} > 0$ because $\sigma_\alpha^2 > 0$, $c_t^{(1)}$ tends to be smaller than c_t^*. Nevertheless, it can be shown that policymaker 1's response coefficient is larger than $c_t^{(1)}$ under certain circumstances. In particular,

$$c_t^{(1)} > c_t^* \quad iff \quad s_t^{(1)} < \frac{\alpha_t^2}{4} \quad and \quad a_t^{(1)} \in \left[\frac{\alpha_t}{2} - \sqrt{\frac{\alpha_t^2}{4} - s}, \frac{\alpha_t}{2} + \sqrt{\frac{\alpha_t^2}{4} - s}\right].$$

Equation (8) illustrates a crucial difference between data and parameter uncertainty. While $p_t^{(1)}$ takes the place which π_t holds in the reaction function under certainty, β/α_t is not replaced $\beta/a_t^{(1)}$ but by a non-linear combination of β, $a_t^{(1)}$ and $s_t^{(1)}$. This reproduces the well-known result that certainty equivalence holds for additive, but not for multiplicative uncertainty.

To illustrate the impact of uncertainty Figure 1 shows the reaction of interest rates and inflation to a transitory increase of inflation by one unit at time $t = 2$ under certainty and uncertainty. While under certainty interest rates are increased such that at $t = 3$ inflation returns to zero, the response is more cautious under uncertainty. We assume that policymaker 1 observers $\pi_2^{(1)} = \pi_2$ correctly. However, since inflation at $t = 1$ equalled zero, policymaker 1 does not fully trust this observation. Instead, he assesses inflation to be somewhat lower and therefore does not increase the interest rate as much as under

Figure 1: Impulse responses



Note: Transitory increase of π_t at $t = 2$. Assumed parameters $A = 0.25$, $\beta = \gamma = \delta = 0.5$, $\sigma_e^2 = \sigma_\pi^2 = \sigma_\alpha^2 = \sigma_\mu^2 = 0.01$.

certainty ($p_2^{(1)} < \pi_2$). Consequently, inflation is not reduced to zero at $t = 3$ and he has to maintain the interest rate above zero to bring inflation back to equilibrium.

In order to document the benefits of deliberation, Table 1 presents simulated descriptive statistics of the interest rate, the impact coefficient, the response coefficient and inflation for the different scenarios (we assume $A = 0.25$, $\beta = \gamma = \delta = 0.5$ and $\sigma_e^2 = \sigma_\pi^2 = \sigma_\alpha^2 = \sigma_\mu^2 = 0.01$). For the case of the single policymaker two points are worth noting. First, the interest rate set by policymaker 1 has a correlation of 0.66 with i_t^*. Thus, his difficulties in observing inflation and the impact coefficient make him frequently adjust monetary policy in the wrong direction. Second, the standard deviation of $i_t^{(1)}$ is smaller than that of i_t^*, which implies that monetary policy is less volatile under uncertainty than under certainty. This is due to the caution with which policymaker 1 changes the interest rate and which arises because of his uncertainty about the impact parameter.

This reduced aggressiveness is also reflected by the fact that the mean of policymaker 1's response coefficient is smaller than c_t^*, while the means of $i_t^{(1)}$, $a_t^{(1)}$ and $p_t^{(1)}$ are identical to those under certainty.

Table 1: Descriptive statistics

	certainty	*single policymaker*	*no deliberation*	*full information*	*deliberation*
deviation $[i_t^* - i_t^{(\cdot)}]^2$	0	0.0070	0.0045	0.0017	0.0022
mean $i_t^{(\cdot)}$	0	0	0	0	0
standard deviation $i_t^{(\cdot)}$	0.112	0.077	0.058	0.099	0.102
correlation with i_t^*	1	0.660	0.871	0.930	0.909
deviation $[\alpha_t - a_t^{(\cdot)}]^2$	0	0.0066	0.0066	0.0012	0.0016
mean $a_t^{(\cdot)}$	0.501	0.501	0.505	0.502	0.502
standard deviation $a_t^{(\cdot)}$	0.115	0.082	0.081	0.110	0.112
correlation with α_t	1	0.705	0.706	0.952	0.937
deviation $[c_t^* - c_t^{(\cdot)}]^2$	0	0.094	0.097	0.050	0.055
mean $c_t^{(\cdot)}$	1.064	0.975	0.967	0.997	0.998
standard deviation $c_t^{(\cdot)}$	0.362	0.155	0.149	0.224	0.229
correlation with c_t^*	1	0.615	0.599	0.832	0.798
deviation $[\pi_t - p_t^{(\cdot)}]^2$	0	0.0054	0.0036	0.0011	0.0015
mean $p_t^{(\cdot)}$	0	0	0	0	0
standard deviation $p_t^{(\cdot)}$	0.100	0.078	0.061	0.097	0.099
correlation with π_t	1	0.682	0.878	0.942	0.922

Note: Descriptive statistics of a simulation over 10000 periods with $A = 0.25$, $\beta = \gamma = \delta = 0.5$ and $\sigma_e^2 = \sigma_\pi^2 = \sigma_\alpha^2 = \sigma_\mu^2 = 0.01$. The statistics for the MPC case are derived assuming $N = 10$. We set $\sigma_{e\pi}^2 = \sigma_{e\alpha}^2 = 0.005$ for the case of deliberation.

Before proceeding it is important to note that it is impossible to infer $a_t^{(1)}$ and $p_t^{(1)}$ from $i_t^{(1)}$ since policymaker 1 can set the same level of the interest rate under quite different circumstances. Consider for example the situation in which he thinks that inflation is far above its target of zero and the impact coefficient is large. To bring inflation back to equilibrium, he increases $i_t^{(1)}$ only slightly above zero since he expects this small interest rate change to have a large effect on π_{t+1}. However, policymaker 1 may set the same $i_t^{(1)}$ if he perceives inflation to be only a little above target and α_t to be small. In order to impact on π_{t+1}, he then changes monetary policy more aggressively than he would if he thought the impact coefficient was large. This suggests that the same $i_t^{(1)}$ can arise from an infinite number of pairs of $\pi_t^{(1)}$ and $\alpha_t^{(1)}$. If policymakers in an MPC want to pool their observations of inflation and the impact coefficient, it therefore is not sufficient for them to announce which level of the interest rate each of them favours. Instead, each committee member j needs to reveal his $\pi_t^{(j)}$ and $\alpha_t^{(j)}$.

4 A Model for the MPC

In MPC meetings policymakers discuss the appropriate level of interest rates and the factors underlying their opinions. In terms of the model presented here, we assume that deliberation allows committee member j to communicate his observations of π_t and α_t. However, since in practice policymakers rarely quantify their views of the state and structure of the economy in great detail, we assume that communication is imperfect in a way to be spelt out below. By comparing his own views to those of his colleagues, each MPC member learns about the current state and structure of the economy. Since we assume that policymakers are on average correct, the interest rate setting of a large committee approaches monetary policy under certainty.

It should be noted that this paper does not model strategic behaviour, i.e. any one policymaker's attempt to manipulate the committee decision such that the interest rate outcome is closer to the rate favoured by him. Strategic behaviour is not rational in our model since all MPC members are equally skilled. The assumption of no strategic behaviour implies that the committee decision does not depend on the choice of who speaks first. Since it often is argued that decisions are shaped by the position taken by the first speaker, future work on this topic seems desirable.

4.1 No Deliberation

We assume that all MPC members agree on the loss function (equation (3)) and have equal abilities in the sense that they share the same δ, σ_e^2 and σ_μ^2. Moreover, we let for simplicity all $\pi_t^{(j)}$:s and $\alpha_t^{(j)}$:s be uncorrelated across policymakers.

If the committee does not deliberate, each committee member j performs the signal-extraction analysis based exclusively on his own observation set, which is given by

$$\Omega_t^{(j)} = [\pi_t^{(j)}, \alpha_t^{(j)}, A, \beta, \gamma, \delta, \sigma_e^2, \sigma_\pi^2, \sigma_\alpha^2, \sigma_\mu^2, i_{t-1}^{(n)}, p_{t-1}^{(j)}, a_{t-1}^{(j)}, m_{t-1}^{(j)}],$$

where we let the superscript n denote "no deliberation", so that $i_{t-1}^{(n)}$ is the interest rate set at time $t-1$ by an MPC which votes without prior discussions. Policymaker j's observation equation is given by

$$\begin{bmatrix} \pi_t^{(j)} \\ \alpha_t^{(j)} \end{bmatrix} = H' \begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(j)} \end{bmatrix} + \begin{bmatrix} e_t^{(j)} \\ 0 \end{bmatrix},$$

while his state equation equals

$$\begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(j)} \end{bmatrix} = \begin{bmatrix} 0 \\ A \\ 0 \end{bmatrix} + F_t \begin{bmatrix} \pi_{t-1} \\ \alpha_{t-1} \\ \mu_{t-1}^{(j)} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{\alpha,t} \\ \varepsilon_{\mu,t}^{(j)} \end{bmatrix}$$

with

$$F_t = \begin{bmatrix} \beta & -i_{t-1}^{(n)} & 0 \\ 0 & \gamma & 0 \\ 0 & 0 & \delta \end{bmatrix}.$$

Policymaker j forms his best guess of the current rate of inflation and the impact coefficient using the same process of inference as the single policymaker, and he thus favours the level of the interest rate given by

$$i_t^{(j)} = \frac{\beta a_t^{(j)}}{[a_t^{(j)}]^2 + s_t^{(j)}} p_t^{(j)} = c_t^{(j)} p_t^{(j)}.$$

Since the committee votes, the interest rate is set equal to the level preferred by the median voter m. Monetary policy then is given by

$$i_t^{(n)} = c_t^{(m)} p_t^{(m)}.$$

Column (n) in Table 1 shows simulated statistics for an MPC with $N = 10$. Clearly, $i_t^{(n)}$ and $p_t^{(n)}$ are closer to their counterparts under certainty than in the case of a single policymaker, while in the assessment of the impact coefficient the MPC does roughly as well as the single policymaker. Moreover, due to the fact that the committee has a better judgement, the variability of the interest rate is smaller for an MPC than for a single policymaker. It therefore is beneficial to have a committee as opposed to a single policymaker even if its members do not deliberate.

To illustrate how the performance of monetary policy depends on the committee size, Figure 2 plots the policy error given by

$$E[i_t^* - i_t^{(n)}]^2$$

as a function of N. The larger the committee, the less deviates $i_t^{(n)}$ from i_t^*.[13]

After having reviewed the benchmark of no deliberation, we now turn to the other extreme and assume that policymakers are able to reveal their observations completely.

4.2 Full Information

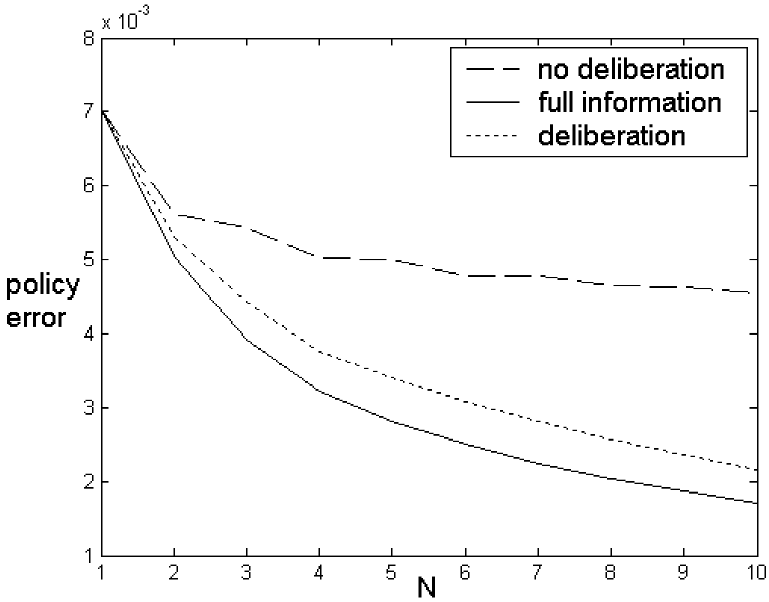
If the MPC members reveal their $\pi_t^{(j)}$:s and $\alpha_t^{(j)}$:s, the interest rate setting is improved since policymakers have more information to base their views on. If we assume perfect communication of these individual observations, policymaker 1's information set is changed to

$$\begin{aligned} \Omega_t^{(1,f)} = & [\pi_t^{(1)}, \alpha_t^{(1)}, A, \beta, \gamma, \delta, \sigma_e^2, \sigma_\pi^2, \sigma_\alpha^2, \sigma_\mu^2, i_{t-1}^{(f)}, p_{t-1}^{(f)}, a_{t-1}^{(f)}, m_{t-1}^{(f)}, \\ & \pi_t^{(2)}, \alpha_t^{(2)} ... \pi_t^{(N)}, \alpha_t^{(N)}], \end{aligned}$$

where f denotes "full information". Note that we have for committee member j $\Omega_t^{(j,f)} = \Omega_t^{(1,f)}$. Since there are N observations each of inflation and the impact coefficient, the

[13] Note that for the case of no deliberation the line is not entirely smooth because there is no true median voter in even-sized committees.

Figure 2: Policy error



Note: Comparison of $E[i_t - i_t^{(\cdot)}]^2$ for MPCs with N members who do not deliberate, have full information about each other's views or who deliberate. 10000 periods with $A = 0.25$, $\beta = \gamma = \delta = 0.5$, $\sigma_e^2 = \sigma_\pi^2 = \sigma_\alpha^2 = \sigma_\mu^2 = 0.01$ and $\sigma_{e\pi}^2 = \sigma_{e\alpha}^2 = 0.005$.

observation equation equals

$$\begin{bmatrix} \pi_t^{(1)} \\ \pi_t^{(2)} \\ \dots \\ \alpha_t^{(1)} \\ \alpha_t^{(2)} \\ \dots \end{bmatrix} = H' \begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(1)} \\ \mu_t^{(2)} \\ \dots \end{bmatrix} + \begin{bmatrix} e_t^{(1)} \\ e_t^{(2)} \\ \dots \\ 0 \\ 0 \\ \dots \end{bmatrix} \tag{9}$$

with H given by

$$\underset{(2N)\times(N+2)}{H'} = \begin{bmatrix} 1 & 0 & 0 & 0 & ... \\ 1 & 0 & 0 & 0 & ... \\ ... & ... & ... & ... & ... \\ 0 & 1 & 1 & 0 & ... \\ 0 & 1 & 0 & 1 & ... \\ ... & ... & ... & ... & ... \end{bmatrix}.$$

The state equation includes $\mu_t^{(1)}$ to $\mu_t^{(N)}$ and is modified to

$$\begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(1)} \\ \mu_t^{(2)} \\ ... \end{bmatrix} = \begin{bmatrix} 0 \\ A \\ 0 \\ 0 \\ ... \end{bmatrix} + F_t \begin{bmatrix} \pi_{t-1} \\ \alpha_{t-1} \\ \mu_{t-1}^{(1)} \\ \mu_{t-1}^{(2)} \\ ... \end{bmatrix} + \begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{\alpha,t} \\ \varepsilon_{\mu,t}^{(1)} \\ \varepsilon_{\mu,t}^{(2)} \\ ... \end{bmatrix}, \tag{10}$$

where

$$\underset{(N+2)\times(N+2)}{F_t} = \begin{bmatrix} \beta & -i_{t-1}^{(f)} & 0 & 0 & ... \\ 0 & \gamma & 0 & 0 & ... \\ 0 & 0 & \delta & 0 & ... \\ 0 & 0 & 0 & \delta & ... \\ ... & ... & ... & ... & ... \end{bmatrix}.$$

Moreover, we assume that

$$\begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{\alpha,t} \\ \varepsilon_{\mu,t}^{(1)} \\ \varepsilon_{\mu,t}^{(2)} \\ ... \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ .... \end{bmatrix}, Q \right)$$

with

$$\underset{(N+2)\times(N+2)}{Q} = \begin{bmatrix} \sigma_\pi^2 & 0 & 0 & 0 & ... \\ 0 & \sigma_\alpha^2 & 0 & 0 & ... \\ 0 & 0 & \sigma_\mu^2 & 0 & ... \\ 0 & 0 & 0 & \sigma_\mu^2 & ... \\ ... & ... & ... & ... & ... \end{bmatrix}.$$

Given this modified state space system, the most likely values of inflation, of the impact coefficient and of the individual $\mu_t^{(j)}$:s are given by

$$\begin{bmatrix} p_t^{(f)} \\ a_t^{(f)} \\ m_t^{(f,1)} \\ m_t^{(f,2)} \\ \dots \end{bmatrix} = \Phi_t \begin{bmatrix} \pi_t^{(1)} \\ \pi_t^{(2)} \\ \dots \\ \alpha_t^{(1)} \\ \alpha_t^{(2)} \\ \dots \end{bmatrix} + (I - \Phi_t H') \left(\begin{bmatrix} 0 \\ A \\ 0 \\ 0 \\ \dots \end{bmatrix} + F_t \begin{bmatrix} p_{t-1}^{(f)} \\ a_{t-1}^{(f)} \\ m_{t-1}^{(f,1)} \\ m_{t-1}^{(f,2)} \\ \dots \end{bmatrix} \right).$$

I is an $(N+2) \times (N+2)$ identity matrix and

$$\underset{(N+2)\times 2N}{\Phi_t} = P_{t|t-1} H \left(H' P_{t|t-1} H + R \right)^{-1}$$

with

$$\underset{2N\times 2N}{R} = \begin{bmatrix} \sigma_e^2 & 0 & \dots & 0 & 0 & \dots \\ 0 & \sigma_e^2 & \dots & 0 & 0 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 0 & 0 & \dots \\ 0 & 0 & \dots & 0 & 0 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix}.$$

The covariance matrix of the forecast errors is given by

$$\underset{(N+2)\times(N+2)}{P_{t|t-1}} = F_t (P_{t-1|t-2} - \Phi_{t-1} H' P_{t-1|t-2}) F_t' + Q,$$

where we denote the $(2,2)$ element of $P_{t|t-1}$ as $s_t^{(f)}$. This variance again captures the uncertainty attached to the assessment $a_t^{(f)}$. Thus, we have that an MPC with full information sets the interest rate according to

$$i_t^{(f)} = \frac{\beta a_t^{(f)}}{[a_t^{(f)}]^2 + s_t^{(f)}} p_t^{(f)}.$$

Three findings are of interest. First, under full information there is only one best estimate of current inflation and the impact coefficient and all MPC members agree on these $p_t^{(f)}$ and $a_t^{(f)}$. In terms of the literature on common knowledge, they cannot "agree to disagree." Second, if we were to allow the σ_e^2:s to differ across policymakers, a committee member j with a large variance of the observation error would have little influence on the interest rate decision because the elements in the jth column of Φ_t would be small. Third, and as is shown in Figure 2, the uncertainty about π_t and α_t disappears fast as the committee is enlarged. This is due to two effects. The first of these is that a larger MPC is able to form better estimates of inflation and the impact coefficient because it has more observations to draw from. The second effect is that pooling more and more pieces of information makes the caution with regard to the choice of the response coefficient disappear (formally, $s_t^{(f)} \rightarrow 0$ for $N \rightarrow \infty$). This is reflected in Table 1, where the correlation of $c_t^{(f)}$ with c_t^* is with 0.83 the largest for the different scenarios considered.

4.3 Deliberation

It is an empirical fact that MPC members regularly disagree (see Gerlach-Kristen [11]). If policymakers are rational, have the same goals and do not behave strategically, dissents must arise because they use different information sets. Thus, while committee members adjust their views in light of their colleagues' opinions, the sharing of information during the discussions in the MPC appears to be incomplete.

We model deliberation in the MPC by letting committee member k announce his observations of inflation and the impact coefficient in a way which makes his colleagues observe $\pi_t^{(k)}$ and $\alpha_t^{(k)}$ with an error. This assumption seems reasonable since MPC members most likely discuss their views in a qualitative rather than a quantitative manner. Assume policymaker k observes $\alpha_t^{(k)} = 0.1$ but states "I feel that monetary policy is currently subject to strong headwinds". It seems likely the committee member j may not understand that this implies that $\alpha_t^{(k)} = 0.1$ exactly, but he nevertheless perceives that policymaker k must think that the impact coefficient is low. We let MPC member j's understanding of $\pi_t^{(k)}$ and $\alpha_t^{(k)}$ be given as

$$\pi_t^{(j,k)} = \pi_t^{(k)} + e_{\pi,t}^{(j,k)}$$

and

$$\alpha_t^{(j,k)} = \alpha_t^{(k)} + e_{\alpha,t}^{(j,k)}$$

where

$$\begin{bmatrix} e_{\pi,t}^{(j,k)} \\ e_{\alpha,t}^{(j,k)} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{e\pi}^2 & 0 \\ 0 & \sigma_{e\alpha}^2 \end{bmatrix}\right)$$

for any $j \neq k$. Since we assume a mean of zero for the communication errors, we let policymaker j on average understand committee member k correctly. We assume for simplicity that $e_{\pi,t}^{(j,k)}$ and $e_{\alpha,t}^{(j,k)}$ are uncorrelated with all other errors and across policymakers and that $\sigma_{e\pi}^2$ and $\sigma_{e\alpha}^2$ are identical for all policymakers, which implies that the committee members have identical communication skills. The larger $\sigma_{e\pi}^2$ and $\sigma_{e\alpha}^2$, the less efficient is the communication in the MPC.

If the committee deliberates policymaker 1 relies in his assessment of inflation and the impact coefficient on his own observations $\pi_t^{(1)}$ and $\alpha_t^{(1)}$ and on his perception of his colleagues' views. His information set equals

$$\begin{aligned} \Omega_t^{(1,d)} &= [\pi_t^{(1)}, \alpha_t^{(1)}, A, \beta, \gamma, \delta, \sigma_e^2, \sigma_\pi^2, \sigma_\alpha^2, \sigma_\mu^2, i_{t-1}^{(d)}, p_{t-1}^{(d,1)}, a_{t-1}^{(d,1)}, m_{t-1}^{(d,1,1)}, m_{t-1}^{(d,1,2)} ... m_{t-1}^{(d,1,N)}, \\ &\quad \pi_t^{(1,2)}, \alpha_t^{(1,2)} ... \pi_t^{(1,N)}, \alpha_t^{(1,N)}], \end{aligned}$$

where d denotes "deliberation" and $m_{t-1}^{(d,1,2)}$ policymaker 1's assessment of $\mu_{t-1}^{(2)}$. Committee member 2 uses a slightly different information set which is given by

$$\begin{aligned} \Omega_t^{(2,d)} &= [\pi_t^{(2)}, \alpha_t^{(2)}, A, \beta, \gamma, \delta, \sigma_e^2, \sigma_\pi^2, \sigma_\alpha^2, \sigma_\mu^2, i_{t-1}^{(d)}, p_{t-1}^{(d,2)}, a_{t-1}^{(d,2)}, m_{t-1}^{(d,2,1)}, m_{t-1}^{(d,2,2)} ... m_{t-1}^{(d,2,N)}, \\ &\quad \pi_t^{(2,1)}, \alpha_t^{(2,1)} ... \pi_t^{(2,N)}, \alpha_t^{(2,N)}]. \end{aligned}$$

While the state equation is the same as in equation (10), policymaker 1's observation equation is modified from equation (9) to

$$\begin{bmatrix} \pi_t^{(1)} \\ \pi_t^{(1,2)} \\ ... \\ \alpha_t^{(1)} \\ \alpha_t^{(1,2)} \\ ... \end{bmatrix} = H' \begin{bmatrix} \pi_t \\ \alpha_t \\ \mu_t^{(1)} \\ \mu_t^{(2)} \\ ... \end{bmatrix} + \begin{bmatrix} e_t^{(1)} \\ e_t^{(2)} + e_{\pi,t}^{(1,2)} \\ ... \\ 0 \\ e_{\alpha,t}^{(1,2)} \\ ... \end{bmatrix}$$

Consequently, his best guess of current inflation, the impact coefficient and the individual

$\mu^{(j)}$:s is given by

$$\begin{bmatrix} p_t^{(d,1)} \\ a_t^{(d,1)} \\ m_t^{(d,1,1)} \\ m_t^{(d,1,2)} \\ ... \end{bmatrix} = \Phi_t^{(1)} \begin{bmatrix} \pi_t^{(1)} \\ \pi_t^{(1,2)} \\ ... \\ \alpha_t^{(1)} \\ \alpha_t^{(1,2)} \\ ... \end{bmatrix} + [I - \Phi_t^{(1)} H'] \left(\begin{bmatrix} 0 \\ A \\ 0 \\ 0 \\ ... \end{bmatrix} + F_t \begin{bmatrix} p_{t-1}^{(d,1)} \\ a_{t-1}^{(d,1)} \\ m_{t-1}^{(d,1,1)} \\ m_{t-1}^{(d,1,2)} \\ ... \end{bmatrix} \right)$$

with

$$\underset{(N+2)\times(N+2)}{F_t} = \begin{bmatrix} \beta & -i_{t-1}^{(d)} & 0 & 0 & ... \\ 0 & \gamma & 0 & 0 & ... \\ 0 & 0 & \delta & 0 & ... \\ 0 & 0 & 0 & \delta & ... \\ ... & ... & ... & ... & ... \end{bmatrix}.$$

For policymaker 2 the corresponding expression is

$$\begin{bmatrix} p_t^{(d,2)} \\ a_t^{(d,2)} \\ m_t^{(d,2,1)} \\ m_t^{(d,2,2)} \\ ... \end{bmatrix} = \Phi_t^{(2)} \begin{bmatrix} \pi_t^{(2,1)} \\ \pi_t^{(2)} \\ ... \\ \alpha_t^{(2,1)} \\ \alpha_t^{(2)} \\ ... \end{bmatrix} + [I - \Phi_t^{(2)} H'] \left(\begin{bmatrix} 0 \\ A \\ 0 \\ 0 \\ ... \end{bmatrix} + F_t \begin{bmatrix} p_{t-1}^{(d,2)} \\ a_{t-1}^{(d,2)} \\ m_{t-1}^{(d,2,1)} \\ m_{t-1}^{(d,2,2)} \\ ... \end{bmatrix} \right)$$

Note that Φ_t differs between MPC members and is for committee member 1 given by

$$\underset{(N+2)\times 2N}{\Phi_t^{(1)}} = P_{t|t-1} H \left(H' P_{t|t-1} H + R^{(1)} \right)^{-1},$$

with

$$\underset{2N\times 2N}{R^{(1)}} = \begin{bmatrix} \sigma_e^2 & 0 & ... & 0 & 0 & ... \\ 0 & \sigma_e^2 + \sigma_{e\pi}^2 & ... & 0 & 0 & ... \\ ... & ... & ... & ... & ... & ... \\ 0 & 0 & ... & 0 & 0 & ... \\ 0 & 0 & ... & 0 & \sigma_{e\alpha}^2 & ... \\ ... & ... & ... & ... & ... & ... \end{bmatrix}$$

Denoting the $(2,2)$ element of $P_{t|t-1}$ as $s_t^{(d,1)}$, policymaker 1 thinks that the interest rate should be set equal to

$$i_t^{(d,1)} = \frac{\beta a_t^{(d,1)}}{[a_t^{(d,1)}]^2 + s_t^{(d,1)}} p_t^{(d,1)}.$$

Likewise, committee member 2, using $\Omega_t^{(2,d)}$ instead of $\Omega_t^{(1,d)}$, favours

$$i_t^{(d,2)} = \frac{\beta a_t^{(d,2)}}{[a_t^{(d,2)}]^2 + s_t^{(d,2)}} p_t^{(d,2)}.$$

Since the pooling of information is imperfect, disagreement persists even after deliberation. The MPC then decides on the level of the interest rate in a vote. Again denoting the median voter as m, we thus have that

$$i_t^{(d)} = c_t^{(d,m)} p_t^{(d,m)}.$$

Table 1 shows $i_t^{(d)}$, $a_t^{(d)}$, $c_t^{(d)}$ and $p_t^{(d)}$ are closer to i_t^*, α_t, c_t^* and π_t than if the committee does not deliberate. This implies that discussions in the MPC are beneficial. A second striking finding is that the volatility of all variables considered is larger than under no deliberation and full information. This suggests that policymakers who have discussed their views are more activist and willing to be more aggressive than they would be otherwise.

5 Conclusions

This paper models the benefits of deliberation in MPCs. The existing theoretical literature typically stylises interest rate decisions in MPCs in a way which provides no rationale for why policymakers deliberate. However, discussions appear to be a crucial element of actual committee meetings. We argue that if the state and structure of the economy are observed imprecisely, deliberation is important because it helps the MPC reduce the uncertainty about the appropriate level of interest rates.

We consider three procedures for the interest rate decision. First, we assume that MPC members vote without deliberating beforehand. Monetary policy deviates considerably from the path it would follow if there were no uncertainty. Second, we let the committee members fully share their information, which makes them agree on the appropriate stance of policy and reduces the extent to which interest rates deviate from their pattern under certainty. Since empirically disagreement is the rule rather than the exception in MPCs, the assumption of full information seems unrealistic. Third, we consider the case of deliberation, in which MPC members explain their views to each other but fail to do so perfectly. Policymakers adjust their assessment of the economy during the discussion somewhat but not enough to come to an agreement on which level of the interest rate to implement. Their decision is then made in a vote, and we demonstrate that the policy outcome is superior to that under no deliberation.

One interesting extension of the analysis would be to allow for strategic behaviour. If policymakers exaggerate their views, it might matter who speaks first in the MPC meeting. We leave this issue for future research.

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