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Monetary Policy Committees and Model Uncertainty

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Abstract: We introduce heterogeneity into a monetary policy committee by allowing the degree of model uncertainty to differ across members. It is shown that in this framework the stage at which members reach consensus matters. An aggregation protocol under which members only average policy deemed optimal from each member's point of view leads to more volatility compared to an alternative protocol in which members agree on a common worst-case scenario from which optimal policy is then derived. The reason is that inflation, output and the interest rate are convex functions of each member's idiosyncratic degree of model uncertainty. If the degree of model uncertainty becomes more heterogenous, inflation volatility falls due to more vigorous stabilization policy. The degree of heterogeneity across members is therefore an important determinant of macroeconomic volatility. Interestingly, the implications for the committee design under a min-max approach to model uncertainty are identical to those derived from a Bayesian approach.

Keywords: Robustness, Model Uncertainty, Monetary Policy Committee, Optimal Monetary Policy

JEL classification: E31, E32

¹I thank Martin Mandler for very helpful comments.

"[Monetary policy committee] members certainly do not know - nor think they know - the true model of the economy."

Alan Blinder (2009)

1 Introduction

In almost all major central banks such as the Federal Reserve, the European Central Bank, and the Bank of England monetary policy decisions are not taken by a single person, but by a collegium of experts. Often these monetary policy committees (MPC) consist of internal members, i.e. members of the executive board or senior staff members, and external members such as academic experts or regional representatives. This tendency stands in remarkable contrast to models of optimal monetary policy, which formulate monetary policy mostly in terms of a single decision maker. Only recently, a vivid literature studies the implications of the diversity of MPC members for macroeconomic outcomes, i.e. inflation, output and interest rate volatility.

Among the issues that receive particular attention are heterogeneous information sets across members, different preferences concerning output and inflation stabilization, differences between external and internal members, the role of the chairman, and the effect of transparency on the debate within the MPC. An important characteristic of committee members, however, has not yet been studied: heterogeneity of MPC members in their degree of model uncertainty. Suppose all members agree on a reference model as the best available representation of the economic structure. This does not imply that all members have the same level of confidence in the accuracy and reliability of the model for policy simulations and forecasting. It is plausible to assume that members, while sharing the idea of a common benchmark model, entertain individual degrees of model uncertainty. In this paper we study the implications of this aspect of committee heterogeneity for optimal monetary policy and macroeconomic outcomes.

We assume that members address model uncertainty by formulating a robust policy response. That is, the interest rate adjustment should lead to acceptable outcomes even if the model turns out to be distorted. One way to implement this policy is to follow a min-max or robust control approach. Policymakers design policy to minimize the welfare loss from a worst-case outcome. Under heterogeneous degrees of model uncertainty, MPC members consider individual

worst-case scenarios. It is shown that in this framework the nature of the aggregation mechanism across members' votes as well as the stage of deliberation at which consensus is reached matters. The reason is that inflation, output and the interest rate are convex functions of each member's degree of model uncertainty. Averaging the degrees of uncertainty, hence, is different from averaging the optimal policy recommendations. An aggregation protocol under which members only average the final individual interest rate policy deemed optimal from each member's point of view leads to suboptimal outcomes compared to an alternative protocol in which members agree on a common worst-case scenario from which optimal policy is then derived. The degree of heterogeneity across MPC members is therefore an important determinant of macroeconomic volatility. A government cannot only choose to delegate policy to a committee with a specific preference for output versus inflation stabilization, but can also affect inflation and output volatility by selecting members with a specific degree of model uncertainty.

A second key result is that the implications for the committee design under a min-max approach to model uncertainty are identical to those derived from a Bayesian approach. Although both approaches suggest opposite effects of uncertainty on the strength of interest rate adjustment for a single decision maker, they support the same conclusion as regards heterogeneity across committee members. In both cases heterogeneity across members gives rise to more aggressive interest rate policy.

The present paper is organized as follows: Section two surveys the literature on monetary policy committees. Section three introduces the reference model, the notion of model uncertainty, and derives optimal policy responses under three alternative voting protocols. Section four analyzes the problem of the government that selects heterogenous MPC members and, by doing so, affects macroeconomic volatility. Section five contrasts the robust control approach to model uncertainty with a Bayesian approach and section six draws some tentative conclusions.

2 Monetary policy committees

The literature on monetary policy committees exploded in recent years. This renewed interest is partly due to the delegation of responsibility for monetary policy in the UK to the Bank of England's Monetary Policy Committee. Thanks to the high degree of transparency with respect to the publication of minutes and members' voting record, there is plenty of empirical research on the dynamics

within the Bank of England's MPC.

A complete survey of the voluminous literature is beyond the scope of this paper. Fortunately, a set of recent survey articles presents insightful overviews, see Gerling et al. (2005), Vandenbussche (2006), Blinder (2009) and, with a special focus on the design of the ECB, Berger (2006). We briefly highlight some directions of research that are related to this paper.

First, there is evidence on the degree of heterogeneity across members. For the Bank of England's monetary policy committee, Gerlach-Kristen (2009) shows interesting differences between outsiders and insiders in the pattern of dissent and their policy preferences. Gerlach-Kristen (2008) models the role of the chairman in decision making in policy committees, whose main role is to build consensus. Recent papers study member-specific policy reaction functions for the Bank of England's MPC. Riboni and Ruge-Murcia (2008) and Besley, Meads, and Surico (2008) argue that heterogeneity in interest rate proposals cannot be explained by individual preferences, but that policy recommendations differ according to the career background and the nature of the membership. For the Federal Reserve, the evidence on heterogeneity across FOMC members is relatively scarce. Chappell, Havrilesky, and McGregor (1997) illustrate heterogeneous preferences in the pre-Volcker era, while the impressive monograph by Chappell, McGregor, and Vermilyea (2005) provides detailed studies on consensus building within the FOMC. More recent data is used by Meade (2005) to analyze the dissenting behavior of FOMC members.

Second, Sibert (2003) and Mihov and Sibert (2006) study theoretically the implications of the committee structure for the problem of time inconsistency of monetary policy. They show that being a committee member affects the incentive to gain reputation for anti-inflation toughness when the type of the policymaker is unknown to the public.

Third, Blinder and Morgan (2005), Morgan (2005), and Lombardelli, Proudman, and Talbot (2005) provide experimental evidence on the interaction within an MPC. They show that groups are not slower in decision making than individuals. Moreover, they tend to make better decision than individual decision makers. In a theoretical model, Gerlach-Kristen (2006) shows that multiple-member committees are more capable in forming a view on the state of the economy than a single individual that relies mostly on her own information and judgment. Faced with an uncertain environment committees will be able to make better decisions than individual decision makers.

A fourth strand considers alternative designs of voting protocols. Although at most central banks policy decisions are taken by committees, there are subtle

differences across countries in the design of the decision making process. While decisions of the ECB and the Fed are characterized by a large degree of consensus with few if any formal dissent, decisions at the Bank of England's MPC are often the outcome of majority voting across members with competing views. Riboni and Ruge-Murcia (2010) study the theoretical and empirical implications of alternative voting protocols in a model with asymmetric central bank preferences. They find that the consensus model fits most central bank policies best. Despite institutional differences, the policy outcome of committee-based policy is observationally equivalent. Interestingly, they also assume that committee members differ in their relative degree of prudence, i.e. their costs of overshooting and undershooting the inflation target differ.

Previous research highlights heterogeneity across committee members with respect to preferences and information. This paper focuses on a hitherto neglected issue: heterogeneity with respect to model uncertainty. All members are assumed to have one single reference model. There is, however, an idiosyncratic degree of confidence in this model or, put differently, an individual degree of model uncertainty. Mariathasan (2009) introduces subjective beliefs of committee members about the true model of the economy into a model of Bayesian decision making. Members differ with respect to priors attached to one of two alternative models of the economy's law of motion. In our papers, members have individual degrees of model uncertainty and follow a min-max approach. Instead of entertaining beliefs about alternative models they consider individually sized distortions from a consensus model. However, we also show the results being robust to the choice of a Bayesian framework.

We assume that all members pursue a worst-case or min-max approach, respectively, to policymaking. Ellison and Sargent (2009) address the forecasting performance of the FOMC. In an ingenious paper, they argue that forecasts submitted by FOMC members are in fact describing worst-case scenarios against which monetary policy has to shield the economy. Policymakers put greater weight on adverse outcomes, i.e. inflation being further away from target, than the staff or external forecasters. Here we assume that members entertain an individual degree of model uncertainty which is not necessarily shared by fellow committee members. This leads to idiosyncratic worst-case distortions considered by MPC members. The next sections show that the design of the MPC is crucial in this environment.

3 Robust monetary policy

This section studies the implications of committee and decision design on macro-economic outcomes. Hansen and Sargent (2008) provide a seminal analysis of robust control problems in economics. Leitemo and Söderström (2008a) apply robust control techniques to a standard New Keynesian model and derive optimal monetary policy. As in Leitemo and Söderström (2008a, b), the model in this paper is simple enough to facilitate an analytical solution of the policy problem.²

3.1 The reference model

The reference model is a standard New-Keynesian framework, see Clarida, Galí, and Gertler (1999). Households consume goods and provide labor. Firms set prices under monopolistic competition and are subject to a scheme of staggered price adjustment. The forward-looking Phillips curve

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t + e_t \quad (1)$$

and the IS curve represent log-linearised equilibrium conditions

$$y_t = \mathbb{E}_t y_{t+1} - \sigma^{-1} (R_t - \mathbb{E}_t \pi_{t+1}) \quad (2)$$

where π_t is the inflation rate, y_t the output gap, R_t the risk-free nominal interest rate controlled by the central bank, and \mathbb{E}_t is the expectations operator. All variables are expressed in percentage deviations from their respective steady state values. The discount factor is denoted by β , σ is the coefficient of relative risk aversion, and κ , the slope coefficient of the Phillips curve, depends negatively on the degree of price stickiness. The cost-push shock e_t follows an i.i.d. process with $e_t \sim \mathcal{N}(0, 1)$.

Monetary policy is assumed to set interest rates in order to minimize the welfare loss due to sticky-prices which is described in terms of inflation volatility and output gap volatility weighted by the parameter $\lambda > 0$

$$\min_{R_t} \{ \pi_t^2 + \lambda y_t^2 \} \quad (3)$$

Throughout the paper we assume that policy is unable to commit to the optimal inertial plan. Instead, policy is conducted under discretionary optimization.

²See Levine and Pearlman (2007) for another recent application of robust control techniques to the design of optimal monetary policy.

3.2 Robust policy by a single decision maker

The central banker considers the model presented in the previous section as the reference model which represents the most likely description of the economic structure. However, the policymaker knows that this model could be subject to a wide range of distortions. The task is to reformulate the central bank's optimization problem such that the resulting policy performs well even if the model deviates from the reference model. We transform the minimization problem into a min-max problem. The central bank wants to minimize the maximum welfare loss due to model misspecifications by specifying an appropriate policy. To illustrate the problem, we introduce a fictitious second rational agent, the evil agent, whose only goal is to maximize the central bank's loss. Hence, the equilibrium is the outcome of a two-person game. Note that the evil agent is only a convenient metaphor for the central bank's cautionary behavior.

The set of potential misspecifications, the control vector of the evil agent, takes the form of an error term. Let z_t denote the misspecification chosen by the evil agent. The only constraint imposed upon the evil agent is his budget constraint requiring $z_t^2 \leq \omega$. The parameter ω measures the amount of misspecification the evil agent has available with the standard rational expectations solution for optimal monetary policy corresponding to $\omega = 0$, such that the evil agent's budget is empty. The model thus becomes

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t + e_t + z_t \quad (4)$$

$$y_t = \mathbb{E}_t y_{t+1} - \sigma^{-1} (R_t - \mathbb{E}_t \pi_{t+1}) \quad (5)$$

and

$$\min_{R_t} \max_{z_t} \{ \pi_t^2 + \lambda y_t^2 \} \quad (6)$$

If the full amount of possible misspecifications realizes, we refer to the resulting model as the worst-case model. If, on the other hand, the reference model turns out to be undistorted but policy is nevertheless robust to misspecifications, we refer to the resulting model as the approximating model.

The Lagrangian of the policy problem can be written as follows

$$\begin{aligned} \mathcal{L} = & \pi_t^2 + \lambda y_t^2 - \theta z_t^2 \\ & - \mu_t^\pi (\pi_t - \beta \mathbb{E}_t \pi_{t+1} - \kappa y_t - e_t - z_t) \\ & - \mu_t^y (y_t - \mathbb{E}_t y_{t+1} + \sigma^{-1} R_t - \sigma^{-1} \mathbb{E}_t \pi_{t+1}) \end{aligned} \quad (7)$$

where μ_t^π and μ_t^y denote the Lagrange multipliers associated with the macroeconomic constraints. The Lagrange parameter θ is inversely related to ω and

measures the level of confidence in the reference model the decision maker has.³ In the following, we will also loosely refer to the inverse of θ as the degree of robustness or the degree of uncertainty, respectively. A lower θ means that the central bank designs a policy, which is appropriate for a wider set of possible misspecifications. Therefore, a lower θ is equivalent to a higher degree of robustness.

The first order conditions under discretion imply

$$y_t = -\frac{\kappa}{\lambda}\pi_t \quad (8)$$

$$z_t = \theta^{-1}\pi_t \quad (9)$$

Condition (8) is the standard trade-off characterizing optimal discretionary monetary policy. Condition (9) describes the evil agent's choice of model perturbations. The higher the degree of uncertainty, the larger the distortions z_t .

The first-order conditions can be used to derive the worst case solution for output, inflation, and the interest rate. Insert the first-order conditions into the distorted Phillips curve and substitute the interest rate given by the IS curve to obtain the worst case solution for the inflation rate

$$\pi_{t,worst} = \frac{\lambda}{\lambda(1 - \theta^{-1}) + \kappa^2}e_t \quad (10)$$

If uncertainty becomes larger (θ falls), the central bank fears inflation in the worst case to be higher following both types of shocks. The worst case output dynamics are obtained by inserting this expression into the first-order condition (8)

$$y_{t,worst} = -\frac{\kappa}{\lambda(1 - \theta^{-1}) + \kappa^2}e_t \quad (11)$$

Substitute $\pi_{t,worst}$ in the IS curve to obtain the optimal interest rate

$$R_t = \frac{\sigma\kappa}{\lambda(1 - \theta^{-1}) + \kappa^2}e_t \quad (12)$$

If the central bank sets interest rates according to (12), monetary policy shields the economy against worst case model perturbations. If the reference model is in fact undistorted ($z_t = 0$) and the central bank nevertheless pursues its robust optimal policy, the outcome is referred to as the approximating model.

³The rational expectations case corresponds to $\theta \rightarrow \infty$. In this case, the evil agent maximizes the welfare loss by choosing $z_t = 0$.

Insert the robust interest rate policy (12) into the undistorted model to obtain the solution for output and inflation in the approximating model

$$\pi_{t,appr} = \frac{\lambda(1 - \theta^{-1})}{\lambda(1 - \theta^{-1}) + \kappa^2} e_t \quad (13)$$

$$y_{t,appr} = -\frac{\kappa}{\lambda(1 - \theta^{-1}) + \kappa^2} e_t \quad (14)$$

Two properties of this solution will be crucial for the central argument of this paper: First, the inflation rate increases in θ . Hence, a higher aversion to model uncertainty makes inflation less volatile. This is because with a lower θ the central bank makes more aggressive use of its policy instrument, see (12), such that inflation volatility is subdued.⁴ Second, the volatility of all three endogenous variables is a convex function of θ . The effect of θ on the variances becomes larger with a lower θ .

4 Robust policy by committees

Thus far monetary policy is set by a single decision maker. As mentioned before, however, in almost all central banks nowadays a committee decides about interest rate policy. We now study the implications of the design of the committee on the resulting macroeconomic outcome.

The decision making committee of the central bank consists of n members. Each member $i = 1, \dots, n$ entertains a level of confidence in the reference model indexed by θ_i . In all other respects members are identical, i.e. they share the same preference for inflation versus output stabilization and have access to the same information set. Alternatively, a different θ_i implies that member differ in their perceived worst-case scenario. The committee is non-interactive.

All members, including the chairman, are assumed to have equal voting power.⁵ Members use simple averaging to find a consensus. Put differently, we model a "genuinely collegial committee" (Blinder and Wyplosz 2004), in which members

⁴In this sense the robust control approach sheds new light on the classical result of Brainard (1967). Brainard argued that multiplicative parameter uncertainty should lead to an attenuated adjustment of the policy instrument. Giannoni (2002) and Onatski and Stock (2002) show that model uncertainty under the min-max paradigm no longer justify a cautious monetary policy response since the policymaker fears inflation in the worst-case outcome to be higher than under certainty and, consequently, adjusts the policy instrument more aggressively.

⁵Note that in practical policymaking the chairman has a particular role in forging consensus. For an in-depth analysis see Gerlach-Kristen (2008).

discuss their own views behind closed doors to reach unanimous or nearly unanimous decisions. This is a realistic description of decision making at the ECB and the Fed under chairman Bernanke.⁶ It is less appropriate for the highly individualistic style of decision making at the Bank of England's MPC. As in Matsen and Roisland (2005) and other papers, the consensus is found by simply averaging individual views.

We distinguish three distinct protocols:

- I. MPC members average their individual levels of confidence in the reference model, i.e. their θ values, before deciding about policy.
- II. MPC members average individual worst-case distortions before deciding about interest rates.
- III. MPC members average only their individual optimal interest rate responses.

The crucial difference across protocols is the point in time at which members average their heterogenous views. Under protocol I, members agree on a common θ before entering the deliberation stage. Under protocol III, each member derives the policy response that is optimal based on his individual θ . At the end of the MPC meeting, members simply average these individual policy responses. This procedure is also known as conclusion-based decision making, see Claussen and Roisland (2007). Protocol II, in contrast, can be interpreted as a case of premise-based decision making as members find consensus on one essential input for the derivation of optimal policy. We now study the implications on inflation and output variability and, hence, on welfare under each protocol in detail. Note again that we only focus on the aggregation of idiosyncratic levels of confidence in the reference model. We do not discuss the effect of the committee structure on the communication across members, the incentives for revealing private information, and the role of the chairman for achieving consensus.

4.1 Averaging θ before deciding (protocol I)

If members use simple averaging to find a representative degree of robustness with respect to model uncertainty, the result will be given by

$$\tilde{\theta} = \frac{1}{n} \sum_{i=1}^n \theta_i \tag{15}$$

⁶For example, in a press conference on January 10 2008 ECB President Trichet explained: "... we do not vote and have never voted in the past. Today, we took a consensus decision ...".

In this case, the robust interest rate policy is

$$R_t^I = \frac{\sigma\kappa}{\lambda(1 - \tilde{\theta}^{-1}) + \kappa^2} e_t \quad (16)$$

where the superscript I denotes the outcome under protocol I. The resulting inflation and output outcomes in the approximating model are

$$\pi_{t,appr}^I = \frac{\lambda(1 - \tilde{\theta}^{-1})}{\lambda(1 - \tilde{\theta}^{-1}) + \kappa^2} e_t \quad (17)$$

$$y_{t,appr}^I = -\frac{\kappa}{\lambda(1 - \tilde{\theta}^{-1}) + \kappa^2} e_t \quad (18)$$

This protocol is tantamount to the case of a single decision maker with the average $\tilde{\theta}$ instead of θ . Under this protocol any heterogeneity in the degree of model uncertainty is averaged out before entering the computation of optimal policy. The properties of the solution remain identical to those presented before. Hence, the results are less interesting than the remaining protocols and are not analyzed in further detail.

4.2 Averaging worst-case distortions before deciding (protocol II)

Since each member is assumed to pursue an individual degree of model uncertainty, she also has a corresponding idiosyncratic worst-case distortion. Under this voting protocol, members compute the average of individual worst-case distortions $z_{t,i} = \theta_i^{-1}\pi_t$. The result will be an average distortion \tilde{z}_t

$$\tilde{z}_t = \left(\frac{1}{n} \sum_{i=1}^n \theta_i^{-1} \right) \pi_t \quad (19)$$

The robust interest rate policy is

$$R_t^{II} = \frac{\sigma\kappa}{\lambda(1 - \frac{1}{n} \sum_{i=1}^n \theta_i^{-1}) + \kappa^2} e_t \quad (20)$$

and the resulting outcome in the approximating model is

$$\pi_{t,appr}^{II} = \frac{\lambda(1 - \frac{1}{n} \sum_{i=1}^n \theta_i^{-1})}{\lambda(1 - \frac{1}{n} \sum_{i=1}^n \theta_i^{-1}) + \kappa^2} e_t \quad (21)$$

$$y_{t,appr}^{II} = -\frac{\kappa}{\lambda(1 - \frac{1}{n} \sum_{i=1}^n \theta_i^{-1}) + \kappa^2} e_t \quad (22)$$

The interest rate is a convex function of θ . Jensen's inequality implies

$$\frac{1}{n} \sum_i^n \theta_i^{-1} > \left(\frac{1}{n} \sum_{i=1}^n \theta_i \right)^{-1} = \tilde{\theta}^{-1} \quad (23)$$

The effective degree of robustness of monetary policy is higher than under voting protocol I. Averaging the worst-case scenarios by heterogeneous committee members leads to average model uncertainty being larger than in the case of a single decision maker. This implies that the interest rate response for the average of θ_i^{-1} is larger than for the inverse of the average of θ_i . The interest rate is adjusted more vigorously the larger the degree of heterogeneity of θ across members. For a given size of the supply shock, $R^{II} > R^I$. Since the interest rate is used more aggressively to stabilize the economy than under protocol I, inflation variance will be lower and output variance will be higher. The consequences for designing the optimal committee, i.e. finding the optimal degree of heterogeneity across members, are discussed below.

To illustrate the effects, let us assume the committee consists of $n = 3$ members with $\theta_1 < \theta_2 < \theta_3$.⁷ The "mean member" has a degree of model uncertainty equal to $\theta_2 = \tilde{\theta}$, while the remaining members have $\theta_1 = \tilde{\theta} + \Delta$ and $\theta_3 = \tilde{\theta} - \Delta$ with $\Delta \geq 0$. Hence, Δ measures the degree of heterogeneity in the committee with respect to the worst-case scenario. All parameters values are standard: $\sigma = 1.80$, $\kappa = 0.10$, and $\lambda = 0.25$. The drawback of the theory on robust control is that θ is a free parameter bounded only by zero. The rational expectations case corresponds to $\theta^{RE} = \infty$. Here we set the mean degree of robustness to $\tilde{\theta} = 4$ and let Δ vary between 0 and 2.5. Changing the magnitude of θ only affects the size of the effects but not the sign.

The resulting variance of the interest rate is plotted in figure (1). If Δ increases, the effective degree of model uncertainty becomes larger and, consequently, the interest rate response also increases. As a result, inflation becomes less volatile, see figure (2), while output fluctuations become larger.

4.3 Averaging optimal interest rate policies (protocol III)

Under voting protocol III, members maintain their individual worst-case scenarios and average only the resulting interest rate recommendations. The result will

⁷As an example, take the governing board of the Swiss National Bank that consists of three members.

be the average of the optimal interest rate responses $R_{t,i}$ for each member i

$$R_t^{III} = \frac{1}{n} \sum_{i=1}^n R_{t,i} = \frac{1}{n} \sum_{i=1}^n \left(\frac{\sigma \kappa}{\lambda (1 - \theta_i^{-1}) + \kappa^2} \right) e_t$$

Substituting this policy rule into the undistorted reference model gives output and inflation in the approximating model under protocol III.

To illustrate the result, assume again $n = 3$, $\theta_2 = \tilde{\theta}$, $\theta_1 = \tilde{\theta} + \Delta$ and $\theta_3 = \tilde{\theta} - \Delta$ with $\Delta \geq 0$. The resulting interest rate variance is depicted in figure (1). The MPC adjusts the interest rate more aggressively than under protocol II. Moreover, the interest rate variance responds stronger to an increase in heterogeneity than under protocol II. As a result the effects of Δ on inflation and output volatility are reinforced, see figure (2).

5 Designing optimal committees

Here we ask the following question: Suppose the government delegates policy to a committee with a given preference of inflation stabilization over output stabilization and a given size $n = 3$. For that purpose the government considers the inflation and output results in the approximating model. Suppose further the government chooses among candidates with heterogenous preferences for robustness. What is the optimal degree of heterogeneity with respect to model uncertainty in a MPC, i.e. the optimal Δ ?⁸ To address this question, the government considers the following problem

$$\min_{\Delta} \mathcal{L}^{j, gov} = [\pi_{t,appr}^j(\Delta) |\lambda|]^2 + \lambda^{gov} [y_{t,appr}^j(\Delta) |\lambda|]^2 \quad \text{for } j = II, III \quad (24)$$

Inflation and output are functions of the heterogeneity parameter Δ . For a given λ and a given protocol j , the government chooses Δ such that the loss in the approximating model is minimized.

The previous section showed that inflation volatility falls and output volatility increases in Δ . Figures (3) and (4) show \mathcal{L}^{gov} as a function of λ^{gov} and Δ under voting protocol II and III. For a very conservative government, i.e. a policy-maker with a low λ^{gov} who puts a large relative weight on inflation stabilization, the effect of heterogeneity on inflation volatility dominates the effect on output

⁸In the reference model there is no "stabilization bias" of discretionary policy as inflation is stabilized efficiently, see Clarida, Galí, and Gertler (1999). The reason is that the cost-push shock is white noise. Therefore, appointing a conservative central banker, who puts larger weight on inflation stabilization than the government, cannot per se raise welfare.

volatility. The government should choose MPC members such that the degree of heterogeneity becomes larger. For a liberal government, i.e. when λ^{gov} is large, the opposite is true. The impact of Δ on output dominates the inflation effect and, as a result, the welfare loss increases in Δ . It follows that the committee should consist of members with a relatively more homogeneous degree of model uncertainty.⁹ These effects are strongest under protocol III.

If the government instead chooses the heterogeneity of the monetary policy committee based on the worst-case outcome, i.e. $\pi_{t,worst}$ and $y_{t,worst}$, a single decision maker is always best, see figure (5). The reason is that, to the extent the committee consists of more than one member, the effective degree of model confidence lies above the confidence of the single decision maker. It follows that, if the worst-case actually occurs, the policy response is suboptimal.

A second question pertaining to the design of the decision making process is choice of the aggregation protocol. Figure (6) presents the relative welfare loss $\mathcal{L}^{III}/\mathcal{L}^{II}$, i.e. the disadvantage of using protocol III. Welfare is generally higher under protocol II than under protocol III as a function of Δ . As the degree of heterogeneity increases, protocol III becomes even more adverse to welfare. When asked to design an aggregation protocol, the argument for a premise-based decision rule becomes stronger if the degree of members' heterogeneity increases.

6 A Bayesian approach to uncertainty

A central result of this paper is that heterogeneity across members in their degree of model uncertainty makes interest rate setting in a min-max approach more aggressive. Robust decision making is based on the assumption that the central bank is unable to formulate a probability distribution over alternative model specifications. Instead MPC members take the worst-case realizations of model distortions into account.

⁹Recent empirical studies also show that the size of the MPC is related to the variance of inflation. Erhart, Lehment, and Vasquez Paz (2007) find that countries in which the MPC has fewer than five members have a higher inflation variance than countries with a larger MPC. Berger and Nitsch (2009) study the impact of the MPC size on inflation volatility in 30 countries between 1960 and 2006. These authors find a U-shaped pattern. The lowest level of variance is reached at MPCs with intermediate size of about five to nine members. Although Berger and Nitsch (2009) do not study heterogeneity of committee members as a systematic determinant of inflation volatility, they control for the presence of regional representatives in the MPC. Interestingly, they find that regional representation, which might reflect heterogeneity, reduces inflation volatility. Farvaque, Hammadou, and Stanek (2006) argue that heterogeneity of committee members with respect to their professional experience reduces inflation.

An alternative approach to model monetary policy under uncertainty allows the decision makers to be able to attach priors to alternative model specifications. For simplicity, let us focus on parameter uncertainty. Members are uncertain about the parameter κ , which is of crucial importance for the monetary transmission process.

Instead of assuming a budget of unspecified distortions available to the evil agent, we follow Walsh (2010) and assume members have a prior on κ , which is subject to white noise stochastic disturbances. The degree of uncertainty of a single decision maker is represented by the variance of this disturbances σ_κ^2

$$\kappa_t = \bar{\kappa} + \varepsilon_t \quad \text{with } \varepsilon_t \sim \mathcal{N}(0, \sigma_\kappa^2)$$

Monetary policy sets the instrument to maximize welfare before uncertainty is resolved. As a consequence, the central bank maximizes the expected welfare loss given in (3). The first order condition is now given by $\mathbb{E}_t(\kappa_t \pi_t + \lambda y_t) = 0$. The solution for the interest rate for a single decision maker is

$$R_t^{Bayes} = \frac{\sigma \bar{\kappa}}{\lambda + (\bar{\kappa} + \sigma_\kappa^2)} e_t \quad (25)$$

The interest rate variance falls if uncertainty increases. This reflects the different policy recommendations of the robust control approach to uncertainty and the Bayesian approach. Here uncertainty makes policy less aggressive, while in the previous analysis of the robust control approach policy becomes more aggressive. Now assume different degrees of parameter uncertainty across members as reflected in an idiosyncratic degree of uncertainty $\sigma_{\kappa,i}^2$ for member i . Averaging σ_κ^2 across members gives the mean degree of uncertainty. This case is not further analyzed. More interesting is the case in which members average their individual interest rate recommendations $R_{t,i}^{Bayes}$ resulting from the idiosyncratic degrees of uncertainty $\sigma_{\kappa,i}^2$. The decisive insight here is that the results presented before for the aggregation carry over to the case of Bayesian uncertainty, although the effect of uncertainty on policy aggressiveness per se is exactly the opposite. Again the interest rate is a convex function of the degree of uncertainty. If members average their individual interest rate proposals, they effectively implement a policy stance that is more aggressive than the policy a single decision maker with the same average degree of uncertainty would implement. Figure (7) depicts the resulting interest rate variance for $\sigma_{\kappa,2}^2 = \sigma_\kappa^2$, $\sigma_{\kappa,1}^2 = \sigma_\kappa^2 + \Delta$ and $\sigma_{\kappa,3}^2 = \sigma_\kappa^2 - \Delta$ with $\Delta \geq 0$. We set $\sigma_\kappa^2 = 2$. The variance of the interest rate increases in Δ . Hence, choosing the composition of the MPC affects macroeconomic volatility in the same way as in the robust control approach presented before. Put differently, the results are insensitive to the specific way uncertainty is modeled.

7 Conclusions

Members of monetary policy committees are most likely to differ with respect to their level of confidence in the benchmark model of the economy. To the extent members follow a min-max approach to shield the economy from distortions, the aggregation protocol matters. This paper shows that the inflation variance falls in the degree of members' heterogeneity. The results are robust to the way uncertainty is addressed. Under both a robust control approach and a Bayesian approach heterogeneity across members gives rise to more aggressive interest rate policy.

This result has interesting implications for the practical design of monetary committees. First, premised-based decision making appears to lead to a more favorable outcome than conclusion-based decision making. Second, for a conservative government, a heterogeneous composition of the MPC is preferable over a more homogeneous one. Faced with an enlargement of the Euro area, the ECB council is likely to become more heterogeneous in the near future. Based on the results in this paper, this should lead to a more vigorous stabilization policy.

One important caveat, however, should be kept in mind when interpreting these findings. The committee in this paper is non-interactive. Members do not discuss the pros and cons of alternative model distortions, but use simple averaging. In reality, however, some members might have a reputation for being more familiar with modelling the economy - maybe due to their academic background. Others such as the chairman may have privileged access to the research department's resources. This will lend support to their level of model uncertainty and will affect other members' decisions. Introducing interaction of policymakers in the light of model uncertainty is an interesting area of future research.

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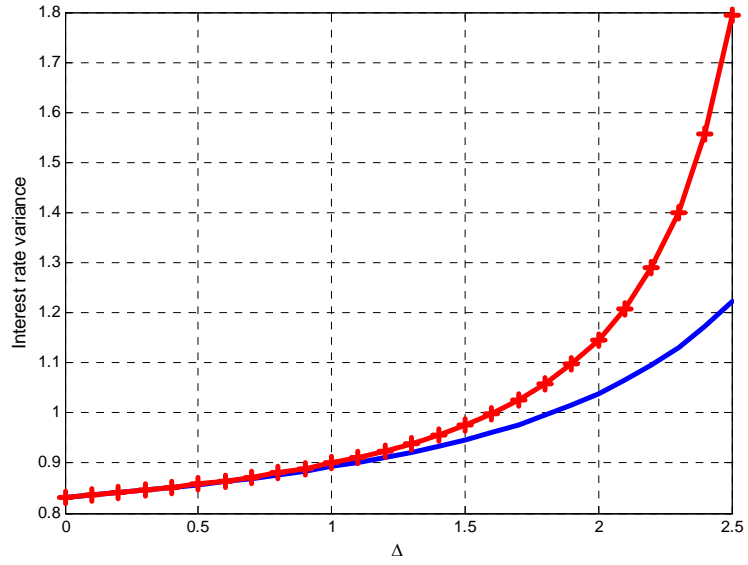


Figure 1: Interest rate variance as a function of Δ under protocol II (blue line) and protocol III (red line, crosses)

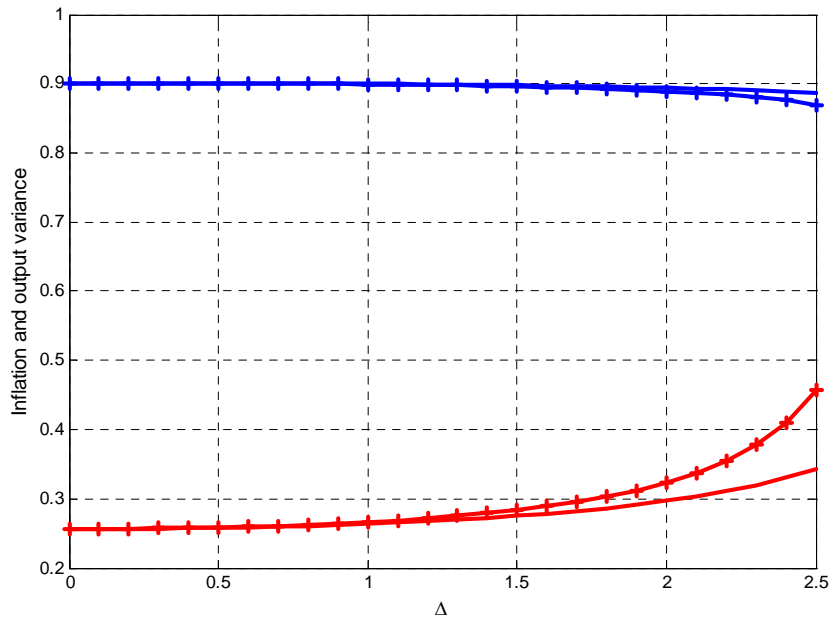


Figure 2: Inflation (blue line) and output (red line) variance as a function of Δ under protocol II (solid line) and protocol III (crosses)

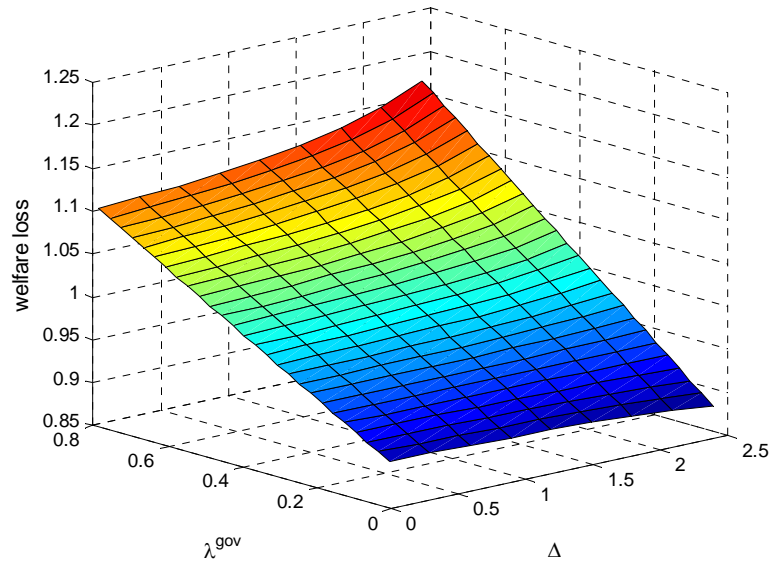


Figure 3: The welfare loss in the approximating model for a given λ as a function of λ^{gov} and Δ under protocol II

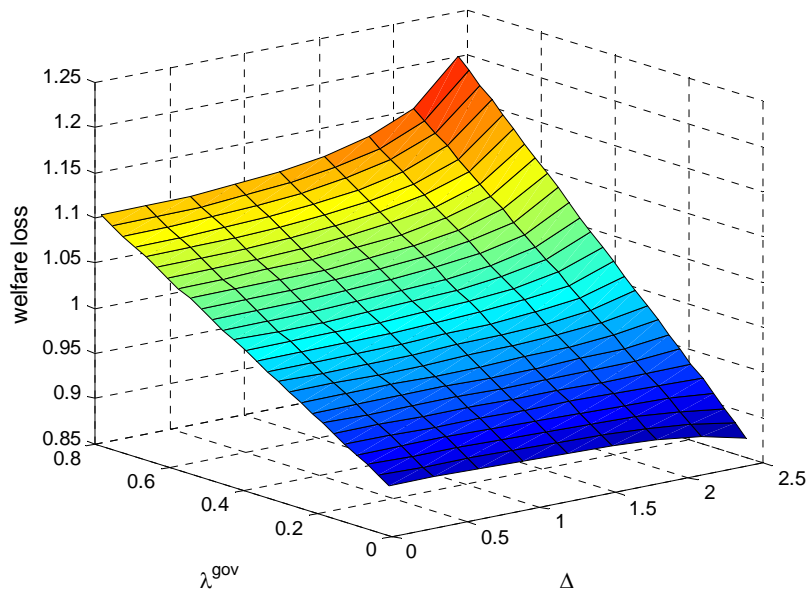


Figure 4: The welfare loss in the approximating model for a given λ as a function of λ^{gov} and Δ under protocol III

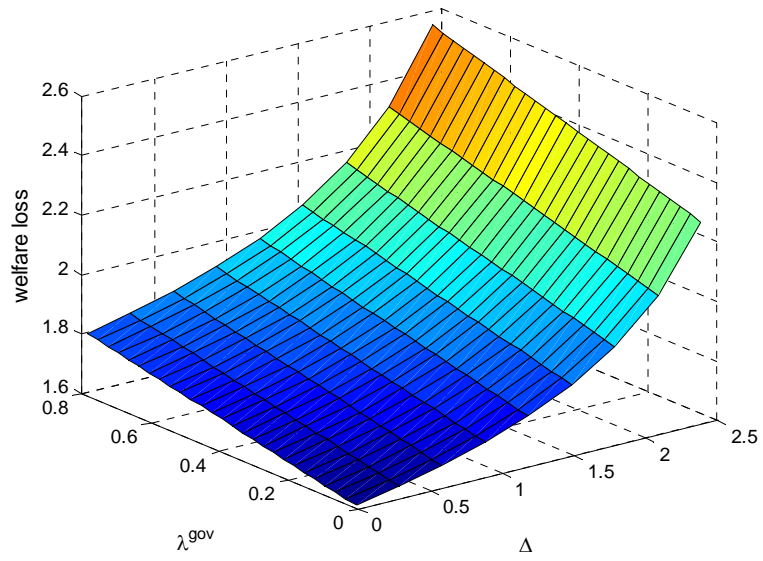


Figure 5: The welfare loss in the worst-case model for a given λ as a function of λ^{gov} and Δ under protocol II

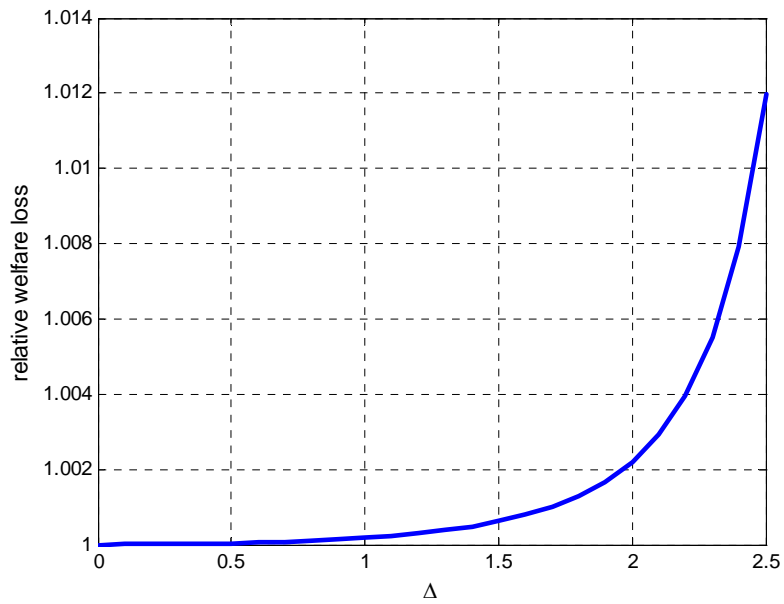


Figure 6: Welfare loss under protocol III relative to protocol II as a function of Δ

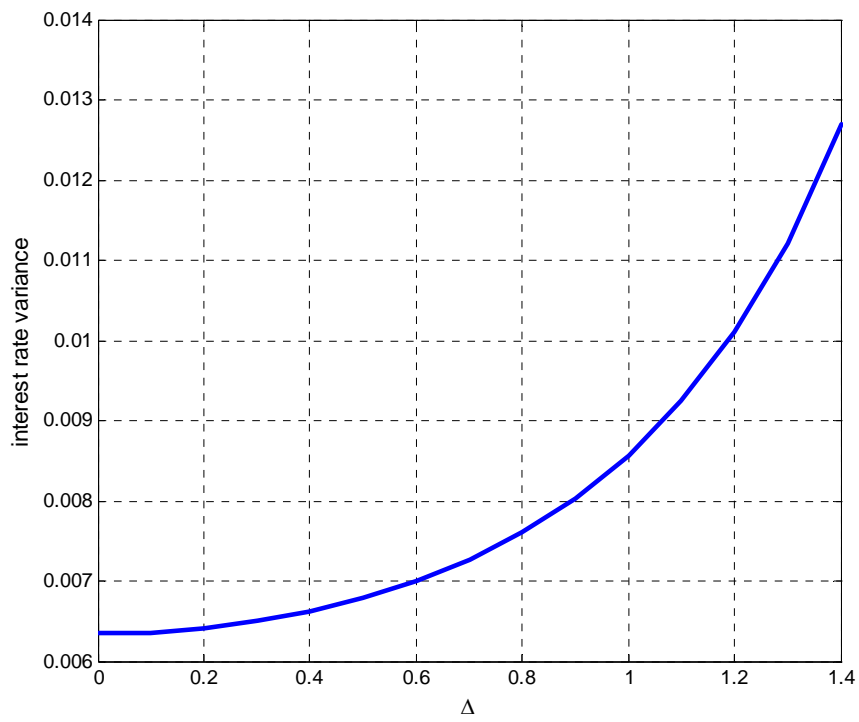


Figure 7: The interest rate variance as a function of Δ under a Bayesian approach to uncertainty