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Abstract

Transcripts from the meetings of the Federal Open Market Committee (FOMC) show that the policy proposed by its chair is always adopted with a majority of votes and limited dissent. An interpretation of this observation is that the power of the chair vis-a-vis the other members is so large that the policy selected by the committee is basically that preferred by the chair. Instead, this paper argues that the observation that the chair's proposal is always approved is an equilibrium outcome: the proposal passes because it is designed to pass and it does not necessarily correspond to the policy preferred by the chair. We construct a model of inclusive voting where the chair has agenda-setting powers to make the proposal that is initially put to a vote but is subject to an acceptance constraint that incorporates the preferences of the median and the probability of counter-proposals. The model is estimated by the method of maximum likelihood using real-time data from FOMC meetings. Results for the full sample and sub-samples for each chair between 1974 and 2008 show that the data prefer a version of our model where the chair is moderately inclusive over a dictator model. Thus, the workings of the FOMC appear to be stable over time and no chair, regardless of personality and recognized ability, can deviate far from the median view.

JEL Classification: N/A

Keywords: Inclusive-voting, agenda-setting, Consensus, FOMC, collective decision-making

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The Power of the Federal Reserve Chair*

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This version: June 2020

Abstract

Transcripts from the meetings of the Federal Open Market Committee (FOMC) show that the policy proposed by its chair is always adopted with a majority of votes and limited dissent. An interpretation of this observation is that the power of the chair *vis-a-vis* the other members is so large that the policy selected by the committee is basically that preferred by the chair. Instead, this paper argues that the observation that the chair's proposal is always approved is an equilibrium outcome: the proposal passes because it is designed to pass and it does not necessarily correspond to the policy preferred by the chair. We construct a model of inclusive voting where the chair has agenda-setting powers to make the proposal that is initially put to a vote but is subject to an acceptance constraint that incorporates the preferences of the median and the probability of counter-proposals. The model is estimated by the method of maximum likelihood using real-time data from FOMC meetings. Results for the full sample and sub-samples for each chair between 1974 and 2008 show that the data prefer a version of our model where the chair is moderately inclusive over a dictator model. Thus, the workings of the FOMC appear to be stable over time and no chair, regardless of personality and recognized ability, can deviate far from the median view.

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1. Introduction

Transcripts from the meetings of the Federal Open Market Committee (FOMC) show that the policy proposed by its chair is always adopted with the support of a majority of votes. Although dissents are not uncommon and occur in about one-third of meetings, the number of dissenting votes is relatively small and, by definition, dissenting members were unable to prevent the implementation of the policy proposed by the chair. Meyer (2004, p. 53) argues that during his time as member of the Board there were only two "dissent seats" to be filled in the alphabetical order in which votes were cast. Gerlach-Kristen and Meade (2010) find statistical support for this claim. In his typology of monetary policy committees, Blinder (2004, p. 54) classifies the FOMC as an autocratically collegial committee where the chair more or less dictates the group "consensus." An interpretation of these observations is that the prestige, influence, and institutional role of the Federal Reserve chair is so extensive, and the power of its holder *vis-a-vis* the other members of the FOMC is so large, that the policy selected by the committee is basically that preferred by the chair.

This paper argues that the observation that the policy proposed by the FOMC chair is always approved is an equilibrium outcome: the chair's proposal passes because it is designed to pass and it does not necessarily correspond to the policy preferred by the chair. We construct a model of inclusive voting where the chair of the committee has agenda-setting powers and formulates the policy proposal that is initially put to a vote but members may subsequently make counter-proposals to the chair. We then show that in equilibrium, the chair's proposal meets an acceptance constraint that incorporates both the median's preferred policy and the possibility of counter-proposals. The proposal is as close to the chair's ideal point as it is acceptable to the median and it is approved by the committee with the support of both the chair and the median in the first voting round.

The model is estimated by maximum likelihood using real-time data from FOMC meetings between October 1974 and December 2008, for the full sample and for sub-samples for each chair in this period, namely Arthur Burns, William Miller, Paul Volcker, Alan Greenspan, and Ben Bernanke. Results show that for all samples, the data prefer a version of our model where the chair is moderately inclusive. Furthermore, for all samples, the data prefer the moderately-inclusive voting model to a dictator model where the policy selected in every meeting is that preferred by the chair, albeit subject to a size friction whereby the committee adjusts the interest rate only if it deviates by more than 25 basis points from the chair's preferred value. These results are important because they show that despite the fact that different individuals may act as FOMC chair, the workings of the committee are themselves stable over time and power is shared between the chair and the rest of the committee. Hence the FOMC's unique structure achieves an "internal system of checks and balances" (Blinder, 1998) and no chair, regardless of personality and recognized ability, can deviate far from the median view.

The monetary policy committee consists of policy-makers who agree on the optimal inflation rate but associate different marginal disutilities to positive and negative deviations from this rate. As a result, committee members have heterogenous preferences over the optimal interest rate given current output and inflation. The committee makes decisions by voting, but one of its members–the chair—has the power to make the initial policy proposal to the other members in every meeting. The median member could be subsequently selected to make counter-proposals to the chair with probability $\gamma \in [0, 1]$. This probability measures the inclusiveness of the voting protocol and it may be different for different FOMC chairs. The inclusiveness of the voting process has implications on policy decisions. A less inclusive voting procedure (lower γ) worsens the median's outside option of rejecting the chair's proposal. This strengthens the relative power of the chair, who can successfully propose a policy closer to her ideal point.

In the special case where the probability γ is zero, the chair has absolute proposal power and her initial proposal is actually a take-it-or-leave-it offer. This special case corresponds to the well-known agenda-setting model of Romer and Rosenthal (1978). When instead γ goes to one, proposal power is concentrated in the median. As discussed above, the data do not support extreme values of γ and prefer instead a version of the model where the chair is moderately inclusive and the policy outcome resembles that in the consensus model in Riboni and Ruge-Murcia (2010). However, their consensus model is based on the *ad-hoc* assumption that support from a super-majority of members is required for a policy change in a committee where all members have equal power. Instead, the consensus outcome arises here endogenously when the discussion is sufficiently (but not too) inclusive to allow counter-proposals by the median and despite the fact that the chair has special responsibilities and authority.

Previous literature that studies the influence of the Federal Reserve Chair on FOMC decisions includes Romer and Romer (2004), who review transcripts from FOMC meetings and conclude that the chair's beliefs are almost always central to policy-making and that the chair is generally able to impose his or her views on the committee. Chappell et al. (2005, p. 109) infer the preferred policies of individual voting members and conclude that Arthur Burns' voting weight was approximately 40% to 50%. Meade and Stasavage (2008) show that after 1993, when FOMC members learnt that their deliberations would be made public after five years, the tendency to dissent from the chair decreased. Our work complements theirs by explicitly modeling strategic interactions among committee members and deriving the policy outcome under a fully-specified protocol where the chair and the median have specific roles. Our empirical analysis does not require us to infer the preferred policies of individual voting members and, indeed, we take the view that the "preferred" policies and proposals stated in FOMC transcripts (most notably by the chair) do not truly represent preferred policies but incorporate the notion of what is acceptable to other members. In line with Romer and Romer's narrative evidence, we find that the chair has a unique role in shaping policy and may propose and get approved policies closer to his or her ideal point.

The paper is organized as follows. Section 2 presents the model of individual policy preferences and inclusive-voting in a monetary policy committee. Section 3 presents a "dictator" model where the committee adopts the policy preferred by the chair but subject to a friction in the size of interest-rate adjustments. Section 4 describes the data and estimation strategy, discusses identification, and reports empirical results. Section 6 concludes.

2. A Model of Inclusive Voting

This section presents a model of the interest rate preferred by the members of a monetary policy committee and describes the protocol used by the committee to make a decision. A key feature of the protocol is that the chair of the committee has agenda-setting powers and formulates the policy proposal that is initially put to a vote but members may subsequently make counter-proposals to the chair.

2.1 Preferences

Assume that the policy-maker n has preferences that can be represented by the function

$$E_s\left(\sum_{t=s}^{\infty}\beta^{s-t}U_n(\pi_t-\pi^*)\right), \tag{1}$$

where E_s is the expectation conditional on information available at time s, $\beta \in (0,1)$ is the discount factor, π_t is the inflation rate, π^* is the optimal inflation rate, and $U_n(\pi_t-\pi^*)$ is instantaneous utility. The instantaneous utility function is

$$U_n(\pi_t-\pi^*) = \begin{cases} -\lambda_n|\pi_t-\pi^*|, & \text{if} \quad \pi_t-\pi^*>0, \\ -(1-\lambda_n)|\pi_t-\pi^*|, & \text{if} \quad \pi_t-\pi^*\leqslant 0, \end{cases} \tag{2}$$

where $\lambda_n \in (0,1)$ is a preference parameter.[1] The subscript n in λ_n makes explicit that the value of this parameter depends on the identity of the policy-maker. Hence, policy-makers associate different

[1] Since the U.S. Federal Reserve is subject to a dual mandate, it may be argued that instantaneous utility should include an output measure as well. In preliminary work we considered models where utility is a function of both inflation and output and the relative output weight is heterogenous across members, but unfortunately these models are not analytically tractable (for example, the ordering of preferred interest rates can no longer be represented along a single dimension).

marginal disutilities to positive and negative deviations from optimal inflation. The piece-wise linear function (2) is symmetric in the special case where $\lambda_n = 1/2$, meaning that the marginal disutility of positive and negative deviations from optimal inflation is the same in absolute value. The function is asymmetric in the more general case where $\lambda_n \neq 1/2$. For instance, when $\lambda_n \in (1/2, 1)$ the marginal disutility of positive deviations is larger in absolute value than the marginal disutility of negative deviations. The converse is true in the case where $\lambda_n \in (0, 1/2)$. Figure 1 plots the utility function (2) for different values of λ_n.

As in Svensson (1997), the behavior of the private sector is summarized by a Phillips curve and an aggregate demand curve,

$$\pi_{t+1} = \pi_t + \alpha y_t + \zeta_{t+1}, \tag{3}$$

$$y_{t+1} = \eta y_t - \psi(i_t - \pi_t - \iota) + \xi_{t+1}, \tag{4}$$

where y_t is an output measure, i_t is the nominal interest rate, ι is the real interest rate, $\alpha, \psi > 0$ and $0 < \eta < 1$ are parameters, and ξ_t and ζ_t are disturbances. The disturbances follow the moving-average processes

$$\zeta_t = u_t + \omega u_{t-1}, \tag{5}$$

$$\xi_t = v_t + \varsigma v_{t-1}, \tag{6}$$

where u_t and v_t are mutually independent innovations. The innovations are normally distributed white noises with mean zero and variances σ_u^2 and σ_v^2, respectively. Note that (3) and (4) imply that the interest rate selected at time t affects inflation only after two periods through its effect on output after one period, and that realized inflation at time $t+2$ will be different from π^* as a result of shocks that occur during this control-lag period.

Define the interest rate preferred by policy-maker n at time t to maximize expected utility at time $t+2$ as

$$i_{n,t}^* = \arg\max \beta^2 E_t U_n(\pi_{t+2} - \pi^*), \tag{7}$$

where the maximization is subject to (3) and (4). For the utility function in (2), equation (7) may be written as

$$i_{n,t}^* = \arg\max \beta^2 E_t((1 - \lambda_n) - I(\pi_{t+2} - \pi^* > 0))(\pi_{t+2} - \pi^*),$$

where $I(\cdot)$ is an indicator function that takes value 1 if the condition $\pi_{t+2} - \pi^* > 0$ is satisfied and 0 otherwise. Appendix A shows that the first-order condition for this problem is

$$E_t(\pi_{t+2}) = \pi^* - \sigma\Phi^{-1}(\lambda_n), \tag{8}$$

where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal distribution, $\Phi^{-1}(\lambda_n)$ is the quantile associated with λ_n, and σ is the standard deviation of a linear combination of the innovations in periods $t+1$ and $t+2$ (see below).

In the special case where the utility function is symmetric, $\Phi^{-1}(1/2) = 0$ and $E_t(\pi_{t+2}) = \pi^*$. Hence, the utility-maximizing interest rate is such that expected inflation at time $t+2$ is the optimal inflation rate. In the more general case where the utility function is asymmetric, the interest rate is such that expected inflation is systematically different from the optimal rate. The bias is proportional to the standard deviation of the shocks in the control-lag period and depends nonlinearly on the preference parameter λ_n. The bias is negative in the case where $\lambda_n \in (1/2, 1)$ and the marginal disutility of positive deviations is larger in absolute value than the marginal disutility of negative deviations. The bias is positive in the converse case where $\lambda_n \in (0, 1/2)$.[2]

Finally, using the constraints (3) and (4), and the first-order condition (8), the interest rate preferred by policy-maker n can be written as

$$i^*_{n,t} = a_n + b\pi_t + dy_t + \epsilon_t, \tag{9}$$

where

$$a_n = \iota - (1/\alpha\psi)\pi^* + (\sigma/\alpha\psi)\Phi^{-1}(\lambda_n) \tag{10}$$

is an individual-specific intercept, $b = 1 + (1/\alpha\psi)$ and $d = (1+\eta)/\psi$ are coefficients common to all policy-makers, and $\epsilon_t = \omega u_t/\alpha\psi + \varsigma v_t/\psi$ is a white noise disturbance with variance $\sigma^2 = (\omega/\alpha\psi)^2 \sigma_u^2 + (\varsigma/\psi)^2 \sigma_v^2$. Because shocks are also common to all policy-makers, the relative distance between their preferred interest rates is constant and given by the relative distance of the intercepts in their individual reaction functions (a_n). Since $\sigma/\alpha\psi > 0$ and $\Phi^{-1}(\lambda_n)$ is monotonically increasing in λ_n, then a policy-maker with a higher λ_n prefers a higher interest rate than another one with a lower λ_n, for the same current output and inflation. The reason is that the prudence implied by the asymmetric utility function (2) induces the former policy-maker—who suffers a larger marginal disutility from positive inflation deviations from the optimal rate than the latter one—to prefer an interest rate that reduces the probability of inflation going above the optimal rate.

[2] There are comparable results in the forecasting literature. For symmetric loss functions (for instance, the quadratic function) the optimal forecast is the conditional mean, while for asymmetric loss functions (for instance, the linex function) the optimal forecast is the conditional mean plus or minus a bias term (see Elliot and Timmermann, 2004).

2.2 Voting

The interest rate, i_t, is selected by a committee that consists of N policy-makers and takes decisions by vote. For simplicity, assume that N is odd.[3] The interest rates that can be considered by the committee belong to the interval $I = \left[0, \bar{i}\right]$. Policy-makers are heterogenous in their preference parameter λ_n. Rank committee members as follows: $0 < \lambda_1 < \lambda_2 < ... < \lambda_N < 1$. Since $\sigma/\alpha\psi$ is strictly positive and $\Phi^{-1}(\lambda_n)$ increases monotonically in λ_n, (9) implies that $i^*_{1,t} < i^*_{n,2} < ... < i^*_{N,t}$. Under the assumptions in section 2.1, the ranking over preferred interest rates is stable over time.

Policy-makers differ in their institutional role within the committee. In particular, the chair of the committee (denoted by c) has the power to set the agenda and formulates the policy proposal that is initially put to a vote. The chair shares proposal power with the median of the committee (denoted by m), who can make counter-proposals to the chair. Concerning the voting rule, it is assumed that a policy change is approved if two conditions hold: 1) the policy change is approved by (at least) a majority $(N+1)/2$ of committee members, and 2) the policy change is approved by the chair. An implication of 2) is that the chair holds veto power over policy decisions.[4]

Write the induced utility of each committee member as a function of the interest rate selected by the committee as

$$U_n(i_t) = \begin{cases} -\phi(1-\lambda_n)|i_t - i^*_{n,t}|, & \text{if} \quad i_t - i^*_{n,t} > 0, \\ -\phi\lambda_n|i_t - i^*_{n,t}|, & \text{if} \quad i_t - i^*_{n,t} \leqslant 0, \end{cases} \tag{11}$$

where $\phi \equiv \beta^2\alpha\psi > 0$.[5] This specification implies that the most hawkish members of the committee, who are characterized by a higher λ_n, have a lower marginal disutility when the committee sets an interest rate above their preferred interest rate (that is, $i_t - i^*_{n,t} > 0$) than when the committee sets an interest rate below their preferred interest rate (that is, $i_t - i^*_{n,t} < 0$). The converse is true for the most dovish members of the committee, who are characterized by a lower λ_n.

Our voting model builds on the seminal paper by Baron and Ferejohn (1989).[6] In each period t, the meeting takes as given the status quo policy (q_t), which coincides with the interest rate selected by the committee in the previous meeting, i.e., $q_t = i_{t-1}$. The meeting unfolds as follows.

[3] This assumptions is not satisfied by the FOMC, which has twelve voting members. However, the assumption is only made to ease exposition—since it allows us to uniquely pin down the identity of the median—and it is not essential for our analysis.

[4] Veto power is not among the formal prerogatives of the FOMC chair, but this modeling assumption accords well with the widely held view that the chair would be able to block an interest rate change that she strongly dislikes.

[5] Strictly speaking this formulation involves a piece-wise linear approximation to the induced utility implied by (2), which is smooth in the neighbourhood of $i^*_{n,t}$ as a result of the expectations operator. This approximation is essential to allow the analytical solution of the system of equations that determines the equilibrium proposals of the chair and the median. The approximation, however, preserves the bliss point and the linearity of the induced utility away from $i^*_{n,t}$.

[6] See also Banks and Duggan (2006), Cardona and Ponsati (2011) and Predtetchinski (2011).

Divide the meeting in sub-periods or "rounds" denoted by $\tau \geq 1$. At $\tau = 1$, the chair makes an initial policy proposal to the committee. Afterwards, all individuals simultaneously vote to either accept or reject this proposal. If a majority of members cast a "yes" vote, the meeting ends and the successful proposal is implemented and replaces the status quo. If, instead, the chair's proposal is rejected, the meeting moves to the next round. At $\tau = 2$, the median is selected with probability γ to make a counter-proposal.[7] Alternatively, the chair is selected with probability $1 - \gamma$ to make a new proposal. If either proposal passes, the meeting ends and the successful proposal replaces the status quo. If the proposal is rejected, the meeting moves to round $\tau = 3$ where, again, with probability γ (resp. $1 - \gamma$) the median (resp. the chair) is selected to make a new proposal. The meeting continues indefinitely until a proposal is accepted.

There is no discounting across bargaining rounds but there is an exogenous risk of negotiation breakdown in every round of the meeting. That is, after a committee member (either c or m) is selected to make a proposal, the meeting may end with probability $p \in [0, 1)$. In case of breakdown, the status quo is maintained meaning $i_t = i_{t-1}$. The breakdown risk is a modeling device that makes it costly to indefinitely delay an agreement. In the end, we will solve the policy outcome in the limiting case when p goes to zero (see Osborne and Rubinstein, 1990, ch. 4.2).

A key parameter in the voting game is γ, which measures the "inclusiveness" of the voting procedure, meaning how proposal power is shared between the chair and the median. As formally shown in the next sections, a higher γ (resp. lower γ) implies that the implemented policy is closer to the preferences of the chair (resp. median). When $\gamma = 0$, the median is never selected to make counter-proposals. In this case, the chair has absolute proposal power and her proposals are *de facto* take-it-or-leave-it offers to the committee. It is shown below that this special case corresponds to the agenda-setting model of Romer and Rosenthal (1978). There is also an intermediate range of values of γ (to be made precise below) for which the meeting is sufficiently inclusive that the decision is effectively made by consensus, in the sense of Riboni and Ruge-Murcia (2010). Finally, as γ tends to 1, the proposal power of the chair vanishes.

We study stationary Markov-perfect equilibria. That is, we rule out history-dependent strategies. Furthermore, members' strategies do not depend on either t or τ. If member $n = c, m$ is recognized to propose, given the initial status quo policy, her strategy is a proposal $i_n \in I$. As it is standard in the literature on legislative bargaining, we assume that policy-makers vote as if they were pivotal and support only proposals that they weakly prefer to the utility of moving to the next bargaining round. We solve the equilibrium outcome within each meeting and assume that

[7] Results would be virtually unchanged if we were to assume that with positive probability other committee members, in addition to the median, could make counter-proposals.

committee members abstract from the consequences of their voting decision on future meetings via the status quo.

The solution of the bargaining model depends on the location of the chair's preferred interest rate relative to the median's in the ordering $i^*_{1,t} < i^*_{n,2} < ... < i^*_{N,t}$. There are three possible cases, namely $i^*_{c,t} > i^*_{m,t}$, $i^*_{c,t} < i^*_{m,t}$, or $i^*_{c,t} = i^*_{m,t}$. In the case where $i^*_{c,t} > i^*_{m,t}$, the chair is more hawkish than the median member in the sense that, conditional on inflation and output, c prefers a higher interest rate than m. However, this does not imply that the chair is the most hawkish member of the committee and there may be members that systematically prefer higher interest rates than the chair does. In the case where $i^*_{c,t} < i^*_{m,t}$, the chair is more dovish than the median member, but, again, there may be members that systematically prefer lower interest rates than the chair. Finally, in the case where $i^*_{c,t} = i^*_{m,t}$, the interest rate preferred by the chair and the median coincide.

A key feature of the voting model is that the median and the chair are "decisive," meaning that any winning coalition must include both of them. The "decisiveness" of the chair follows from her veto power, while the "decisiveness" of the median follows from the requirement that any policy change must be approved by a majority of committee members. In addition, note that equilibrium-winning coalitions are connected. In other terms, any proposal to decrease the interest rate that is not accepted by the median will not be accepted by any member who is more hawkish (i.e., has a higher λ_n) than the median. Similarly, any proposal to increase the interest rate that is not accepted by the median will not be accepted by any voter whose λ_n is lower than λ_m. The interval between $i^*_{c,t}$ and $i^*_{m,t}$, which are the preferred points of the two key committee members, is the "core" or "gridlock interval"—that is, the set of policies for which there does not exist another policy that is strictly preferred by a decisive coalition—. We state the following result.

Lemma 1: *When* $q \in [\min\{i^*_{c,t}, i^*_{m,t}\}, \max\{i^*_{c,t}, i^*_{m,t}\}]$*, no policy change is politically feasible, the status quo policy is maintained, and* $i_t = i_{t-1}$.
Proof: see appendix B.

The result that any policy in the gridlock interval is stable follows immediately from the fact that starting from any policy in this set, it is not possible to increase the utility of either m or c without decreasing the utility of the other member.

To determine the equilibrium, we compute the set of acceptable policies for the two decisive members. (To avoid cluttered notation, we drop momentarily the time index and will reintroduce it below in section 4.3 where we derive the likelihood function.) Recall that i_c and i_m denote the equilibrium proposal by the chair and by the median, respectively. When the chair is entitled to propose, the median accepts policy x if and only if doing so makes him at least as well-off as rejecting it. That is,

$$U_m(x) \geq pU_m(q) + \gamma(1-p)U_m(i_m) + (1-\gamma)(1-p)U_m(i_c). \tag{12}$$

The left-hand side is the utility of implementing the chair's proposal. Recalling that there is no discounting, the right-hand side is the expected value of rejecting the proposal and moving the discussion to the next bargaining round, counting on the possibility of being recognized to make a counter-proposal. If negotiation breaks down, which is an event that occurs with probability p, the status quo is maintained. Otherwise, with probability γ (resp. $1-\gamma$) the median (resp. the chair) will make a new proposal, which is expected to pass. Inequality (12) is the acceptance constraint of the chair. Notice that a "bad" status quo policy lowers the median's outside option of rejecting the chair's proposal. This widens the set of policies acceptable to the median, allowing the chair to propose a policy closer to i_c^*. In addition, when the median is unlikely to be recognized to make a proposal (γ is low), the median's bargaining power weakens.

Similarly, when the median is entitled to propose, the chair accepts proposal x if and only if

$$U_c(x) \geq pU_c(q) + \gamma(1-p)U_c(i_m) + (1-\gamma)(1-p)U_c(i_c). \tag{13}$$

That is, the chair's utility of accepting the proposal must be greater than or equal to the utility of rejecting it. The acceptance sets of the median (denoted by A_m) and of the chair (denoted by A_c) contain all proposals that satisfy inequality (12) and (13), respectively. These are the proposals that the median and the chair would find acceptable. Given that members' utility is concave, it is immediate that both sets are closed intervals.

As discussed below and proven formally in appendix B, the chair proposes in the first period her preferred policy among those acceptable by the median. Thus, the equilibrium features no delay: the initial proposal is passed and the meeting ends in the first bargaining round.[8] The outside options of m and c contain the equilibrium proposals and, consequently, are endogenous to the model. To characterize the equilibrium, we must then solve for a fixed point in i_c and i_m. Note that even if the median's proposal is not observed in equilibrium, i_m affects policy outcomes indirectly through (12).

2.3 Hawkish Chair

In this section we solve the case where $i_c^* > i_m^*$, meaning that the chair of the committee is more hawkish than the median member. In equilibrium, the chair proposes her preferred policy

[8] Delays in reaching an agreement may arise when individuals are incompletely informed (see Osborne and Rubinstein, 1990, ch. 5). Note, however, that in this paper players have complete information of preferences, of the current shocks, and of the structure of the game.

among those that the median finds acceptable, i.e., $i_c = \min\{i_c^*, \max\{A_m\}\}$. Similarly, the median proposes his preferred policy within the chair's acceptance set, i.e., $i_m = \max\{i_m^*, \min\{A_c\}\}$. In any equilibrium, i_c and i_m must belong to the gridlock interval. This is intuitive because proposing an interest rate outside this interval is sub-optimal for both c and m.

To further characterize the equilibrium, we need to distinguish different cases depending on the location of the status quo. From lemma 1, when $q \in [i_m^*, i_c^*]$, the status quo cannot be changed meaning that $i_c = i_m = q$. Consider next the case where the status quo is to the right of the ideal points of both members, that is $q > i_c^* > i_m^*$. Suppose further that the status quo is not too high (in a manner to be made precise below). We solve for the endpoints of the acceptance sets and then determine the equilibrium proposals i_c and i_m by solving the following system of two equations with two unknowns,

$$\begin{aligned} i_c &= \min\left\{i_c^*, \frac{qp + (1-p)\gamma i_m}{1-(1-p)(1-\gamma)}\right\}, && (14) \\ i_m &= \max\left\{i_m^*, \frac{(1-p)(1-\gamma)\lambda_c i_c + p i_c^* - qp(1-\lambda_c)}{(1-(1-p)\gamma)\lambda_c}\right\}. && (15) \end{aligned}$$

Then, taking the limit as p goes to zero shows that the proposal by both decisive players coincide. This means that as delaying becomes costless, the chair's first-proposer advantage vanishes. The proposal made by m and c is

$$i_c = i_m = min\left\{q - (\gamma/\lambda_c)(q - i_c^*), i_c^*\right\}, \tag{16}$$

By quick inspection of (16), when $\gamma \leq \lambda_c$ the equilibrium proposal is equal to i_c^*. This is intuitive: when the discussion is not sufficiently inclusive, in the sense that γ is low (relative to λ_c), then the outcome is the same as under the agenda-setting model of Romer and Rosenthal (1978).[9] Instead, when $\gamma > \lambda_c$, the voting procedure is inclusive enough that the median is able to obtain a policy lower than i_c^*, namely $q - (\gamma/\lambda_c)(q - i_c^*)$, and closer to his ideal point. The higher is q, the more dovish the chair's proposal. Finally, note that (16) holds only if the status quo is not too large, otherwise the proposal $q - (\gamma/\lambda_c)(q - i_c^*)$ would be lower than i_m^*, which is outside the core and, thus, suboptimal. The condition that $q - (\gamma/\lambda_c)(q - i_c^*) \geq i_m^*$, implies an upper bound on q,

$$q_{ub}^1 = (i_m^* - (\gamma/\lambda_c)i_c^*)/(1 - (\gamma/\lambda_c)), \tag{17}$$

beyond which the proposal is $i_c = i_m^*$.

Consider now the case where the status quo is to the left of the ideal points of both players, that is $q < i_m^* < i_c^*$, but not too low (more on this below). Then, after computing $\max\{A_m\}$ and $\min\{A_c\}$, the two conditions that equilibrium proposals must satisfy are

[9] Alternatively, the same outcome would arise when λ_c is high (relative to γ). The reason is that a high λ_c raises the bargaining power of the chair because she would suffer less than the median from keeping the status quo.

$$
\begin{aligned}
i_c &= \min\left\{ i_c^*, \frac{(1-p)\gamma(1-\lambda_m)i_m + pi_m^* - qp\lambda_m}{(1-(1-p)(1-\gamma))(1-\lambda_m)} \right\}, && (18) \\
i_m &= \max\left\{ i_m^*, \frac{pq + (1-p)(1-\gamma)}{1-(1-p)\gamma} \right\}. && (19)
\end{aligned}
$$

Solving this system of simultaneous linear equations and taking the limit as p goes to zero show that the proposal by both decisive players coincide and is

$$
i_c = i_m = max\left\{ i_m^* (1-\gamma) / (1-\lambda_m) - q((1-\gamma) / (1-\lambda_m) - 1), i_m^* \right\}. \tag{20}
$$

Notice from (20) that when $\gamma \geq \lambda_m$ the equilibrium proposal is equal to i_m^*. The median obtains his preferred policy when his proposal power is sufficiently large, in the sense that γ is high (relative to λ_m) or, conversely, λ_m is high (relative to γ), meaning that his bargaining power is high because he would suffer less than the chair from keeping the status quo. Instead, when $\gamma < \lambda_m$ the inclusiveness of the voting procedure is low enough that the chair can propose a policy higher than i_m^*, that is $i_m^* (1-\gamma) / (1-\lambda_m) - q((1-\gamma) / (1-\lambda_m) - 1)$, which is closer to her ideal point. Again, (20) holds only if the status quo is not too low relative to i_m^* so that the proposal still belongs to the gridlock interval. The condition that $i_m^* (1-\gamma) / (1-\lambda_m) - q((1-\gamma) / (1-\lambda_m) - 1) \leq i_c^*$ implies a lower bound on q,

$$
q_{lb}^1 = \left(i_c^* - i_m^* (1-\gamma) / (1-\lambda_m)\right) / (1 - (1-\gamma) / (1-\lambda_m)), \tag{21}
$$

below which the proposal is $i_c = i_c^*$.

On the basis of the above discussion, we state the following proposition.

Proposition 1 (Hawkish Chair): *Let $\lambda_c > \lambda_m$ so that $i_c^* > i_m^*$. Suppose $0 \leq \gamma < \lambda_m$. The policy outcome is*

$$
i = \begin{cases} i_c^*, & if \quad q < q_{lb}^1, \\ i_m^* (1-\gamma) / (1-\lambda_m) - q((1-\gamma) / (1-\lambda_m) - 1), & if \quad q_{lb}^1 \leq q \leq i_m^*, \\ q, & if \quad i_m^* < q \leq i_c^*, \\ i_c^*, & if \quad i_c^* \leq q, \end{cases} \tag{22}
$$

where $q_{lb}^1 = \left(i_c^* - i_m^* (1-\gamma) / (1-\lambda_m)\right) / (1 - (1-\gamma) / (1-\lambda_m))$. Suppose $\lambda_m \leq \gamma \leq \lambda_c$. The policy outcome is

$$
i = \begin{cases} i_m^*, & if \quad 0 \leq q < i_m^*, \\ q, & if \quad i_m^* < q \leq i_c^*, \\ i_c^*, & if \quad q > i_c^*. \end{cases} \tag{23}
$$

Finally, suppose $\lambda_c < \gamma \leq 1$. *The policy outcome is*

$$i = \begin{cases} i_m^*, & \text{if} \quad 0 \leq q < i_m^*, \\ q, & \text{if} \quad i_m^* < q \leq i_c^*, \\ q - (\gamma/\lambda_c)(q - i_c^*), & \text{if} \quad i_c^* \leq q \leq q_{ub}^1, \\ i_m^*, & \text{if} \quad q > q_{ub}^1, \end{cases} \tag{24}$$

where $q_{ub}^1 = (i_m^* - (\gamma/\lambda_c)i_c^*)/(1 - (\gamma/\lambda_c))$.
Proof: see appendix B.

Proposition 1 states that when the status quo lies outside the core, the committee agrees to select a policy inside the core. The parameter γ, which measures the proposal power of the median relative to the chair, is key to determine which core policy is selected. The implemented policy is closer to i_c^* (resp. i_m^*) when the chair (resp. the median) is more likely to be recognized as proposer. Furthermore, the proposed policy depends on q_t, which constitutes the threat point in case of a negotiation breakdown. Different status quo locations are associated with different threat-point utilities for the median and the chair, thus changing their relative bargaining power. *Ceteris paribus*, a more extreme status quo policy reinforces the bargaining power of the committee member with higher proposal power. When the status quo policies are close to the boundaries of the policy space, we find that the implemented policy coincides with i_c^* (resp. i_m^*) when γ is relatively low (resp. high).

More specifically, consider first a status quo policy higher than i_c^* so that most committee members, including the chair, would like to cut the interest rate. A high status quo strengthens the chair's bargaining power because the chair stands to lose less than the median if the negotiation breaks down. Notice in fact that the chair's (median's) marginal disutility evaluated at the status quo is given by $1 - \lambda_c$ (resp. $1 - \lambda_m$). Proposition 1 states that the chair is able to impose her preferred policy when $\gamma \leq \lambda_c$. This cutoff has an intuitive explanation: the chair is able to extract all surplus associated with the interest rate cut when the median is less likely to make counter-offers (lower γ) or when the chair's threat point increases (higher λ_c). When instead $\gamma > \lambda_c$, the chair must compromise with the median. The higher is q, the more dovish her proposal.

Consider now a low status quo policy ($q < i_m^*$) so that most committee members, including the median, would like to increase the interest rate. The median's (resp. chair's) marginal utility evaluated at q is given by λ_m (resp. λ_c). A low status quo policy strengthens the median's bargaining position because the chair stands to lose more than the median if the status quo is maintained. Proposition 1 states that when the voting protocol is sufficiently inclusive (namely, $\gamma \geq \lambda_m$) the chair cannot do better than proposing the median's preferred policy. When instead

$\gamma < \lambda_m$, the chair is able to successfully propose a policy closer to i_c^*. The lower is q, the more hawkish the chair's proposal.

The policy outcome in proposition 1 nests three special cases in the literature. First, in the case where $\lambda_m \leq \gamma \leq \lambda_c$, when the status quo policy is above i_c^* (resp. below i_m^*) the chair proposes her (resp. the median's) preferred policy. This policy outcome corresponds to that in the consensus model in Riboni and Ruge-Murcia (2010). However, their consensus model is based on the ad-hoc assumption that support from a super-majority of members is required for a policy change in a setup where all members, including the chair, have equal power or influence. Instead, the consensus outcome arises here endogenously when the discussion is inclusive enough to allow counter-proposals by the median and despite the fact that the chair has unique powers not vested in other members. Second, in the case where $\gamma \to 1$, the chair's proposal power vanishes and, hence, when the status quo lies outside the gridlock interval, the proposed policies are close to the median's ideal point. However, even when γ goes to 1, the model does not converge to the median model because the chair has veto power. Finally, when $\gamma \to 0$, the chair has absolute proposal power and our model corresponds to the agenda-setting model of Romer and Rosenthal (1978) with a chair who is more hawkish than the median. However, having absolute proposal power does not mean that the chair is a dictator because she still requires the approval of a majority of committee members to implement a policy change. More formally,

Corollary 1 (Agenda-setting Model with a Hawkish Chair): *When $\gamma = 0$ the chair has an absolute proposal power. Then, when $i_c^* > i_m^*$ the policy outcome is*

$$i = \begin{cases} i_c^*, & \text{if} \quad q > i_c^*, \\ q, & \text{if} \quad i_m^* \leq q \leq i_c^*, \\ (1/(1-\lambda_m))(i_m^* - \lambda_m q), & \text{if} \quad (1/\lambda_m)(i_m^* - (1-\lambda_m)i_c^*) \leq q < i_m^*, \\ i_c^*, & \text{if} \quad q < (1/\lambda_m))(i_m^* - (1-\lambda_m)i_c^*). \end{cases} \tag{25}$$

2.4 Dovish Chair

In this section we solve the case where $i_c^* < i_m^*$, meaning that the chair is more dovish than the median committee member. This case is isomorphic to the case where $i_c^* > i_m^*$ and the reader may skip this section without loss. As in section 2.3, to characterize the equilibrium we need to distinguish different cases depending on the location of the status quo. Recall from lemma 1 that when $q \in [i_c^*, i_m^*]$, the interest rate cannot be adjusted meaning that $i_c = i_m = q$. Consider now the case where the status quo is to the right of the ideal points of both player, that is $q > i_m^* > i_c^*$. The chair proposes her preferred alternative within the set A_m, that is, $i_c = \max\{i_c^*, \min\{A_m\}\}$, and the median proposes his preferred alternative within the set A_c, that is, $i_m = \min\{i_m^*, \max\{A_c\}\}$.

Hence,

$$i_c = \max\left\{i_c^*, \frac{(1-p)\gamma\lambda_m i_m + p i_m^* - qp(1-\lambda_m)}{(1-(1-p)(1-\gamma))\lambda_m}\right\}, \tag{26}$$

$$i_m = \min\left\{i_m^*, \frac{qp + (1-p)(1-\gamma)i_c}{1-(1-p)\gamma}\right\}. \tag{27}$$

Solving this system of simultaneous linear equations and taking the limit as p goes to zero shows that the proposal by both decisive players coincide and is given by

$$i_c = i_m = min\left\{q + ((1-\gamma)/\lambda_m)(i_m^* - q), i_m^*\right\}. \tag{28}$$

When $\gamma \geq 1 - \lambda_m$, the proposal is $i_c = i_m^*$, which is the policy preferred by the median. When $\gamma < (1 - \lambda_m)$, the voting procedure is less inclusive and the chair can obtain a policy closer to i_c^*, that is $q + ((1-\gamma)/\lambda_m)(i_m^* - q)$. Note, however, that (28) holds only if the status quo is not too large, otherwise the proposal $q + ((1-\gamma)/\lambda_m)(i_m^* - q)$ would be lower than i_c^*, which is outside the core and, thus, suboptimal. The condition that $q + ((1-\gamma)/\lambda_m)(i_m^* - q) \geq i_c^*$ implies an upper bound on q,

$$q_{ub}^2 = (i_c^* - ((1-\gamma)/\lambda_m)i_m^*)/(1-(1-\gamma)/\lambda_m), \tag{29}$$

beyond which the proposal is $i_c = i_c^*$.

Consider now the case where the status quo is to the left of the ideal points of both players, that is $q < i_c^* < i_m^*$. As before, the chair proposes her preferred with the set A_m and the median proposes his preferred alternative within the set A_c. Hence,

$$i_c = \max\left\{i_c^*, \frac{pq + (1-p)\gamma}{1-(1-p)(1-\gamma)}\right\}, \tag{30}$$

$$i_m = \min\left\{i_m^*, \frac{(1-p)(1-\gamma)(1-\lambda_c)i_c + p i_c^* - qp\lambda_c}{(1-(1-p)\gamma)(1-\lambda_c)}\right\}. \tag{31}$$

Solving this system of simultaneous linear equations and taking the limit as p goes to zero shows that the proposal by both decisive players coincide and is given by

$$i_c = i_m = max\left\{q - (\gamma/(1-\lambda_c))(q - i_c^*), i_c^*\right\}. \tag{32}$$

When $\gamma \leq (1 - \lambda_c)$, the proposal is $i_c = i_c^*$, which is the policy preferred by the chair. When $\gamma > (1-\lambda_c)$ the inclusiveness of the voting procedure is high enough that the median can propose a policy that is higher than i_c^*, that is $q - (\gamma/(1-\lambda_c))(q - i_c^*)$. Again, (32) holds only if the status quo is not too small relative to i_c^*, so that the proposal belongs to the gridlock interval. The condition that $q - (\gamma/(1-\lambda_c))(q - i_c^*) \leq i_m^*$ implies a lower bound on q, that is

$$q_{lb}^2 = (i_m^* - (\gamma/(1-\lambda_c))i_c^*)\,/(1-\gamma/(1-\lambda_c)), \tag{33}$$

beyond which the proposal is $i_c = i_m^*$.

On the basis of the above discussion, we state the following proposition.

Proposition 2 (Dovish Chair): *Let $\lambda_c < \lambda_m$ so that $i_c^* < i_m^*$. Suppose $0 \leq \gamma < 1 - \lambda_m$. The policy outcome is*

$$i = \begin{cases} i_c^*, & \text{if} \quad 0 \leq q < i_c^*, \\ q, & \text{if} \quad i_c^* < q \leq i_m^*, \\ q + ((1-\gamma)/\lambda_m)(i_m^* - q), & \text{if} \quad i_m^* < q \leq q_{ub}^2, \\ i_c^*, & \text{if} \quad q \geq q_{ub}^2, \end{cases} \tag{34}$$

where $q_{ub}^2 = (i_c^* - ((1-\gamma)/\lambda_m)i_m^*)/(1-(1-\gamma)/\lambda_m)$. Suppose $1 - \lambda_m \leq \gamma \leq 1 - \lambda_c$. The policy outcome is

$$i = \begin{cases} i_c^*, & \text{if} \quad 0 \leq q < i_c^*, \\ q, & \text{if} \quad i_c^* < q \leq i_m^*, \\ i_m^*, & \text{if} \quad q > i_m^*. \end{cases} \tag{35}$$

Suppose $1 - \lambda_c < \gamma \leq 1$. The policy outcome is

$$i = \begin{cases} i_m^*, & \text{if} \quad q < q_{lb}^2, \\ q - (\gamma/(1-\lambda_c))(q - i_c^*), & \text{if} \quad q_{lb}^2 \leq q \leq i_c^*, \\ q, & \text{if} \quad i_c^* < q \leq i_m^*, \\ i_m^*, & \text{if} \quad i_m^* < q, \end{cases} \tag{36}$$

where $q_{lb}^2 = \left(i_m^* - (\gamma/(1-\lambda_c))i_c^*\right)/(1-\gamma/(1-\lambda_c))$.
Proof: see appendix B.

When $\gamma \to 0$, the chair has absolute proposal power and our model corresponds to the agenda-setting model of Romer and Rosenthal (1978) with a chair who is more dovish than the median. More formally,

Corollary 2 (Agenda-setting Model with a Dovish Chair): *When $\gamma = 0$ the chair has an absolute proposal power. Then, when $i_c^* > i_m^*$ the policy outcome is*

$$i = \begin{cases} i_c^*, & \text{if} \quad 0 \leq q < i_c^*, \\ q, & \text{if} \quad i_c^* < q \leq i_m^*, \\ q + (1/\lambda_m)(i_m^* - q), & \text{if} \quad i_m^* < q \leq (\lambda_m i_c^* - i_m^*)/(\lambda_m - 1), \\ i_c^*, & \text{if} \quad q \geq (\lambda_m i_c^* - i_m^*)/(\lambda_m - 1). \end{cases} \tag{37}$$

2.5 Median Model

Finally, consider now that case where $i_c^* = i_m^*$, meaning that the chair and the median prefer the same policy. In this case, the chair will propose the preferred policy and the median will accept. This would be identical to the median model.

Proposition 3 (Median Model): *Let* $i_c^* = i_m^*$. *The policy outcome is*

$$i = i_m^*, \quad \textit{for any } q_t. \tag{38}$$

The median outcome may also arise if the chair has no veto power and the probability p of a negotiation breakdown goes to zero. In this case, the median has an incentive to wait until he has the possibility to make a proposal. As a result, the chair proposes i_m^*, which is the only policy that the median would find acceptable.

3. Dictator Model

Consider now a protocol where the chair has absolute power over the committee. In a frictionless environment the policy outcome would be

$$i = i_c^*, \quad \text{for any } q_t \text{ and } i_m^*, \tag{39}$$

meaning that the policy selected by the committee is that preferred by the chair regardless of the identity and preferences of the median. This policy outcome is the same as for the inclusive-voting model in the special case where $i_c^* = i_m^*$. However, although the policy outcomes are observationally equivalent, there are key differences between them. First, the result that $i = i_c^*$ for any status quo holds for all possible values of i_m^* in this model but only for $i_m^* = i_c^*$ in the model in section 2. Second, the policy selected in the former case is that preferred by one of the members (the chair), while the policy selected in the latter case is that jointly preferred by the chair and the median, and coincides with the median outcome. More generally, a chair working under the inclusive-voting protocol can bring the policy outcome as close as possible to her preferred option subject to an acceptance constraint, which will bind when the status quo is not too far from the policy preferred by the median. In contrast, a chair acting as a dictator is not subject to such a constraint and can always pick her preferred policy among the policy alternatives.

The model in (39) counterfactually implies that the committee adjusts the interest rate in every meeting and, hence, it cannot account for the large proportion of instances (about 53% in our sample) where the FOMC has left the federal funds rate target unchanged. A realistic extension of this model would incorporate the empirical observation that adjustments to the funds target cannot be smaller than 25 basis points (bps) (multiples of 6.25 bps prior to December 1989). While this size friction is admittedly *ad-hoc*, it is a feature of the data and a plausible alternative to the decision-making frictions considered in section 2. A chair with absolute power over the committee but subject to size frictions would adjust the interest rate only if it deviates by more than Δ basis points from her preferred value. As discussed above, in practice, Δ is equal to 25 basis points. A simple way to represent these ideas is the following statistical model:

$$i = \begin{cases} i_c^*, & if\ q_t > i_c^* + \Delta, \\ q, & if\ i_c^* - \Delta \leq q \leq i_c^* + \Delta, \\ i_c^*, & if\ q < i_c^* - \Delta. \end{cases} \tag{40}$$

This model features a gridlock interval of width 2Δ basis points where the interest rate is not adjusted and $i = q$. The model also predicts that should there be an adjustment, the new interest rate selected by the committee would be that preferred by the chair. This means that the time series process that describes interest rate increases and decreases is the same and corresponds to the one that generates i_c^*, namely (9) with $n = c$.

4. Maximum Likelihood Estimation

4.1 Data

The data consist of 274 regular face-to-face meetings of the FOMC between October 1974 and December 2008. The sample excludes the meetings between October 1979 and October 1982 when the Fed pursued a policy of non-borrowed reserves targeting.[10] The sample ends with the onset of the financial crisis of 2008, when the federal funds rate reached its effective lower bound and quantitative easing became the main monetary policy instrument. Chairs during the sample period were Arthur Burns (February 1970 to March 1978), William Miller (March 1978 to August 1979), Paul Volcker (August 1979 to August 1987), Alan Greenspan (August 1987 to January 2006), and Ben Bernanke (February 2006 to January 2014). In addition to face-to-face meeting, the FOMC also holds conference calls in exceptional circumstances. However, conference calls do not follow an established protocol and, in contrast to regular meetings, they are not preceded by the production of the Greenbooks, which we use here as a source of real-time data.[11] For these reasons, we follow the literature (e.g., Meade, 2005) in focusing only on face-to-face meetings and excluding conference calls from the sample.

[10] The sample does include, however, the meeting on October 6, 1979, where the FOMC first signalled its new emphasis on reserves. This decision is based on the fact that in this meeting, and in contrast to subsequent meetings, the chair stated a precise, "ideal" value for the federal funds rate. See p. 55 of the transcript available from the Web site of the Federal Reserve (www.federalreserve.gov/monetarypolicy/fomc_historical.htm). In October 1982 the FOMC moved to a borrowed reserves operating procedure. Thornton (2004) argues that transcripts from meetings and other documentary evidence indicate that the committee effectively switched to a fed funds rate targeting regime in 1982.

[11] Also, conference calls do not always involve a policy decision or, more narrowly, an interest rate decision. For instance, the conference call on March 10, 1978, was convened to decide whether to increase the Fed's swap line with the Bundesbank, and the one on October 17, 1988, was convened to discuss the economic situation in Mexico.

The source of the federal funds rate decisions by the FOMC are as follows: for the period prior to February 1978 and from August 1987 to December 1996 the source are the appendices 4 and 5 in Chappell et al. (2005), for the period from October 1982 to July 1987 the source is Thornton (2005), and for the periods from March 1978 to October 1979 and from January 1997 to December 2008 the source are transcripts of the FOMC meetings. For the period from March 1978 to October 1979 we also use the Record of Policy Actions, which describes the actions taken by the FOMC since the previous meeting, and the Minutes of Actions, which details the instructions given to the Trading Desk of the Federal Reserve Bank of New York. In instances where the federal funds rate target is defined as a range, we use its mid-point as the funds target.[12] The primary sources of Chappell et al. and Thornton are the same as ours (though Thornton also has access to data from the Trading Desk of the New York Fed) and we made every effort to ensure that our recording criteria are consistent with theirs.

In addition to the federal funds rate decision, the estimation of our model requires the status quo policy (that is, the interest rate that was in place at the beginning of the meeting). Conference calls occasionally led to a change in the federal funds target and inter-meeting policy adjustments were relatively common in the 1970s and 1980s.[13] Thus, some detective work is necessary to uncover changes in the fed funds target outside face-to-face meetings. Rudebusch (1995), Thornton and Wheelock (2000), and Thornton (2005) construct fed funds target series that include conference calls and inter-meeting policy adjustments. In particular, we use the federal funds rate target series constructed by Rudebusch (1995) for the period from September 1974 to September 1979 and by Thornton (2005) for the period from September 1982 to December 1993. For the latter period we check the robustness of our results using the series constructed by Rudebusch (1995) for the period from March 1984 to September 1982 and by Thornton and Wheelock (2000) for the period from September 1982 to December 1993.[14] For the period after 1993, all inter-meeting policy adjustments are the result of actions decided in conference calls and, thus, we use the transcripts from those calls to determine whether there was a change in the federal funds rate target and its magnitude (if there was a change).

Finally, the real-time data available to policy-makers in each FOMC meeting were taken from the

[12] The only exception is the meeting of May 22, 1979, where the transcripts make clear that the target is asymmetric. See the intervention of Chair Miller in p. 33 of the transcript of this meeting.

[13] See the discussion in Thornton (2005).

[14] These series are similar to the ones that we consider except for 1) small differences in the timing of the change (say, by one day or two), 2) the interpretation of a change in the funds rate as a policy action or a reaction of the markets, or 3) small numerically differences in the size of the adjustment. For the 1970s, Cook and Hahn (1989) construct a series of federal funds target changes, but it is based on reports contained in the *Wall Street Journal*. This series follows closely the one in Rudebusch (1995), but we abstained from using it because it is based on the possibly noisy interpretation by the newspaper of market data as policy actions.

Greenbooks (formally entitled "Current Economic and Financial Conditions") which are compiled by staff at the Federal Reserve Board before each meeting. The Greenbooks contain historical values and forecasts of many economic variables and the detailed analysis of the U.S. and international economies. These data are available from the Real-Time Data Research Center at the Federal Reserve Bank of Philadelphia (www.philadelphiafed.org). As a measure of inflation we use the annualized quarter-over-quarter growth in the GDP deflator (GDP deflator after 1992Q1).[15] As a measure of output we use the unemployment rate, but we also report results using the annualized quarter-over-quarter growth in real GDP (real GDP after 1992Q1).

4.2 Identification

In this section we discuss the identification of the parameters of the inclusive-voting model and the extent to which the data allow us to distinguish between the several cases in propositions 1 and 2. First note that, in general, the parameters γ, λ_m, and λ_c are not separately identified. To see why consider for example the policy outcomes for the hawkish chair (proposition 1). In the case where $0 \leq \gamma < \lambda_m$ (see equation (22)), the parameter λ_c does not appear explicitly in the policy outcome and it is not identified, while γ and λ_m appear only as the ratio $(1-\gamma)/(1-\lambda_m)$. The ratio is identified, but the parameters γ and λ_m are not separately identified.[16] Conversely, in the case where $\lambda_c < \gamma \leq 1$ (see equation (24)), the parameter λ_m does not appear in the policy outcome and it is not identified, while γ and λ_c appear only as the ratio γ/λ_c. Again, the ratio is identified, but the parameters γ and λ_c are not separately identified. Finally, in the case where $\lambda_m \leq \gamma \leq \lambda_c$ (see equation (23)), none of the parameters appears explicitly in the policy outcome and they are not identified. Similar issues arise in proposition 2, where the chair is more dovish than the median. The reduced-form parameters a_c, a_m, b, d, and σ are identified but with the aforementioned caveat concerning the structural interpretation of the two intercepts a_c and a_m.

The general version of the inclusive-voting model consists of six cases—three in proposition 1 and three in proposition 2—but three pairs are observationally equivalent. The first such a pair is the case of the least-inclusive hawk (22), where $i_c^* > i_m^*$ and $0 \leq \gamma < \lambda_m$, and the most-inclusive dove (36), where $i_m^* > i_c^*$ and $1-\lambda_c < \gamma \leq 1$. Given inflation and unemployment, these two protocols generate exactly the same time series for the nominal interest rate. To see this, notice that both policy outcomes are the same if one interchanges the labels of the chair and the median and, to be consistent with this relabeling, one redefines the probability that the median makes a

[15] Note that annualized quarter-over-quarter headline CPI inflation is only reported in the Greenbooks after October 1979.

[16] The parameters λ_c and λ_m appear implicitly in the policy outcome as part of the intercepts of the reaction functions (that is, a_c and a_m, respectively). However, they cannot be recovered from the intercept estimates because the latter are reduced-form parameters that depend on other structural parameters (that is, ι, α, ψ, π^*, and σ).

counter-proposal as $\gamma' = 1 - \gamma$. Intuitively, the data does not allow us to distinguish between a chair that prefers higher interest rates (a hawk) and is unlikely to allow counter-proposals by the median, and a chair that prefers lower interest rates (a dove) but is likely to allow counter-proposals by a median that prefers higher interest rates.

The second such a pair is the case of the most-inclusive hawk (24), where $i_c^* > i_m^*$ and $\lambda_c < \gamma \leq 1$, and the least-inclusive dove (34), where $i_m^* > i_c^*$ and $1 - \lambda_c < \gamma \leq 1$. Again, interchanging the labels of the chair and the median and redefining that probability that the median makes a counter-proposal as $\gamma' = 1 - \gamma$ show that both cases are observationally equivalent meaning that they generate the same nominal interest rate. That is, we cannot distinguish between a chair that prefers higher interest rates (a hawk) but is likely to allow counter-proposals by a median that prefer lower interest rates, and a chair that prefers lower interest rates (a dove) but is unlikely to allow counter-proposals by the median.

Finally, the third pair is the moderately-inclusive hawk, where $i_c^* > i_m^*$ and $\lambda_m \leq \gamma \leq \lambda_c$, and the moderately-inclusive dove, where $i_m^* > i_c^*$ and $1 - \lambda_m \leq \gamma \leq 1 - \lambda_c$. Interchanging labels and redefining the counter-proposal probability show that both protocols are observationally equivalent and, thus, the data does not allow us to conclude whether the chair is to the left (she is a dove) or to the right (she is hawk) of the median.

In the case of the dictator model, λ_m and γ are not identified because the preferences and actions of the median are not relevant in the decision-making process, while λ_c cannot be recovered from the estimate of the reduced-form intercept, a_c. However, the interpretation of this constant is unambiguous under this protocol as the intercept in the reaction function of the chair.

In summary, the combination of theory and data (inflation, unemployment, and interest rate decisions) allow us to some make progress in determining the protocol under which the FOMC made decisions under different chairs. In particular, we are able to distinguish between the dictator model and three versions of the inclusive-voting model. In what follows, we estimate these different protocols by the method of maximum likelihood and compare them statistically.

4.3 Likelihood Functions

In this section, we present the likelihood functions of the decision-making protocols in sections 2 and 3 under the maintained assumption that shocks are normally distributed. The detailed derivation of the likelihood functions can be found in appendix C.

4.3.1 Inclusive-Voting Model

For the inclusive-voting model, consider the case where the chair is more hawkish than the median. The policy outcome for this case is described in proposition 1 and we present here the likelihood function for each of the three possible cases in the proposition. Given the identification issue discussed above, deriving the likelihood function in the case where the chair is more dovish than the median is superfluous. Define the set $\Omega_t = \{i_{t-1}, \pi_t, y_t\}$ with the predetermined variables at time t and the sets Ξ_1, Ξ_2 and Ξ_3 that respectively contain the observations where the interest rate is increased, left unchanged, and cut. The number of observations in each of these sets is respectively denoted by T_1, T_2 and T_3, with $T = T_1 + T_2 + T_3$ being the total number of observations in the sample. Since the data clearly shows the instances where the FOMC took each of these three possible actions, it follows that the sample separation is perfectly observable by the econometrician and each interest rate observation can be unambiguously assigned to its corresponding set.

For the case where $0 \leq \gamma < \lambda_m$, proposition 1 shows that the top two regimes of the political aggregator involve an interest rate increase (that is, $i_t > q_t$), the third regime (from the top) implies that the interest rate is left unchanged (that is, $i_t = q_t$), and the bottom regime involves an interest rate cut (that is, $i_t < q_t$). Note, however, that for an interest rate increase, the value selected by the committee depends on whether the shock is large enough that the acceptance constraint binds. This means that, although the observation can be assigned to Ξ_1, the econometrician cannot be sure which of the two regimes generated the interest rate. Appendix C shows that the density for this observation is a mixture of two normal distributions,

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right) I\left(x_{1,t}\right) + \frac{1}{\delta\sigma}\phi\left(\frac{i_t - \delta(a_m + b\pi_t + dy_t) - (1-\delta)i_{t-1}}{\delta\sigma}\right)\left(1 - I\left(x_{1,t}\right)\right),$$

where is σ is the standard deviation of ϵ_t, $\phi(\cdot)$ is the density function of the standard normal distribution, $x_{1,t}$ is short-hand for the condition $(1-\delta)(i_t - i_{t-1}) - \delta(a_m - a_c) < 0$, $\delta = (1-\gamma)/(1-\lambda_m) > 1$, and $I(\cdot)$ is an indicator function that takes the value one if its argument is true and zero otherwise.

For an observation where the interest rate is unchanged, the density is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right),$$

where $z_{m,t} = \left(i_{t-1} - a_m - b\pi_t - dy_t\right)/\sigma$ and $z_{c,t} = \left(i_{t-1} - a_c - b\pi_t - dy_t\right)/\sigma$. This is the density of a variable censored above and below and it is similar to that studied by Rosett (1959), who generalizes the two-sided Tobit model to allow the mass point anywhere in the conditional cumulative distribution function.

Finally, for an interest rate cut the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

Thus, the log likelihood function of the T available interest rate observations is

$$\begin{aligned} L(\theta) &= -(T_1+T_3)\sigma \\ &+ \sum_{i_t\in\Xi_1} \log\left(\phi\Big(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\Big)I\big(x_{1,t}\big) + \frac{1}{\delta}\phi\Big(\frac{i_t - \delta(a_m + b\pi_t + dy_t) - (1-\delta)i_{t-1}}{\delta\sigma}\Big)\big(1 - I\big(x_{1,t}\big)\big)\right) \\ &+ \sum_{i_t\in\Xi_2} \log\left(\Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right)\right) + \sum_{i_t\in\Xi_3} \log\left(\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)\right), \end{aligned}$$

where $\theta = \{a_c,\ a_m,\ \delta,\ b,\ c,\ \sigma\}$ is the set of unknown parameters. Maximizing this function with respect to θ delivers consistent and asymptotically efficient maximum likelihood estimates of the parameters. In order to guard against possibility of local maxima, we maximized the log likelihood function using the simulated annealing algorithm, which is a genetic algorithm robust to local maxima.

For the case where $\lambda_m \leq \gamma \leq \lambda_c$, proposition 1 shows that the top regime involves an interest rate increase, the middle regime implies that the interest rate is left unchanged, and the bottom regime involves an interest rate cut. Exploiting the fact that the sample separation is perfectly observable, the density for an interest increase is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right),$$

the density for an observation where the interest rate is left unchanged is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right),$$

and the density for an interest rate cut is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

Then, the log likelihood function of the T available interest rate observations is

$$\begin{aligned} L(\theta) &= -(T_1+T_3)\sigma + \sum_{i_t\in\Xi 1} \log\left(\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right)\right) + \sum_{i_t\in\Xi_2} \log\left(\Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right)\right) \\ &+ \sum_{i_t\in\Xi_3} \log\left(\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)\right), \end{aligned}$$

where $\theta = \{a_c,\ a_m,\ b,\ c,\ \sigma\}$ is the set of unknown parameters.

Finally, for the case where $\lambda_c < \gamma \leq 1$, proposition 1 shows that the top regime of the political aggregator involves an interest rate increase, the second regime (from the top) implies that the interest rate is left unchanged, and the bottom two regimes involve an interest rate cut. For an interest rate increase the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right).$$

For an observation where the interest rate is unchanged the density is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right).$$

For an interest rate cut, the value selected by the committee depends on whether the shock is small enough that acceptance constraint binds. Again, although the observation can be assigned to Ξ_3, the econometrician cannot be sure which of the two regimes generated the interest rate. As shown in appendix C, the density for this observation is a mixture of two normal distributions,

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right) I\left(x_{2,t}\right) + \frac{1}{\kappa\sigma}\phi\left(\frac{i_t - \kappa(a_c + b\pi_t + dy_t) - (1-\kappa)i_{t-1}}{\kappa\sigma}\right)\left(1 - I\left(x_{2,t}\right)\right),$$

where $x_{2,t}$ is short-hand for the condition $(1-\kappa)(i_t - i_{t-1}) - \kappa(a_m - a_c) > 0$, and $\kappa = \gamma/\lambda_c > 1$. Thus, the log likelihood function of the T available interest rate observations is

$$\begin{aligned} L(\theta) \quad = \quad & -(T_1 + T_3)\sigma + \sum_{i_t \in \Xi_2} \log\left(\Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right)\right) + \sum_{i_t \in \Xi 1} \log\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right) \\ & + \sum_{i_t \in \Xi_3} \log\left(\phi\Big(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\Big) I\big(x_{2,t}\big) + \frac{1}{\kappa}\phi\Big(\frac{i_t - \kappa(a_c + b\pi_t + dy_t) - (1-\kappa)i_{t-1}}{\kappa\sigma}\Big)\big(1 - I\big(x_{2,t}\big)\big)\right), \end{aligned}$$

where $\theta = \{a_c,\, a_m,\, \kappa,\, b,\, c,\, \sigma\}$ is the set of unknown parameters.

4.3.2 Dictator Model

The policy outcome of the dictator model is described by (40). The top regime involves an interest rate increase, the middle regime implies that the interest rate is unchanged, and the bottom regime involves an interest rate cut. For an interest increase the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

For an observation where the interest rate is left unchanged the density is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{u,t}\right) - \Phi\left(z_{l,t}\right),$$

with $z_{u,t} = (i_{t-1} - a_m - b\pi_t - dy_t + \Delta)/\sigma$ and $z_{l,t} = (i_{t-1} - a_c - b\pi_t - dy_t - \Delta)/\sigma$. Finally, for an interest rate cut the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

Then, the log likelihood function of the T available interest rate observations is

$$L(\theta) = -(T_1 + T_3)\sigma + \sum_{i_t \in \{\Xi 1, \Xi_3\}} \log\left(\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)\right) + \sum_{i_t \in \Xi_2} \log\left(\Phi\left(z_{u,t}\right) - \Phi\left(z_{l,t}\right)\right),$$

where $\theta = \{a_c,\, b,\, c,\, \sigma\}$ is the set of unknown parameters.

4.4 Results for the Full Sample

Table 1 reports maximum likelihood estimates (panel A), model selection criteria (panel B), and quantitative predictions (panel C) for the inclusive-voting and dictator models for the full sample from October 1974 to December 2008.

For the inclusive-voting model, proposition 1 describes three possible cases depending on the magnitude of γ relative to the preference parameters λ_m and λ_c. We initially estimated each case separately, but for the case of the least-inclusive hawk, where $0 \leq \gamma < \lambda_m$, the coefficient $\delta = (1-\gamma)/(1-\lambda_m) > 1$ would tend to 1, which is at the boundary of the parameter space. Without imposing the constraint $\delta > 1$, the ML estimate would go below 1 implying that $\gamma \geq \lambda_m$. Similarly for the case of the most-inclusive hawk, where $\lambda_c < \gamma \leq 1$, the coefficient $\kappa = \gamma/\lambda_c > 1$ would tend to 1, which is at the boundary of the parameter space. Without the constraint $\kappa > 1$, the ML estimate would go below 1 implying that $\gamma \leq \lambda_c$. These results are displayed graphically in figure 2, which plots the cross-section of the log likelihood function along the dimensions of the parameters δ and κ, holding all other parameters at their ML estimates. The global maximum in both cases is the corner solution where $\delta = 1$ and $\kappa = 1$, which corresponds in fact to the boundary of the moderately-inclusive hawk.

These results indicate that among the three possible cases in proposition 1, the one preferred by the data is the moderately-inclusive hawk, where $0 < \lambda_m \leq \gamma \leq \lambda_c < 1$. Estimates for this model are reported in panel A of table 1 using unemployment (column 1) and real GDP growth (column 3) as output measures. ML estimates of the coefficients of inflation and output growth are positive and statistically significant, while the estimates of the coefficient of unemployment are negative but not statistically significant. In interpreting these estimates it is important to keep in mind that since the moderately-inclusive hawk is observationally indistinguishable from the moderately-inclusive dove (see section 4.2), the data do not allow us to conclude whether the chair is to the right (she is hawk) or to the left (she is a dove) of the median.

The fact that the data prefer the moderately-inclusive voting model—with γ interior in the interval $[0, 1]$ and away from both extremes—means that even though the FOMC chairmanship carries substantial prestige and influence *vis-a-vis* the committee and the chair formulates the initial proposal that is put to a vote, the chair actually shares power with other committee members. The power of the latter arises, most obviously, from the fact that a successful proposal needs the support of a majority of members to pass and, less obviously, from the probability of counter-proposals should the committee reject the chair's proposal. Counter-proposals need not be observed in equilibrium for their possibility to have an effect on the chair's proposal. Indeed, there may be few instances when we actually observe formal counter-proposals in a meeting. One such an instance is the meeting on September 20, 1977, under Chairman Burns, where there were a number of straw polls leading to a final proposal that was approved seven to five.[17] Another example is the meeting of May 16, 1978, under Chairman Miller, where there were back and forth discussions between the chair and the committee before an acceptable proposal was found and approved.[18]

The model predicts that the chair's proposal should meet an acceptance constraint that incorporates the preferences of the median and the probability of a counter-proposal, and it will be approved by the committee in the first round of voting. This prediction is in line with evidence from FOMC transcripts that shows that the chair's proposal is (almost) always approved in the first round. This result is also in line with the views of former FOMC members. For instance, Sherman Maisel (1973, p. 124) observes that the chairman "does not make policy alone," while Laurence Meyer (2004, p. 52) notes that the chair "does not necessarily always get his way." See also Chappell et al. (2005, pp. 125-128), who present some evidence on the influence of the committee on Chairman Greenspan.

Panel B compares the inclusive-voting and dictator models using three model selection criteria.[19] Recall that under the former, the chair's proposal is not her preferred interest rate but simply the rate closest to her ideal policy that satisfies an acceptance constraint. Under the latter, the chair's proposal is her preferred interest rate but an adjustment takes place only if it deviates by more than 25 basis points from the current rate. Both models predict that the chair's proposal is approved by the committee, but they differ in the power they attribute to the FOMC chair. The selection criteria in panel B are the Akaike Information Criteria (AIC), the Root Mean Squared Error (RMSE), and the Mean Absolute Error (MAE), and they are respectively computed as $AIC = 2k - 2L(\theta)$,

[17] See pp. 53-56 of the transcripts, where the chair asks for a show of hands on three occasions prior the formulation of the final proposal. It is clear from the transcripts that the chair is attempting to find a proposal that would be acceptable to a majority of members.

[18] See the exchange between Miller and several committee members in pp. 43-47 of the transcripts.

[19] We follow this evaluation strategy because the models are not statistically nested and, hence, usual tests do not have a standard distribution.

$RMSE = \left(\left(\sum_{t=1}^{T}(i_i - E(i_i|\Omega_t))^2\right)/T\right)^{1/2}$, and $MAE = \left(\sum_{t=1}^{T}|i_i - E(i_i|\Omega_t)|\right)/T$, where k is the number of parameters and $\Omega_t = \{i_{t-1}, \pi_t, y_t\}$. For both output measures, all criteria are smaller for the inclusive-voting model than for the dictator model suggesting that the former fits the federal funds rate better than the latter.

Panel C reports the quantitative predictions of the models and compares them with the data. The predictions are derived by means of stochastic simulation as follows. Taking as given current inflation and unemployment (or GDP growth), and the status quo policy, we draw a realization of ϵ_t from a normal distribution with zero mean and standard deviation equal to the ML estimate of σ. Then, for each model, we compute the policy preferred by the key member(s) using the ML estimates of their reaction function parameters in table 1 and use the appropriate political aggregator in section 2 and 3 to obtain the interest rate selected by the committee. Repeating this algorithm for each pair of observations of inflation and unemployment (or GDP growth) in the data, we obtain a simulated path for the nominal interest rate. Using this simulated sample, we compute the autocorrelation and standard deviation of the interest rate, and the proportion of interest rate cuts, increases, no changes, and policy reversals. Policy reversals are defined as interest rate changes of opposite sign in two consecutive meetings. The numbers reported in panel C are averages of these statistics over 200 replications of this procedure.

Panel C shows that both models predict a standard deviation for the interest rate of similar magnitude to that of the federal funds rate. However, regardless of the output measure, the models differ in their predicted autocorrelation, proportion of each policy action (increase, cut, or leave unchanged) and proportion of policy reversals. The inclusive-voting model predicts substantially higher interest-rate autocorrelation, and closer to the value computed from the data, than the dictator model. The inclusive-voting model also predicts proportions of meeting where the interest rate was increased, cut, or left unchanged that are in rough agreement with the data. In particular, leaving the interest rate unchanged is the most common policy decision in this model, as it is the data. In contrast, the dictator model predicts that leaving the interest rate unchanged is the least common policy decision, occurring less than 7% of the times. Put differently, the constraint that interest rate adjustments must be above 25 basis points is not a sufficiently large friction to account for the large proportion of meeting where the FOMC keeps the interest rate unchanged. Finally, the inclusive-voting model generates a low proportion of policy reversals, as it is the case in the U.S. data. In contrast, the dictator model counter-factually predicts a large proportion of policy reversals, close to 60% compared with 3% in the data.

In summary, results in panels B and C support the inclusive-voting model in comparison with the dictator model in that the former fits FOMC decisions better (e.g., it has a lower RMSE), and it generates empirical predictions (e.g., interest-rate autocorrelation and proportion of no changes) that are in better agreement with the data.

4.5 Results for Individual FOMC Chairs

The parameters of the reaction functions in table 1 are fixed over the full sample and implicitly treat the chair's preferences as constant and independent of the individual holding the position. This assumption is likely to be counterfactural given documentary evidence which suggests that different FOMC chairs had different views about inflation and, more broadly, about monetary policy (see, for instance, Romer and Romer, 2004). For this reason we also estimate the models using subsamples for each chair between 1974 and 2008 and report individual results for Arthur Burns (table 2), William Miller (table 3), Paul Volcker (table 4), Alan Greenspan (table 5), and Ben Bernanke (table 6). Subsample results have the advantage that the preference parameters of the chair and the median (and, more generally, all parameters) are allowed to change over time. The results have the drawback that they are based on a small number of observations ranging from 15 meetings for Miller to 151 meetings for Greenspan, but the tight restrictions imposed by the model and the use of the efficient ML estimator lead to reasonably precise parameter estimates.

As for the full sample, estimates of δ, for the least-inclusive hawk, and κ, for the most-inclusive hawk, for all chairs tend to the corner solutions $\delta = 1$ and $\kappa = 1$, which corresponds to the boundary of the moderately-inclusive hawk. Hence, for all chairs the version of the inclusive-voting model preferred by their respective data is the moderately-inclusive hawk where $0 < \lambda_m \leq \gamma \leq \lambda_c < 1$. Recall that decision-making in a committee where the chair is a moderately-inclusive hawk or a moderately-inclusive dove are observationally equivalent. Thus, we cannot conclude whether a chair is to the right (she is hawk) or to the left (she is a dove) of the median.

Recent literature that attempts to classify FOMC chairs (and more generally FOMC members) as hawks or doves includes, among others, Eijffinger et al. (2015), Malmendier et al. (2017), and Istrefi (2018). Eijffinger et al. estimate ideal points for FOMC members using stated preferences from the transcripts and estimate a hierarchical spatial voting model. Malmendier et al. use an adaptive learning rule based on their lifetime inflation data to explain FOMC members' votes and the hawkishness of the tone of their speeches (see, also, Bordo and Istrefi, 2018). Istrefi (2018) studies FOMC chairs' policy preferences based on newspaper and financial media coverage and classifies Burns, Volcker, and Greenspan as hawks and Miller and Bernanke as doves.

Finally, note in panels B and C in tables 2 through 6 that the inclusive-voting model fits FOMC decisions better than the dictator model for all chairs. That is, the inclusive-voting model has lower AIC, lower RMSE, and lower MAE than the dictator model. Furthermore, interest rate autocorrelation, the proportion of each policy action (increase, cut, or leave unchanged), and the proportion of policy reversals predicted by the inclusive-voting model are in general closer to the statistics computed from the data for each chair than those predicted by the dictator model. Hence, the inclusive-voting model is statistically preferred to the dictator model for all chairs.

These results are important because they suggests that despite the fact that different individuals may act as FOMC chair, the workings of the committee are themselves stable over time and power is shared between the chair and the rest of the committee. Hence the FOMC's unique structure, which mixes different viewpoints—national and regional, public and private—achieves an "internal system of checks and balances" (Blinder, 1998). On the one hand, no chair, regardless of personality and recognized ability, can deviate far from the median view. But on the other, the prestige of the chair's position is such that the median view may not prevail even when the chair is not a particularly savvy leader (Romer and Romer, 2004, p. 147).

5. Conclusion

This paper examines the influence exerted by the FOMC chair on monetary policy decisions. A naive interpretation of the observation that the policy proposed by the FOMC chair is always adopted with the support of a majority of votes and limited dissents—namely, that the selected policy is that preferred by the chair—greatly overstates the power of the Federal Reserve chair. The Federal Reserve chair has indeed powers not vested on other FOMC members and which arise from the prestige of the position and its agenda-setting powers. However, in setting policy, the chair is limited by the need to make her proposal acceptable to other committee members and the possibility that counter-proposals may be made in response to an unacceptable proposal. In our model, the possibility of counter-proposals acts as an off-equilibrium threat that moderates the chair's proposal.

Using data from actual FOMC policy decisions under different chairs, our voting model enables us to recover (up to a scalar) the probability that committee members may challenge the chair's proposal. This probability captures the degree of inclusiveness of the voting procedure adopted by each chair. Anecdotal evidence suggests that the voting processes adopted by different chairs differ along this dimension, but we find instead that all chairs in our sample are characterized by a similar degree of inclusiveness. The chair cannot deviate far from the median view but, alone among committee members, the chair can propose and get approved policies closer to his or her ideal point.

We note, however, that the result that all chairs are roughly equally inclusive does not necessarily imply that they all share the same leadership style. In periods with greater consensus on the objectives of monetary policy and the model of the economy (think, for instance, of the Greenspan years), collegiality is not costly from the chair's prospective and the chair can afford to lead the FOMC with a "velvet glove, not with an iron fist" (Blinder, 2004, p. 58). Instead, in periods of intense disagreement, committee members may be more inclined to challenge the chair's proposals and to achieve the same degree of inclusiveness the chair may need to adopt a more assertive leadership style.

Appendix A Derivation of the First-Order Condition

The policy-maker n's problem is to select the interest rate

$$i_{n,t}^{*} = \arg\max \beta^2((1-\lambda_n) - I(\pi_{t+2} - \pi^* > 0))(\pi_{t+2} - \pi^*),$$

subject to the constraints (3) and (4). In what follows, it will be convenient to combine these two constraints into a single one and use (5) and (6) to write

$$\pi_{t+2} = (1+\alpha\psi)\pi_t + \alpha(1+\eta)y_t + \alpha\psi\iota - \alpha\psi i_t + \omega u_t + \alpha\varsigma v_t + (1+\omega)u_{t+1} + \alpha v_{t+1} + u_{t+2}. \quad (41)$$

Define

$$\begin{aligned} e_{t+2} &= \pi_{t+2} - \pi^*, \\ &= \mu_t + \sigma z_{t+2}, \end{aligned}$$

with

$$\begin{aligned} \mu_t &= (1+\alpha\psi)\pi_t + \alpha(1+\eta)y_t + \alpha\psi\iota - \alpha\psi i_t + \omega u_t + \alpha\varsigma v_t - \pi^*, \\ \sigma z_{t+2} &= (1+\omega)u_{t+1} + \alpha v_{t+1} + u_{t+2}, \end{aligned}$$

where z_{t+2} is a standard normal variable and σ the standard deviation of the linear combination $(1+\omega)u_{t+1} + \alpha v_{t+1} + u_{t+2}$. Thus, $\sigma^2 = (2+\omega)^2\sigma_u^2 + \alpha^2\sigma_v^2$. Note that μ_t collects all variables known at time t when the interest rate is selected, and σz_{t+2} collects all variables unknown at time t but which will affect inflation at time $t+2$.

Using the above notation, write the problem as

$$i_{n,t}^{*} = \arg\max \beta^2 \left((1-\lambda_n)E_t(e_{t+2}) - \int_0^\infty e_{t+2} f_{t+2|t}(e_{t+2}) de \right),$$

where $f_{t+2|t}(e_{t+2})$ is conditional probability density function of e_{t+2}. Using the fact that $E_t(e_{t+2}) = \mu_t$ and with a change in variable in the above integral from e_{t+2} to z_{t+2}, rewrite the problem as

$$i_{n,t}^{*} = \arg\max \beta^2 \left((1-\lambda_n)\mu_t - \int_{-\mu_t/\sigma}^\infty (\mu_t + \sigma z_{t+2})\phi(z_{t+2}) dz \right),$$

where $\phi(\cdot)$ is the probability density function of the standard normal distribution.

Take the derivative with respect to i_t applying Leibniz's rule to obtain

$$\beta^2 \left((1-\lambda_n)(-\alpha\psi) - (-\alpha\psi)(1 - \Phi(-\mu_t/\sigma) \right) = 0,$$

where $\Phi(\cdot)$ is the cumulative density function (CDF) of the standard normal distribution. The above condition implies that at the optimum,

$$\Phi(-\mu_t/\sigma) = \lambda_n.$$

Using again the fact that $\mu_t = E_t\left(e_{t+2}\right) = E_t(\pi_{t+2} - \pi^*)$ and taking the inverse of the CDF write

$$-E_t(\pi_{t+2} - \pi^*) = \sigma\Phi^{-1}(\lambda_n),$$

where $\Phi^{-1}(\lambda_n)$ is the quantile associated with λ_n. Hence, the first-order condition of the policy-maker's problem is

$$E_t(\pi_{t+2}) = \pi^* - \sigma\Phi^{-1}\left(\lambda_n\right),$$

which is equation (8) in the text.

Appendix B Proofs

In this section, we prove lemma 1 and propositions 1 and 2. The proof of proposition 3 is straightforward and thus omitted.

2.1 Proof of Lemma 1

We prove lemma 1 when the chair is a hawk: $i_c^* > i_m^*$. Recall that i_c and i_m denote the proposals by m and c. Denote by r the outside option of all committee members. In a no-delay equilibrium, $r = (q, i_m, i_c)$. Given r, the acceptance set of member n is

$$A_n(r) = \{x \in I : U_n(x) \geq pU_n(q) + (1-p)\gamma U_n(i_m) + (1-p)(1-\gamma)U_n(i_c)\}.$$

It is immediate to verify that $A_n(r)$ is a closed interval. Let $\underline{x}_n$ and $\overline{x}_n$ denote the left and right endpoint of $A_n(r)$, respectively. (To simplify the notation, we do not make explicit that these endpoints depend on r.) Define by $\mathcal{D}$ the set of decisive coalitions (i.e., the coalitions that include the chair and at least a majority of members). The acceptance set of group G is denoted by $A_G(r)$, while the "social acceptance set" (the set of proposals that can pass) is denoted by $A(r)$. They are defined, respectively, as

$$\begin{aligned} A_G(r) &= \bigcap_{i \in G} A_i(r), \\ A(r) &= \bigcup_{G \in \mathcal{D}} A_G(r). \end{aligned}$$

Proposals that belong to $A(r)$ are approved with no-delay. Notice that in a no-delay equilibrium i_c and i_m must belong to the core, $[i_m^*, i_c^*]$. If this were not the case, there would be a profitable deviation from these proposals. To avoid cluttering the notation, we will assume that equilibrium proposals lie inside the policy space I. We prove lemma 1 in two steps.

Step 1: *We show that: (i) the chair's preferred policy in $A(r)$ is given by $\min\{\overline{x}_m, i_c^*\}$; (ii) the median's preferred policy in $A(r)$ is given by $\max\{\underline{x}_c, i_m^*\}$.*

Proof: We prove statement (i). There are two cases that need to be considered: $q > i_m^*$ and $q \leq i_m^*$. Suppose first that $q > i_m^*$. In this case, the slope of the median's utility is negative at the current status quo. In addition, because i_c and i_m belong to $[i_m^*, i_c^*]$, the slope of the median's utility is also negative at these proposals. We find $\overline{x}_m$ by solving

$$-(1-\lambda_m)(\overline{x}_m - i_m^*) = -(1-\lambda_m)p(q-i_m^*) - \gamma(1-\lambda_m)(1-p)(i_m - i_m^*) - (1-\gamma)(1-p)(i_c - i_m^*)(1-\lambda_m),$$

and $\underline{x}_m$ by solving

$$-\lambda_m(i^*_m - \underline{x}_m) = -p(q - i^*_m)(1-\lambda_m) - \gamma(1-p)(i_m - i^*_m)(1-\lambda_m) - (1-\gamma)(1-p)(i_c - i^*_m)(1-\lambda_m),$$

to obtain

$$\overline{x}_m = pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c, \tag{42}$$

$$\underline{x}_m = \frac{i^*_m}{\lambda_m} - \frac{(1-\lambda_m)pq}{\lambda_m} - i_m(1-p)\gamma\frac{1-\lambda_m}{\lambda_m} - \frac{1-\lambda_m}{\lambda_m}i_c(1-p)(1-\gamma). \tag{43}$$

When $\overline{x}_m \geq i^*_c$, statement (i) is obviously true. Suppose instead that $\overline{x}_m < i^*_c$. We show that any policy $x > \overline{x}_m$, which the chair strictly prefers, does not pass because it is rejected by the median and by all members $n < m$. To see this, notice that for all members with $\lambda_n < \lambda_m$, $\overline{x}_n$ is also equal to (42). If, instead, the chair proposes $\overline{x}_m$, the proposal is approved by the median and by at least a majority of members.

Suppose now that $q < i^*_m$. We find $\overline{x}_m$ by solving

$$-(1-\lambda_m)(\overline{x}_m - i^*_m) = -\lambda_m p(i^*_m - q) - \gamma(1-\lambda_m)(1-p)(i_m - i^*_m) - (1-\gamma)(1-p)(i_c - i^*_m)(1-\lambda_m),$$

and $\underline{x}_m$ by solving

$$-\lambda_m(i^*_m - \underline{x}_m) = -p(i^*_m - q)(\lambda_m) - \gamma(1-p)(i_m - i^*_m)(1-\lambda_m) - (1-\gamma)(1-p)(i_c - i^*_m)(1-\lambda_m),$$

to obtain

$$\overline{x}_m = i^*_m\frac{p}{1-\lambda_m} - q\frac{p\lambda_m}{1-\lambda_m} + i_c(1-p)(1-\gamma) + (1-p)\gamma i_m, \tag{44}$$

$$\underline{x}_m = i^*_m\frac{1-p}{\lambda_m} + qp - i_c\frac{(1-\lambda_m)(1-p)(1-\gamma)}{\lambda_m} - \frac{1-\lambda_m}{\lambda_m}(1-p)\gamma i_m. \tag{45}$$

In a similar way, we compute the acceptance sets of members $n < m$. For all n such that $i^*_m \geq i^*_n > q$, it is possible to show that $\overline{x}_n$ is increasing in λ_n. For members n such that $i^*_n < q \leq i^*_m$, we find that $\overline{x}_n = pq + i_c(1-p)(1-\gamma) + (1-p)\gamma i_m$, which is lower than (44). Therefore, if the chair proposes a policy $x > \overline{x}_m$, the proposal will rejected. If instead, the chair proposes $\overline{x}_m$, the proposal will pass. To sum up, $\min\{\overline{x}_m, i^*_c\}$ is the chair's preferred policy among the ones that pass. Along similar lines, one can show that $\max\{\underline{x}_c, i^*_m\}$ is the median's preferred policy among the ones that pass. We now prove the statement of lemma 1 for the hawkish case.

Step 2: *When $q \in [i^*_m, i^*_c]$, the social acceptance set is a singleton and only includes the status quo.*
Proof: First, we show that the social acceptance set is a singleton. By contradiction, suppose that the social acceptance set is an interval: $A(r) = [\underline{x}, \overline{x}] \subseteq [i^*_m, i^*_c]$. Since the median and the chair

propose their preferred policy in the social acceptance set, the median proposes $\underline{x}$, while the chair proposes $\overline{x}$. Suppose first that $i_c^* \geq q > \underline{x}$. In this case, it is immediate that the chair rejects $\underline{x}$. In fact,

$$-\lambda_c(i_c^* - \underline{x}) < -p(i_c^* - q)\lambda_c - \gamma(1-p)(i_c^* - \underline{x})\lambda_c - (1-\gamma)(1-p)(i_c^* - \overline{x})\lambda_c.$$

This contradicts the hypothesis that the social acceptance set is an interval. Suppose instead that $i_m^* \leq q < \overline{x}$. In this case, the median would not find acceptable to vote for $\overline{x}$. By step 1, members $n < m$ would also reject this proposal, reaching again a contradiction. After showing that $\overline{x} = \underline{x} = i_m = i_c$, we now show that the social acceptance set coincides with q. By contradiction, suppose $q \neq i_m = i_c$. It is immediate to verify that either the chair or the median would find it profitable to reject the policy in the acceptance set, thus reaching a contradiction. ■

2.2 Proof of Proposition 1

By step 1 in the proof of lemma 1, we have $i_c = \min\{i_c^*, \max\{A_m\}\}$ and $i_m = \max\{i_m^*, \min\{A_c\}\}$. To characterize the equilibrium, we need to distinguish different cases, depending on the status quo location. First suppose $q \in [i_m^*, i_c^*]$. By lemma 1, both m and c propose q and no policy change is feasible.

Second, assume that $q > i_c^* > i_m^*$. Also suppose that the status quo is not too high (in a manner to be made precise below). As shown in step 1, when $q > i_c^*$ and $i_c, i_m \in [i_m^*, i_c^*]$ the median's acceptance set is $A_m(r) = [\underline{x}_m, \overline{x}_m]$ where

$$\overline{x}_m = pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c, \tag{46}$$

$$\underline{x}_m = \frac{i_m^*}{\lambda_m} - \frac{(1-\lambda_m)pq}{\lambda_m} - i_m(1-p)\gamma\frac{1-\lambda_m}{\lambda_m} - \frac{1-\lambda_m}{\lambda_m}i_c(1-p)(1-\gamma). \tag{47}$$

Similarly, the acceptance set of the chair is $A_c(r) = [\underline{x}_c, \overline{x}_c]$. We find $\overline{x}_c$ solving

$$-(1-\lambda_c)(\overline{x}_c - i_c^*) = -(1-\lambda_c)p(q - i_c^*) - \gamma\lambda_c(1-p)(i_c^* - i_m) - (1-\gamma)(1-p)(i_c^* - i_c)\lambda_c,$$

to obtain

$$\overline{x}_c = \frac{i_c^*(1-p)}{1-\lambda_c} + pq - \frac{\lambda_c\gamma(1-p)}{1-\lambda_c}i_m - \frac{\lambda_c(1-\gamma)(1-p)}{1-\lambda_c}i_c. \tag{48}$$

We find $\underline{x}_c$ solving

$$-\lambda_c(i_c^* - \underline{x}_c) = -p(q - i_c^*)(1-\lambda_c) - \gamma(1-p)(i_c^* - i_m)\lambda_c - (1-\gamma)(1-p)(i_c^* - i_c)\lambda_c,$$

to obtain

$$\underline{x}_c = \frac{i_c^* p}{\lambda_c} - \frac{pq(1-\lambda_c)}{\lambda_c} + \frac{(1-p)(1-\gamma)\lambda_c i_c}{\lambda_c} + \frac{(1-p)\gamma\lambda_c i_m}{\lambda_c}. \tag{49}$$

In equilibrium $i_c = \min\{i_c^*, \max\{A_m\}\}$ and $i_m = \max\{i_m^*, \min\{A_c\}\}$. That is,

$$
\begin{aligned}
i_m &= \max\left\{ i_m^*, \frac{i_c^* p}{\lambda_c} - \frac{pq(1-\lambda_c)}{\lambda_c} + \frac{(1-p)(1-\gamma)\lambda_c i_c}{\lambda_c} + \frac{(1-p)\gamma\lambda_c i_m}{\lambda_c} \right\}, \\
i_c &= \min\left\{ i_c^*, pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c \right\}.
\end{aligned}
$$

We solve the above system of two equations with two unknowns, i_c and i_m, to obtain

$$
i_m = \max\left\{ i_m^*, \frac{\gamma i_c^* - \gamma q + i_c^* p + \lambda_c q - pq - \gamma i_c^* p + \gamma pq}{\lambda_c} \right\}, \tag{50}
$$

$$
i_c = \min\left\{ i_c^*, \frac{\gamma i_c^* - \gamma q + \lambda_c q - \gamma p i_c^* + \gamma pq}{\lambda_c} \right\}. \tag{51}
$$

As p goes to zero, i_m and i_c converge to the same value. The social acceptance set becomes a singleton:

$$
i_c = i_m = min\left\{ q - (\gamma/\lambda_c)(q - i_c^*), i_c^* \right\}. \tag{52}
$$

It is immediate to verify from (52) that $i_c = i_c^*$ when $\gamma \leq \lambda_c$. Second, when $\gamma > \lambda_c$, the status quo q cannot be too high, otherwise from (52) we have that the proposal is lower than i_m^* and thus suboptimal. The condition that $q - (\gamma/\lambda_c)(q - i_c^*) \geq i_m^*$, implies an upper bound on q, that is,

$$
q_{ub}^1 = (i_m^* - (\gamma/\lambda_c)i_c^*)/(1 - (\gamma/\lambda_c)).
$$

beyond which the proposal is $i_c = i_m^*$ (i.e., the acceptance constraints are not binding).

Finally, consider the case where the status quo is to the left of the ideal points of both players, that is $q < i_m^* < i_c^*$. As before, the slope of c's utility is positive while the slope of m's utility is negative for the proposals i_m and i_c, which lie inside the gridlock interval. However, since $q < i_m^* < i_c^*$ the slope of both members' utility is positive at the current status quo. Also, we suppose that the status quo is not too low (more on this below). When $q < i_m^*$ and $i_c, i_m \in [i_m^*, i_c^*]$, the acceptance set of the median is $A_m(r) = [\underline{x}_m, \overline{x}_m]$. We find $\overline{x}_m$ and $\underline{x}_m$ solving

$$
\begin{aligned}
-(1-\lambda_m)(\overline{x}_m - i_m^*) &= -\lambda_m p(i_m^* - q) - \gamma(1-\lambda_m)(1-p)(i_m - i_m^*) - (1-\gamma)(1-p)(i_c - i_m^*)(1-\lambda_m), \\
-\lambda_m(i_m^* - \underline{x}_m) &= -p(i_m^* - q)(\lambda_m) - \gamma(1-p)(i_m - i_m^*)(1-\lambda_m) - (1-\gamma)(1-p)(i_c - i_m^*)(1-\lambda_m),
\end{aligned}
$$

to obtain

$$
\overline{x}_m = i_m^* \frac{p}{1-\lambda_m} - q\frac{p\lambda_m}{1-\lambda_m} + i_c(1-p)(1-\gamma) + (1-p)\gamma i_m, \tag{53}
$$

$$
\underline{x}_m = i_m^* \frac{1-p}{\lambda_m} + qp - i_c\frac{(1-\lambda_m)(1-p)(1-\gamma)}{\lambda_m} - \frac{1-\lambda_m}{\lambda_m}(1-p)\gamma i_m \tag{54}
$$

The acceptance set of the chair is $A_c(r) = [\underline{x}_, \overline{x}_c]$. We find $\overline{x}_c$ and $\underline{x}_c$ solving

$$
\begin{aligned}
-(1-\lambda_c)(\overline{x}_c - i_c^*) &= -(\lambda_c)p(i_c^* - q) - \gamma\lambda_c(1-p)(i_c^* - i_m) - (1-\gamma)(1-p)(i_c^* - i_c)\lambda_c, \\
-\lambda_c(i_c^* - \underline{x}_c) &= -p(i_c^* - q)(\lambda_c) - \gamma(1-p)(i_c^* - i_m)(\lambda_c) - (1-\gamma)(1-p)(i_c^* - i_c)(\lambda_c),
\end{aligned}
$$

to obtain

$$\overline{x}_c = \frac{i_c^*}{1-\lambda_c} - \frac{\lambda_c}{1-\lambda} pq - \frac{\gamma\lambda_c(1-p)}{1-\lambda_c} i_m - \frac{(1-\gamma)(1-p)}{1-\lambda_c} i_c, \quad (55)$$

$$\underline{x}_c = pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c. \quad (56)$$

After computing $\max\{A_m\}$ and $\min\{A_c\}$, we write down the two conditions that equilibrium proposals must satisfy

$$\begin{aligned} i_c &= \min\left\{ i_c^*, i_m^* \frac{p}{1-\lambda_m} - q\frac{p\lambda_m}{1-\lambda_m} + i_c(1-p)(1-\gamma) + (1-p)\gamma i_m \right\}, \\ i_m &= \max\left\{ i_m^*, pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c \right\}. \end{aligned}$$

When the solutions are interior to the core,

$$\begin{aligned} i_m &= \frac{i_m^* - \gamma i_m^* + \gamma q - i_m^* p - \lambda_m q + pq + \gamma i_m^* p - \gamma pq}{1-\lambda_m}, \\ i_c &= \frac{i_m^* - \gamma i_m^* + \gamma q - \lambda_m q + \gamma i_m^* p - \gamma pq}{1-\lambda_m}. \end{aligned}$$

As p goes to zero, we obtain that i_m and i_c will converge to the same value:

$$i_c = i_m = max\left\{ i_m^* \left(1-\gamma\right) / \left(1-\lambda_m\right) - q(\left(1-\gamma\right) / \left(1-\lambda_m\right) - 1), i_m^* \right\}. \quad (57)$$

It is immediate to verify from (57) that when $\gamma \geq \lambda_m$, the proposal is $i_c = i_m^*$. Furthermore, when $\gamma < \lambda_m$, in order to insure that proposals are not higher than i_c^*, the status quo cannot be too low q. The condition that $i_m^* \left(1-\gamma\right) / \left(1-\lambda_m\right) - q(\left(1-\gamma\right) / \left(1-\lambda_m\right) - 1) \leq i_c^*$, implies a lower bound on q, that is

$$q_{lb}^1 = \left(i_c^* - i_m^* \left(1-\gamma\right) / \left(1-\lambda_m\right)\right) / (1 - \left(1-\gamma\right) / \left(1-\lambda_m\right)),$$

beyond which the proposal is $i_c = i_c^*$. ■

2.3 Proof of Proposition 2

By step 1 in the proof of lemma 1, we have $i_m = \min\{i_m^*, \max\{A_c\}\}$ and $i_c = \max\{i_c^*, \min\{A_m\}\}$. To characterize the equilibrium, we need to distinguish different cases, depending on the status quo location. First suppose $q \in [i_c^*, i_m^*]$. By lemma 1, both m and c propose q and no policy change is feasible.

Second, suppose that $q > i_m^*$. We compute the acceptance set of the median, $A_m(r) = [\underline{x}_m, \overline{x}_m]$, in the same way as we computed (48) and (49). After interchanging the labels of the chair and of the median, we obtain

$$\begin{aligned} \overline{x}_m &= \frac{i_m^*(1-p)}{1-\lambda_m} + pq - \frac{\lambda_m\gamma(1-p)}{1-\lambda_m} i_m - \frac{\lambda_m(1-\gamma)(1-p)}{1-\lambda_m} i_c, \\ \underline{x}_m &= \frac{i_m^* p}{\lambda_m} - \frac{pq(1-\lambda_m)}{\lambda_m} + \frac{(1-p)(1-\gamma)\lambda_m i_c}{\lambda_m} + \frac{(1-p)\gamma\lambda_m i_m}{\lambda_m}. \end{aligned}$$

The acceptance set of the chair, $A_c(r) = [\underline{x}_c, \overline{x}_c]$, can be obtained from (46) and (47) after interchanging the labels of the chair and of the median

$$\begin{aligned}
\overline{x}_c &= pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c, \\
\underline{x}_c &= \frac{i_c^*}{\lambda_c} - \frac{(1-\lambda_c)pq}{\lambda_c} - i_m(1-p)\gamma\frac{1-\lambda_c}{\lambda_c} - \frac{1-\lambda_c}{\lambda_c}i_c(1-p)(1-\gamma).
\end{aligned}$$

In equilibrium $i_m = \min\{i_m^*, \max\{A_c\}\}$ and $i_c = \max\{i_c^*, \min\{A_m\}\}$. That is,

$$i_c = \max\left\{i_c^*, \frac{i_m^* p}{\lambda_m} - \frac{pq(1-\lambda_m)}{\lambda_m} + \frac{(1-p)(1-\gamma)\lambda_m i_c}{\lambda_m} + \frac{(1-p)\gamma\lambda_m i_m}{\lambda_m}\right\}, \tag{58}$$

$$i_m = \min\left\{i_m^*, pq + \gamma(1-p)i_m + (1-\gamma)(1-p)i_c\right\}. \tag{59}$$

When the solutions are interior to the core

$$\begin{aligned}
i_m &= \frac{(1-\gamma)i_m^* - (1-\gamma)q - i_m^* p + \lambda_m q - pq + \gamma i_m^* p - \gamma pq}{\lambda_m}, \\
i_c &= \frac{(1-\gamma)i_m^* - (1-\gamma)q + \lambda_m q + \gamma p i_m^* - \gamma pq}{\lambda_m}.
\end{aligned}$$

As p goes to zero, we obtain that i_m and i_c converge to the same value: the social acceptance set becomes a singleton,

$$i_c = i_m = min\left\{q + ((1-\gamma)/\lambda_m)(i_m^* - q), i_m^*\right\}. \tag{60}$$

We need to impose the constraint that the proposals belong to $[i_c^*, i_m^*]$. It is immediate from (60) that when $\gamma \geq 1 - \lambda_m$, the proposal is $i_c = i_m^*$. Furthermore, when $\gamma < 1 - \lambda_m$, the status quo q cannot be too high, otherwise from (60) we have that the proposal is lower than i_c^*. The condition that $q + ((1-\gamma)/\lambda_m)(i_m^* - q) \geq i_c^*$, implies an upper bound on q,

$$q_{ub}^2 = (i_c^* - ((1-\gamma)/\lambda_m)i_m^*)/(1 - (1-\gamma)/\lambda_m), \tag{61}$$

beyond which the proposal is $i_c = i_c^*$

Consider now the case where the status quo is $q < i_c^* < i_m^*$. The chair's acceptance set is $A_c(r) = [\underline{x}_c, \overline{x}_c]$. The endpoints can be obtained from (53) and (54) after interchanging the labels of the chair and of the median

$$\begin{aligned}
\overline{x}_c &= i_c^*\frac{p}{1-\lambda_c} - q\frac{p\lambda_c}{1-\lambda_c} + i_c(1-p)(1-\gamma) + (1-p)\gamma i_m, \\
\underline{x}_c &= i_c^*\frac{1-p}{\lambda_c} + qp - i_c\frac{(1-\lambda_c)(1-p)(1-\gamma)}{\lambda_c} - \frac{1-\lambda_c}{\lambda_c}(1-p)\gamma i_c.
\end{aligned}$$

To compute the median's acceptance set $A_m(r) = [\underline{x}_c, \overline{x}_c]$, we interchange the labels of the chair and of the media in (55) and (56),

$$\begin{aligned}
\overline{x}_c &= \frac{i_m^*}{1-\lambda_m} - \frac{\lambda_m}{1-\lambda_m} pq - \frac{\gamma\lambda_m(1-p)}{1-\lambda_m} i_m - \frac{(1-\gamma)(1-p)}{1-\lambda_m} i_c, \\
\underline{x}_c &= pq + \gamma(1-p) i_m + (1-\gamma)(1-p) i_c.
\end{aligned}$$

After computing $\min\{A_m\}$ and $\max\{A_c\}$, we write down the two conditions that equilibrium proposals must satisfy

$$\begin{aligned}
i_m &= \min\left\{ i_m^*, i_c^* \frac{p}{1-\lambda_c} - q\frac{p\lambda_c}{1-\lambda_c} + i_c(1-p)(1-\gamma) + (1-p)\gamma i_m \right\}, \\
i_c &= \max\left\{ i_c^*, pq + \gamma(1-p) i_m + (1-\gamma)(1-p) i_c \right\}.
\end{aligned}$$

When the solutions are interior to the core, we obtain

$$\begin{aligned}
i_m &= \frac{q(1-\gamma) + \gamma i_c^* + p i_c^* - \lambda_c q - pq - \gamma i_c^* p + \gamma pq}{1-\lambda_c}, \\
i_c &= \frac{q(1-\gamma) + \gamma i_c^* - \lambda_c q - \gamma i_c^* p + \gamma pq}{1-\lambda_c}.
\end{aligned}$$

As p goes to zero, i_m and i_c will converge to the same value,

$$i_c = i_m = max\left\{ q - (\gamma/(1-\lambda_c))(q - i_c^*), i_c^* \right\}. \tag{62}$$

We need to impose the constraint that the proposals belong to $[i_c^*, i_m^*]$. It is immediate from (62) that when $\gamma \leq (1-\lambda_c)$, the proposal is $i_c = i_c^*$, which is the policy preferred by the chair. Again, when $\gamma > (1-\lambda_c)$, we require that the status quo is not too small so that the proposal belongs to the gridlock interval. The condition that $q - (\gamma/(1-\lambda_c))(q - i_c^*) \leq i_m^*$, implies a lower bound on q, that is

$$q_{lb}^2 = \left(i_m^* - (\gamma/(1-\lambda_c)) i_c^*\right) / (1 - \gamma/(1-\lambda_c)), \tag{63}$$

beyond which the proposal is $i_c = i_m^*$. ■

Appendix C Derivation of the Likelihood Functions

3.1 Inclusive-Voting Model

We derive the likelihood function for the case where the chair is more hawkish than the median and under the assumption that shocks are normally distributed. Define the set of predetermined variables $\Omega_t = \{i_{t-1}, \pi_t, y_t\}$ and the sets Ξ_1, Ξ_2 and Ξ_3 that respectively contain the observations where the interest rate is increased, left unchanged, and cut. Denote the number of observations in each set as T_1, T_2 and T_3, respectively. The total number of observations in the sample is $T = T_1 + T_2 + T_3$. The sample separation is perfectly observable by the econometrician because the data clearly shows the instances where the FOMC increased, left unchanged, or cut the interest rate.

First, we derive the likelihood function in the case where $0 \leq \gamma < \lambda_m$. From proposition 1, the policy outcome in this case is

$$i_t = \begin{cases} i^*_{c,t}, & \text{if} \quad q_t < q^1_{lb,t}, \\ \delta i^*_{m,t} - (\delta - 1)q_t, & \text{if} \quad q^1_{lb,tt} \leq q_t \leq i^*_{m,t}, \\ q_t, & \text{if} \quad i^*_{m,t} < q_t \leq i^*_{c,t}, \\ i^*_{c,t} & \text{if} \quad i^*_c \leq q_t, \end{cases}$$

where $\delta = (1-\gamma)/(1-\lambda_m) > 1$ and

$$\begin{aligned} q^1_{lb,t} &= (i^*_c - \delta i^*_m)/(1-\delta), \\ i^*_{m,t} &= a_m + b\pi_t + dy_t + \epsilon_t, \\ i^*_{c,t} &= a_c + b\pi_t + dy_t + \epsilon_t, \end{aligned}$$

with $q^1_{lb,t} < i^*_{m,t} < i^*_{c,t}$ being respectively the threshold value above which the acceptance constraint binds, the policy preferred by the median, and the policy preferred by the chair. The top two regimes of the political aggregator above involve an interest rate increase and the observation belongs to Ξ_1. The third regime (from the top) implies that the interest rate is unchanged and the observation belongs to Ξ_2. Finally, the bottom regime implies an interest rate cut and the observation belongs to Ξ_3.

In the derivations that follow, it will be convenient to define

$$\begin{aligned} z^1_{lb,t} &= (i_{t-1} - (a_c - \delta a_m)/(1-\delta) - b\pi_t - dy_t)/\sigma, \\ z_{m,t} &= (i_{t-1} - a_m - b\pi_t - dy_t)/\sigma, \\ z_{c,t} &= (i_{t-1} - a_c - b\pi_t - dy_t)/\sigma, \end{aligned}$$

where is σ is the standard deviation of ϵ_t and we used the fact that the status quo policy is the interest rate selected in the previous meeting (that is, $q_t = i_{t-1}$). Rewrite the policy outcome as

$$i_t = \begin{cases} i^*_{c,t}, & \text{if} \quad \sigma z^1_{lb,t} < \epsilon_t, \\ \delta i^*_{m,t} - (\delta - 1)q_t, & \text{if} \quad \sigma z_{m,t} < \epsilon_t \leq \sigma z^1_{lb,t}, \\ q_t, & \text{if} \quad \sigma z_{c,t} < \epsilon_t \leq \sigma z_{m,t}, \\ i^*_{c,t} & \text{if} \quad \epsilon_t \leq \sigma z_{c,t}. \end{cases}$$

For an interest rate increase, the rate selected by the committee can be either $i^*_{c,t}$ or $\delta i^*_{m,t} - (\delta - 1)q_t$ depending on whether the shock is large enough that acceptance constraint binds. The density for this observation is a mixture of the two normal distributions associated with the processes $i^*_{c,t}$ and $\delta i^*_{m,t} - (\delta - 1)q_t$. Because the disturbance term is the same in both processes, these two distributions are perfectly correlated. A simple approach to derive the density is to consider the limit of the mixture of normals when their correlation coefficient (denoted by ρ) tends to one.[20] That is, the limit as $\rho \to 1$ of

$$\frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)(1 - \Phi(w_{1,t})) + \frac{1}{\delta\sigma}\phi\left(\frac{i_t - \delta(a_m + b\pi_t + dy_t) - (1-\delta)i_{t-1}}{\delta\sigma}\right)(1 - \Phi(-w_{1,t})),$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are the probability and cumulative density functions of the standard normal distribution and

$$w_{1,t} = \frac{(1-\delta)(i_t - i_{t-1}) - \delta(a_m - a_c)}{\delta\sigma\sqrt{(1-\rho^2)}}.$$

This density is a weighted average of two normal densities with weights $(1 - \Phi(w_{1,t})$ and $(1 - \Phi(-w_{1,t}))$. Notice that in the limit as $\rho \to 1$, the former weight tends to one while the latter tends to zero when $(1-\delta)(i_t - i_{t-1}) - \delta(a_m - a_c) < 0$ and the converse is true when $(1-\delta)(i_t - i_{t-1}) - \delta(a_m - a_c) > 0$. Hence, for an interest rate increase the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right) I(x_{1,t}) + \frac{1}{\delta\sigma}\phi\left(\frac{i_t - \delta(a_m + b\pi_t + dy_t) - (1-\delta)i_{t-1}}{\delta\sigma}\right)(1 - I(x_{1,t})),$$

where $x_{1,t}$ is short-hand for the condition $(1-\delta)(i_t - i_{t-1}) - \delta(a_m - a_c) < 0$ and $I(\cdot)$ is an indicator function that takes the value one if its argument is true and zero otherwise.

For an observation where the interest rate is left unchanged, the density is

$$Pr(i_t|\Omega_t) = \Phi(z_{m,t}) - \Phi(z_{c,t}),$$

which is the density of a variable censored above and below. Finally, for an interest rate cut the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

[20] The derivation of the density of the mixture of normal distributions follows standard steps (see, for example, Maddala, 1983) and is omitted here to save space.

The log likelihood function of the T available interest rate observations is

$$\begin{aligned} L(\theta) &= -(T_1+T_3)\sigma \\ &+ \sum_{i_t \in \Xi_1} \log\left(\phi\Big(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\Big) I(x_{1,t}) + \frac{1}{\delta}\phi\Big(\frac{i_t - \delta(a_m + b\pi_t + dy_t) - (1-\delta)i_{t-1}}{\delta\sigma}\Big)\left(1 - I(x_{1,t})\right)\right) \\ &+ \sum_{i_t \in \Xi_2} \log\left(\Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right)\right) + \sum_{i_t \in \Xi_3} \log\left(\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)\right), \end{aligned}$$

where $\theta = \{a_c,\, a_m,\, \delta,\, b,\, c,\, \sigma\}$ is the set of unknown parameters. Note that the indicator function $I(x_{1,t})$ induces a kink in the likelihood function and, consequently, the maximization requires either the use of a non-gradient-based optimization algorithm or a smooth approximation to the indicator function. We followed the latter approach here with ρ fixed to 0.9999.

Second, we derive the likelihood function in the case where $\lambda_m \leq \gamma \leq \lambda_c$. From proposition 1, the policy outcome in this case is

$$i_t = \begin{cases} i^*_{m,t} & \text{if} \quad q_t < i^*_{m,t} \\ q_t, & \text{if} \quad i^*_{m,t} \leq q_t \leq i^*_{c,t}, \\ i^*_{c,t} & \text{if} \quad q_t > i^*_{c,t}. \end{cases}.$$

The top regime involves an interest rate increase and the observation belongs to Ξ_1. The middle regime implies that the interest rate is left unchanged and the observation belongs to Ξ_2. Finally, the bottom regime involves an interest rate cut and the observation belongs to Ξ_3. Using the definitions of $z_{m,t}$ and $z_{c,t}$ above rewrite the policy outcome as

$$i_t = \begin{cases} i^*_{m,t} & \text{if} \quad \epsilon_t > \sigma z_{m,t} \\ q_t & \text{if} \quad \sigma z_{c,t} \leq \epsilon_t \leq \sigma z_{m,t}, \\ i^*_{c,t} & \text{if} \quad \epsilon_t < \sigma z_{c,t}. \end{cases}.$$

For an interest increase the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right).$$

For an observation where the interest rate is left unchanged the density is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right).$$

For an interest rate cut the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

The log likelihood function of the T available interest rate observations is

$$\begin{aligned} L(\theta) &= -(T_1+T_3)\sigma + \sum_{i_t\in\Xi 1} \log\left(\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right)\right) + \sum_{i_t\in\Xi_2} \log\left(\Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right)\right) \\ &\quad + \sum_{i_t\in\Xi_3} \log\left(\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)\right), \end{aligned}$$

where $\theta = \{a_c,\, a_m,\, b,\, c,\, \sigma\}$ is the set of unknown parameters.

Finally, we derive the likelihood function in the case where $\lambda_c < \gamma \leq 1$. From proposition 1, the policy outcome in this case is

$$i_t = \begin{cases} i^*_m & \text{if} \quad q_t < i^*_{m,t} \\ q_t, & \text{if} \quad i^*_{m,t} < q_t \leq i^*_{c,t}, \\ q_t - \kappa(q_t - i^*_c), & \text{if} \quad i^*_{c,t} \leq q_t \leq q^1_{ub,t}, \\ i^*_{m,t}, & \text{if} \quad q_t > q^1_{ub,t}, \end{cases}$$

where $\kappa = \gamma/\lambda_c > 1$ and $q^1_{ub} = (i^*_m - \kappa i^*_c)/(1-\kappa)$ is the threshold value below which the acceptance constraint binds. Note that $i^*_{m,t} < i^*_{c,t} < q^1_{ub,t}$. The top regime of this political aggregator involves an interest rate increase and the observation belongs to Ξ_1. The second regime (from the top) implies that the interest rate is left unchanged and the observation belongs to Ξ_2. The two bottom regimes involve an interest rate cut and the observation belongs to Ξ_3. In the derivations that follow, it will be convenient to define

$$z^1_{ub,t} = \left(i_{t-1} - (a_m - \kappa a_c)/(1-\kappa) - b\pi_t - dy_t\right)/\sigma,$$

and to rewrite the policy outcome as

$$i_t = \begin{cases} i^*_{m,t} & \text{if} \quad \sigma z_{m,t} < \epsilon_t \\ q_t, & \text{if} \quad \sigma z_{c,t} \leq \epsilon_t \leq \sigma z_{m,t},, \\ q_t - \kappa(q_t - i^*_c) & \text{if} \quad \sigma z^1_{ub,t} \leq \epsilon_t < \sigma z_{c,t},, \\ i^*_{m,t}, & \text{if} \quad \epsilon_t < \sigma z^1_{ub,t}. \end{cases}$$

For an interest rate increase the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right).$$

For an observation where the interest rate is unchanged the density is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right).$$

For an interest rate cut, the value selected by the committee may be i^*_m or $q_t - \kappa(q_t - i^*_c)$ depending on whether the shock is small enough that acceptance constraint binds. Although the observation can be assigned to the set Ξ_3, the econometrician cannot be sure which of the two regimes generated the observation and the density for this observation is a mixture of the two normal distributions associated with the processes of $i^*_{m,t}$ and $q_t - \kappa(q_t - i^*_c)$. As before, the disturbance term in both processes is the same and the two distributions are perfectly correlated. Then, the density is limit as $\rho \to 1$ of

$$\frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right)\Phi\left(w_{2,t}\right) + \frac{1}{\kappa\sigma}\phi\left(\frac{i_t - \kappa(a_c + b\pi_t + dy_t) - (1-\kappa)i_{t-1}}{\kappa\sigma}\right)\Phi\left(-w_{2,t}\right),$$

with

$$w_{2,t} = \frac{(1-\kappa)(i_t - i_{t-1}) - \kappa(a_m - a_c)}{\sigma\sqrt{(1-\rho^2)}}.$$

This density is a weighted average of two normal densities with weights $\Phi\left(w_{2,t}\right)$ and $\Phi\left(-w_{2,t}\right)$. In the limit as $\rho \to 1$, the former weight tends to one while the latter tends to zero when $(1-\kappa)(i_t - i_{t-1}) - \kappa(a_m - a_c) > 0$ and the converse is true when $(1-\kappa)(i_t - i_{t-1}) - \kappa(a_m - a_c) < 0$. Hence, for an interest rate increase the density may be written as

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right)I\left(x_{2,t}\right) + \frac{1}{\kappa\sigma}\phi\left(\frac{i_t - \kappa(a_c + b\pi_t + dy_t) - (1-\kappa)i_{t-1}}{\kappa\sigma}\right)\left(1 - I\left(x_{2,t}\right)\right),$$

where $x_{2,t}$ is short-hand for the condition $(1-\kappa)(i_t - i_{t-1}) - \kappa(a_m - a_c) > 0$ and $I(\cdot)$ is an indicator function that takes the value one if its argument is true and zero otherwise.

The log likelihood function of the T available interest rate observations is

$$\begin{aligned} L(\theta) &= -(T_1 + T_3)\sigma + \sum_{i_t \in \Xi_2} \log\left(\Phi\left(z_{m,t}\right) - \Phi\left(z_{c,t}\right)\right) + \sum_{i_t \in \Xi 1} \log\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right) \\ &\quad + \sum_{i_t \in \Xi_3} \log\left(\phi\left(\frac{i_t - a_m - b\pi_t - dy_t}{\sigma}\right)I\big(x_{2,t}\big) + \frac{1}{\kappa}\phi\Big(\frac{i_t - \kappa(a_c + b\pi_t + dy_t) - (1-\kappa)i_{t-1}}{\kappa\sigma}\Big)\big(1 - I\big(x_{2,t}\big)\big)\right), \end{aligned}$$

where $\theta = \{a_c,\, a_m,\, \kappa,\, b,\, c,\, \sigma\}$ is the set of unknown parameters.

3.2 Dictator Model

The policy outcome of the dictator model is

$$i_t = \begin{cases} i^*_{c,t}, & \text{if } q_t > i^*_{c,t} + \Delta, \\ q_t, & \text{if } i^*_c - \Delta \leq q_t \leq i^*_{c,t} + \Delta, \\ i^*_{c,t}, & \text{if } q_t < i^*_{c,t} - \Delta. \end{cases}$$

The top regime of this political aggregator implies an interest rate increase and the observation belongs to Ξ_1. The second regime (from the top) implies that the interest rate is left unchanged and the observation belongs to Ξ_2. The bottom regime implies an interest rate cut and the observation belongs to Ξ_3. Define

$$\begin{aligned} z_{u,t} &= \left(i_{t-1} - a_m - b\pi_t - dy_t + \Delta\right)/\sigma, \\ z_{l,t} &= \left(i_{t-1} - a_c - b\pi_t - dy_t - \Delta\right)/\sigma, \end{aligned}$$

and write the policy outcome as

$$i_t = \begin{cases} i^*_{c,t} & \text{if} \quad \epsilon_t < \sigma z_{i,t} \\ q_t & \text{if} \quad \sigma z_{l,t} \leq \epsilon_t \leq \sigma z_{u,t}, \\ i^*_{c,t} & \text{if} \quad \epsilon_t > \sigma z_{u,t}. \end{cases} .$$

For an interest increase the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

For an observation where the interest rate is left unchanged the density is

$$Pr(i_t|\Omega_t) = \Phi\left(z_{u,t}\right) - \Phi\left(z_{l,t}\right).$$

For an interest rate cut the density is

$$Pr(i_t|\Omega_t) = \frac{1}{\sigma}\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right).$$

Then, the log likelihood function of the T available interest rate observations is

$$L(\theta) = -(T_1 + T_3)\sigma + \sum_{i_t \in \{\Xi 1, \Xi_3\}} \log\left(\phi\left(\frac{i_t - a_c - b\pi_t - dy_t}{\sigma}\right)\right) + \sum_{i_t \in \Xi_2} \log\left(\Phi\left(z_{u,t}\right) - \Phi\left(z_{l,t}\right)\right)$$

where $\theta = \{a_c,\, b,\, c,\, \sigma\}$ is the set of unknown parameters.

Table 1. All Chairs

	Unemployment		GDP Growth		
	Inclusive Voting	Dictator Model	Inclusive Voting	Dictator Model	Data
	(1)	(2)	(3)	(4)	(5)
			A. Maximum Likelihood Estimates		
a_c	6.402*	3.542*	4.982*	3.056*	
	(0.920)	(0.570)	(0.437)	(0.271)	
a_m	0.958		−1.099*		
	(0.912)		(0.540)		
b	0.631*	0.643*	0.664*	0.639*	
	(0.092)	(0.060)	(0.081)	(0.055)	
d	−0.052	−0.043	0.514*	$0.091^{\dagger}$	
	(0.153)	(0.099)	(0.078)	(0.047)	
σ	2.998*	2.051*	2.848*	2.037*	
	(0.192)	(0.088)	(0.181)	(0.087)	
			B. Model Selection Criteria		
$L(\theta)$	−451.199	−686.423	−426.865	−684.635	
AIC	912.398	1380.846	863.730	1377.270	
RMSE	0.945	2.053	0.916	2.039	
MAE	0.742	1.732	0.707	1.743	
			C. Quantitative Predictions		
Autocorrelation	0.689	0.298	0.791	0.308	0.972
Standard deviation	2.280	2.491	2.451	2.504	2.505
Proportion of:					
Cuts	0.223	0.465	0.192	0.467	0.226
Increases	0.218	0.462	0.185	0.462	0.245
No changes	0.556	0.069	0.619	0.067	0.529
Policy reversals	0.126	0.593	0.084	0.597	0.033

Notes: The superscripts $*$ and $\dagger$ denote statistical significance at the five and ten percent levels, respectively. $L(\theta)$ is the value of the log likelihood function at the optimum. AIC, RMSE and MAE stand for Akaike Information Criteria, root mean square error, and mean absolute error, respectively.

Table 2. Burns

	Unemployment		GDP Growth		
	Inclusive Voting	Dictator Model	Inclusive Voting	Dictator Model	Data
	(1)	(2)	(3)	(4)	(5)
			A. Maximum Likelihood Estimates		
a_c	6.500*	5.288*	1.522*	1.195*	
	(1.454)	(0.970)	(0.763)	(0.538)	
a_m	5.441*		0.141		
	(1.420)		(0.805)		
b	0.472*	0.551*	0.671*	0.663*	
	(0.079)	(0.052)	(0.101)	(0.071)	
d	−0.456*	−0.425*	0.093*	0.032	
	(0.155)	(0.106)	(0.038)	(0.025)	
σ	0.752*	0.522*	0.841*	0.604*	
	(0.115)	(0.059)	(0.127)	(0.068)	
			B. Model Selection Criteria		
$L(\theta)$	−45.985	−43.762	−46.467	−49.719	
AIC	101.970	95.524	102.934	107.438	
RMSE	0.337	0.520	0.371	0.606	
MAE	0.267	0.435	0.276	0.494	
			C. Quantitative Predictions		
Autocorrelation	0.676	0.593	0.655	0.554	0.775
Standard deviation	1.227	1.255	1.240	1.279	1.183
Proportion of					
Cuts	0.325	0.396	0.296	0.410	0.366
Increases	0.274	0.354	0.258	0.367	0.220
No changes	0.377	0.225	0.422	0.198	0.415
Policy reversals	0.201	0.394	0.151	0.425	0.049

Notes: see notes to table 1.

Table 3. Miller

	Unemployment		GDP Growth		
	Inclusive Voting	Dictator Model	Inclusive Voting	Dictator Model	Data
	(1)	(2)	(3)	(4)	(5)
	A. Maximum Likelihood Estimates				
a_c	18.490†	16.286*	7.482*	3.020	
	(9.957)	(8.692)	(3.244)	(2.045)	
a_m	16.858†		6.102*		
	(9.858)		(2.828)		
b	0.377	0.985*	0.373	0.826*	
	(0.431)	(0.261)	(0.361)	(0.242)	
d	−1.939	−2.584†	−0.167†	−0.211*	
	(1.606)	(1.409)	(0.089)	(0.075)	
σ	0.899*	0.829*	0.830*	0.742*	
	(0.185)	(0.154)	(0.171)	(0.137)	
	B. Model Selection Criteria				
$L(\theta)$	−18.818	−20.615	−18.056	−18.995	
AIC	47.636	24.615	46.112	45.990	
RMSE	0.541	0.831	0.533	0.748	
MAE	0.418	0.692	0.374	0.579	
	C. Quantitative Predictions				
Autocorrelation	0.411	0.332	0.512	0.434	0.823
Standard deviation	0.890	1.301	1.004	1.365	1.280
Proportion of					
Cuts	0.164	0.350	0.135	0.294	0.200
Increases	0.316	0.450	0.397	0.494	0.600
No changes	0.453	0.133	0.401	0.145	0.200
Policy reversals	0.104	0.421	0.135	0.438	0.067

Notes: see notes to table 1.

Table 4. Volcker

	Unemployment		GDP Growth		
	Inclusive Voting	Dictator Model	Inclusive Voting	Dictator Model	Data
	(1)	(2)	(3)	(4)	(5)
	A. Maximum Likelihood Estimates				
a_c	6.181*	4.765*	4.734*	3.927*	
	(1.781)	(1.075)	(0.804)	(0.507)	
a_m	2.897		2.017*		
	(1.807)		(0.895)		
b	0.724*	0.691*	1.002*	0.898*	
	(0.149)	(0.095)	(0.135)	(0.087)	
d	0.169	0.128	0.421*	0.316*	
	(0.214)	(0.133)	(0.105)	(0.066)	
σ	1.741*	1.149*	1.329*	0.933*	
	(0.294)	(0.127)	(0.220)	(0.103)	
	B. Model Selection Criteria				
$L(\theta)$	−56.974	−81.566	−50.658	−72.939	
AIC	123.948	171.132	111.316	153.878	
RMSE	0.601	1.154	0.482	0.940	
MAE	0.428	0.837	0.337	0.700	
	C. Quantitative Predictions				
Autocorrelation	0.755	0.459	0.820	0.601	0.878
Standard deviation	1.649	1.708	1.746	1.753	1.783
Proportion of					
Cuts	0.241	0.450	0.259	0.437	0.167
Increases	0.190	0.418	0.201	0.415	0.286
No changes	0.545	0.109	0.517	0.125	0.548
Policy reversals	0.113	0.523	0.102	0.487	0.095

Notes: see notes to table 1.

Table 5. Greenspan

	Unemployment		GDP Growth		
	Inclusive Voting	Dictator Model	Inclusive Voting	Dictator Model	Data
	(1)	(2)	(3)	(4)	(5)
	A. Maximum Likelihood Estimates				
a_c	8.650*	6.507*	1.672*	1.184*	
	(1.215)	(0.737)	(0.597)	(0.433)	
a_m	4.312*		−4.670*		
	(1.210)		(0.851)		
b	1.454*	1.458*	1.648*	1.387*	
	(0.166)	(0.107)	(0.183)	(0.128)	
d	−0.941*	−0.964*	1.017*	0.068	
	(0.208)	(0.128)	(0.157)	(0.083)	
σ	1.993*	1.402*	2.029*	1.639*	
	(0.180)	(0.081)	(0.184)	(0.095)	
	B. Model Selection Criteria				
$L(\theta)$	−192.252	−328.000	−173.440	−351.634	
AIC	404.504	664.000	356.880	711.268	
RMSE	0.559	1.403	0.729	1.643	
MAE	0.405	1.126	0.443	1.424	
	C. Quantitative Predictions				
Autocorrelation	0.804	0.475	0.867	0.350	0.990
Standard deviation	1.912	2.199	2.020	2.204	2.212
Proportion of					
Cuts	0.196	0.453	0.121	0.458	0.179
Increases	0.194	0.451	0.131	0.453	0.225
No changes	0.603	0.089	0.742	0.082	0.596
Policy reversals	0.089	0.555	0.025	0.562	0.013

Notes: see notes to table 1.

Table 6. Bernanke

	Unemployment		GDP Growth		
	Inclusive Voting	Dictator Model	Inclusive Voting	Dictator Model	Data
	(1)	(2)	(3)	(4)	(5)
	A. Maximum Likelihood Estimates				
a_c	18.528*	16.019*	3.228*	3.342*	
	(1.808)	(0.965)	(0.602)	(0.467)	
a_m	16.737*		−0.007		
	(1.590)		(1.058)		
b	0.561*	0.299*	0.148	−0.135	
	(0.201)	(0.105)	(0.219)	(0.155)	
d	−3.089*	−2.575*	1.075*	0.702*	
	(0.381)	(0.202)	(0.154)	(0.100)	
σ	0.912*	0.588*	1.106*	0.941*	
	(0.195)	(0.085)	(0.225)	(0.135)	
	B. Model Selection Criteria				
$L(\theta)$	−26.960	−30.720	−26.459	−42.464	
AIC	73.920	69.440	62.918	92.928	
RMSE	0.394	0.586	0.500	0.949	
MAE	0.290	0.422	0.376	0.789	
	C. Quantitative Predictions				
Autocorrelation	0.727	0.681	0.600	0.344	0.870
Standard deviation	1.709	1.674	1.594	1.563	1.679
Proportion of					
Cuts	0.332	0.449	0.258	0.472	0.400
Increases	0.155	0.308	0.099	0.368	0.120
No changes	0.473	0.203	0.603	0.120	0.480
Policy reversals	0.107	0.399	0.055	0.496	0.000

Notes: see notes to table 1.

References

[1] Baron, David P. and John A. Ferejohn., (1989), "Bargaining in Legislatures," *American Political Science Review* 83(4): 1181-1206.

[2] Blinder, Alan S., (1998), *Central Banks in Theory and Practice*, Cambridge: MIT Press.

[3] —— (2004), *The Quiet Revolution: Central Banking Goes Modern*, New Haven: Yale University Press.

[4] Bordo Michael and Istrefi, Klodiana, (2018), "Perceived FOMC: The Making of Hawks, Doves and Swingers," NBER Working Paper No. 24650.

[5] Cardona Daniel and Clara Ponsati, (2011), "Uniqueness of Stationary Equilibria in Bargaining One-dimensional Policies under (Super) Majority Rules," *Games and Economic Behavior* 73: 65-75.

[6] Chappell, Henry W. Jr., Rob Roy McGregor, and Todd A. Vermilyea, (2005), *Committee Decisions on Monetary Policy*, Cambridge: MIT Press.

[7] Cook Timothy and Thomas Hahn, (1989), "The Effect of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970s," *Journal of Monetary Economics*, 24, (3): 331-351.

[8] Banks Jeffrey and John Duggan, (2006), "A General Bargaining Model of Legislative Policy-making," *Quarterly Journal of Political Science* Vol. 1: 49-85.

[9] Eijffinger, Sylvester C. W., Mahieu, Ronald J. and Raes, Louis (2015) "Hawks and Doves at the FOMC," CEPR Discussion Papers 10442.

[10] Elliott Graham and Allan Timmermann, (2004), "Optimal Forecast Combinations under General Loss Functions and Forecast Error Distributions," *Journal of Econometrics*, 122, (1): 47-79.

[11] Gerlach-Kristen, Petra, and Ellen E. Meade, (2010) "Is There a Limit on FOMC Dissents? Evidence from the Greenspan Era," American University, mimeo.

[12] Istrefi, Klodiana, (2018), "In Fed Watchers' Eyes: Hawks, Doves and Monetary Policy," Banque de France Working Paper No. July 2018, WP 725.

[13] Maddala, G. S, (1983), *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge: Cambridge University Press.

[14] Maisel, Sherman, (1973), *Managing the Dollar*, New York: Norton.

[15] Malmendier, Ulrike, Nagel, Stefan and Yan, Zhen, (2017), "The Making of Hawks and Doves: Inflation Experiences on the FOMC," NBER Working Paper No. w23228.

[16] Meade, Ellen E., (2005), "The FOMC: Preferences, Voting, and Consensus," Federal Reserve Bank of St. Louis Review, pp. 93-101.

[17] Meade, Ellen E. and David Stasavage, (2008), "Publicity of Debate and the Incentive to Dissent: Evidence from the US Federal Reserve," *The Economic Journal* 118: 695–717.

[18] Meyer, Laurence H., (2004), *A Term at the Fed*, Harper Collins, New York.

[19] Osborne Martin J. and Ariel Rubinstein, (1990), *Bargaining and Markets*, Cambridge: Academic Press.

[20] Predtetchinski, Arkadi, (2011), "One-dimensional Bargaining," *Games and Economic Behavior* 72(2): 526-543.

[21] Riboni, Alessandro, and Francisco Ruge-Murcia, (2010), "Monetary Policy by Committee: Consensus, Chair Dominance or Simple Majority?," *Quarterly Journal of Economics* 125: 363–416.

[22] Romer, Thomas, and Howard Rosenthal, (1978), "Political Resource Allocation, Controlled Agendas, and the Status Quo," *Public Choice* 33: 27–43.

[23] Romer Christina D. and David H. Romer, (2004), "Choosing the Federal Reserve Chair: Lessons from History," *Journal of Economic Perspectives* Volume 18, Number 1, Winter 2004, 129-162.

[24] Rosett, Richard N., (1959), "A Statistical Model of Friction in Economics," *Econometrica*, 27(2): 263-267.

[25] Rudebusch, Glenn, (1995), "Federal Reserve Interest Rate Targeting, Rational Expectations, and the Term Structure," *Journal of Monetary Economics*, 24: 245-274.

[26] Svensson, Lars E. O., (1997), "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets," *European Economic Review* 41: 1111–1146.

[27] Thornton, Daniel L. and Wheelock, David C., (2000), "A History of the Asymmetric Policy Directive," Federal Reserve Bank of St. Louis Review, September/October 2000, 82(5): 1-16.

[28] Thornton, D. L., (2004), "The Fed and Short-Term Rates: Is It Open Market Operations, Open Mouth Operations, or Interest Rate Smoothing?" *Journal of Banking and Finance* 28: 475-498.

[29] Thornton, D. L., (2005), "A New Federal Funds Rate Target Series: September 27, 1982-December 31, 1993," Federal Reserve Bank of St. Louis Working Paper,

[30] Thornton, D. L., (2006), "When Did the FOMC Begin Targeting the Federal Funds Rate? What the Verbatim Transcripts Tell Us," *Journal of Money, Credit and Banking*, 38(8): 2039-2071.

Figure 1: Instantaneous Utility Function

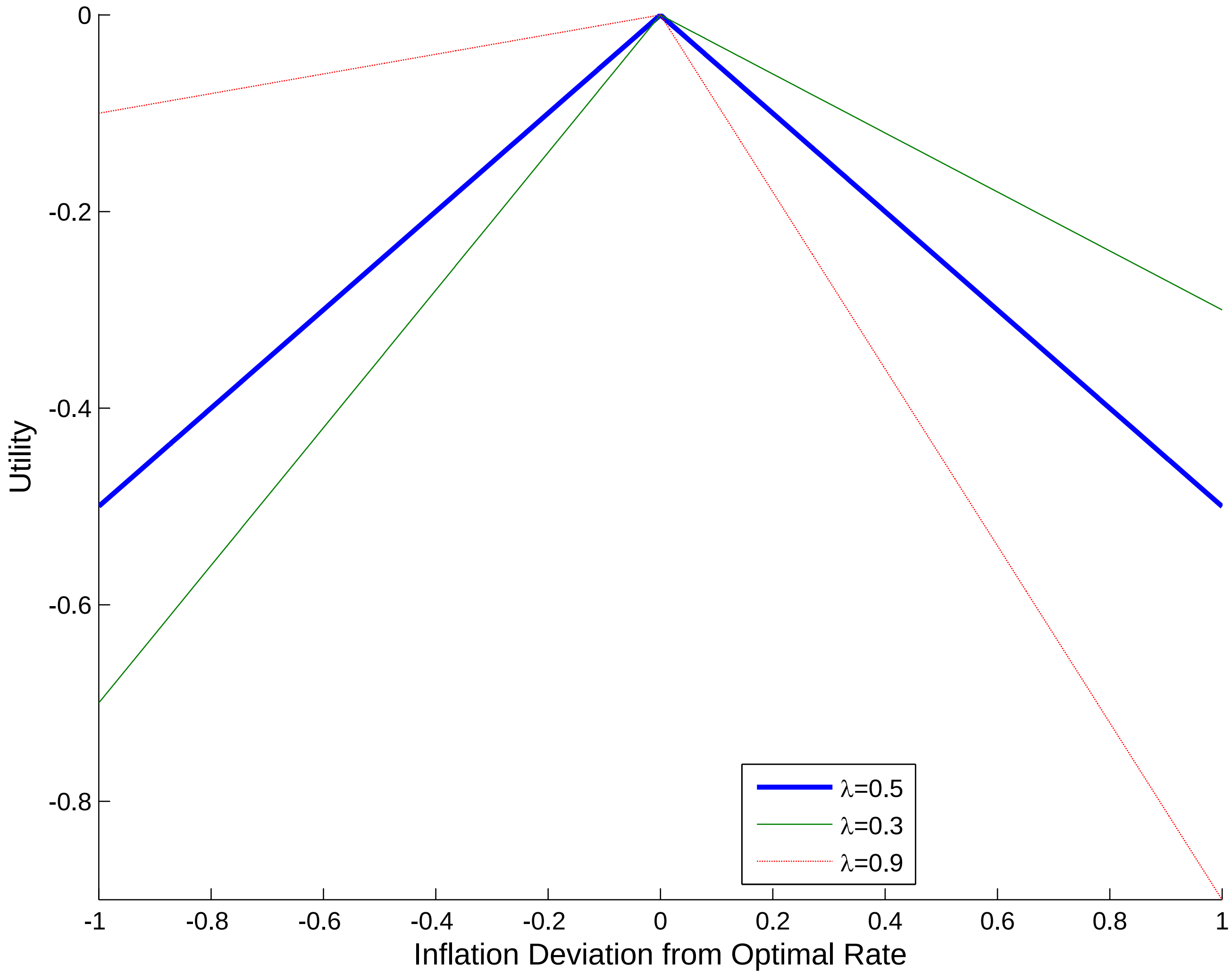

Figure 2: Log-Likelihood Functions