

CREDIBILITY AND FLEXIBILITY WITH INDEPENDENT MONETARY POLICY COMMITTEES

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Abstract: Independent monetary policy committees are a simple way of attaining relatively low inflation without completely sacrificing an activist role for monetary policy. If central bankers' types are unknown, then for a wide range of parameters an independent committee achieves higher social welfare than either a zero-inflation rule or discretionary policy conducted by an opportunistic central banker. A key reason for the committee's superior performance is that committee members are relatively likely to opt for low inflation and building a reputation when shocks are small. When large shocks hit the economy, the incentive to react outweighs the reputation-building benefit.

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I. INTRODUCTION

The purpose of this paper is to consider independent monetary policy committees as a simple way of attaining low and stable inflation without completely sacrificing an activist role for monetary policy. We show that if policy makers' types are their private information, then for a wide range of parameters, committees produce higher expected welfare than either a single central banker with the same preferences as society or a single central banker who can commit to zero inflation. This is because the committee produces smoother inflation than a single policy maker and is relatively likely to pursue low inflation in normal times, but will react to extraordinary shocks.

If output is increasing in unanticipated inflation, then a policy maker may want to generate unexpected inflation even though he dislikes actual inflation. If the public knows the policy maker's objectives and has no informational disadvantage, then in equilibrium its expectations are correct. If the marginal benefit of an increase in unexpected inflation exceeds the marginal cost of actual inflation when actual and expected inflation both equal the socially optimal rate, the outcome is too high inflation and no output gain. This is the familiar time-inconsistency problem of monetary policy.¹

The realization that policy makers may be tempted to act strategically and that this may lead to an inflation bias has led to changes in central bank legislation around the world. Examples of new laws are the Reserve Bank of New Zealand Act of 1989, which statutorily binds the Reserve Bank to price stability, the Bank of England Act of 1997, which imposes an inflation target on the Bank of England and the Bank of Japan Act of 1997, which orders the pursuit of low inflation.

Unfortunately, "tying the hands" of central bankers by legally binding them to low inflation is apt to hinder their ability to react to stochastic shocks that are realized after the public's expectations are formed, but before monetary policy is made. These shocks provide an activist role for the central bank; an inflation target or other institutional mechanism that removes the inflation bias may be at the expense of the central bank being unable to respond to them.

The problem of designing a central bank that is both credible that it will deliver low inflation and at the same time retains the flexibility to respond to

¹ The literature on time inconsistency is enormous. The original papers are by Kydland and Prescott (1977) and Barro and Gordon (1983b). Drazen (2000) provides an excellent survey.

shocks is the focus of a sizable body of research. One type of proposed solution is a contingent inflation contract. Walsh (1995) proposes a contract where the government imposes a linear penalty on a central bank in excess of its target and pays a reward for inflation below its target. If the contract is properly specified, the tradeoff problem is solved. Society gets low inflation with no loss of central bank flexibility.²

Walsh's solution is an important breakthrough in addressing the inflationary bias, but there are several implementation problems. First, it only works if the government is fully credible that it will enforce the contract. However, the time-inconsistency problem arises precisely because policy makers are not credible. McCallum (1995) and Briault, Haldane and King (1997) point out that giving the government the responsibility for monitoring the central bank and punishing deviations merely shifts the time-inconsistency problem from the central bank to the enforcing government. Second, to pick the optimal rule the government must know the exact weight that the monetary policy maker puts on personal compensation relative to social welfare. Obstfeld and Rogoff (1996, p. 644) point out that uncertainty about this weight may introduce additional noise into monetary policy. Possibly as a result of these difficulties, actual examples of Walsh (1995) contracts are hard to find.³

Another solution is proposed by Rogoff (1985). He shows that if society appoints a central banker who is more conservative than society, in the sense that he places more weight on losses due to inflation, the outcome is lower inflation and less response to shocks. If society can precisely pick the policy maker's preferences, it can choose the policy maker who provides the best trade off of flexibility for credibility. Lohmann (1992) extends this idea by suggesting that in normal times monetary policy should be made by an independent conservative central banker. However, if a large shock occurs, the government should threaten to override the central bank if it does not stabilize.⁴ Lohmann shows that this institutional arrangement dominates Rogoff's solution.

Real world examples of attempts at Lohmann's solution do exist. For example, in the face of an economic crisis, the New Zealand government can override the Reserve Bank and the Reserve Bank is allowed to accommodate the first-

² Svensson (1997) shows that a suboptimally low inflation target can achieve the same goal.

³ See Briault, Haldane and King (1997) for a discussion of this.

⁴ Her idea is similar to Flood and Isard's (1989) escape clause model.

round effect of the shock on prices. In 'extreme economic circumstances', the UK Treasury is allowed to instruct the Bank of England on monetary policy for a limited time.

Lohmann's strong welfare results require that the government can precisely pick the preferences of the central banker, as well as the size of the government's cost to overriding him. Compared to Rogoff's proposal, this solution imposes stricter requirements on government's credibility because it requires that at certain times the government, and not the institutions set by the government or the society, conducts policy. It must be believable that the government would intervene in extraordinary times if the central bank does not stabilize, but would refrain from intervention in normal times.⁵

Furthermore, real world escape clause rules face the problem that it is not possible to precisely define the state that triggers intervention. For example, there is unlikely to be agreement over what constitutes 'extreme economic circumstances'. This admits the possibility that opportunistic governments will override the central bank in less than extreme circumstances.

Two important precursors to our paper are the works by Waller (1992) and Faust (1996). Their research shows that delegating monetary policy to a policy board can lead to welfare improvement relative to a policy set by majority voting. Specifically, Waller (1992) shows how the process of appointment of central bank's members can influence the transmission of partisan preferences to policy decisions. In our paper we abstract from the issues of appointment and reappointment in order to keep the model tractable and to focus on the key point, which is the effect of independent committees on the tradeoff between flexibility and discipline. We discuss possible extensions of our model along the lines suggested by Waller (1992) and Faust (1996) in the final section of the paper.

Our model works as follows. We assume that inflation is set by a two-person committee of policy-makers who serve overlapping two-period terms. There are two sorts of central bankers. The first is opportunistic, attempting to use surprise inflation to raise output. The second is mechanistic, always voting for zero inflation. McCallum (1995) claims that some central bankers recognize the futility of opportunistic behavior and simply refrain from it. This second type may also be viewed as single minded, caring solely about inflation. Perhaps Hans

⁵ Obstfeld (1991) also demonstrates that escape clauses such as Lohmann's can lead to multiple equilibria and can thus be destabilizing.

Tietmeyer and Paul Volcker represent examples of this type of central banker. Adopting the avian terminology of the British press, we will call the first type a *dove* and the second type a *hawk*. A policy maker's type is his private information.

In this setup, doves may be deterred from voting for inflation in their first period in office by an incentive to gain a reputation for inflationary toughness. If a dove does not vote for inflation in his first period in office, then the likelihood the public attaches to his being a hawk rises. This lowers future expected inflation, making future inflationary surprises less costly. Thus, doves may masquerade as hawks when they first take office to lower expected inflation later on.⁶

A dove's incentive to mimic a hawk will depend on the size of the current stochastic shock. Doves will find it relatively attractive to pretend to be hawks when shocks are small. However, the reputational gain is less likely to be worth not responding to large shocks. Thus, reputation building produces an endogenous non-linear response to shocks that is similar to Lohmann's (1992) escape clause mechanism.

Because monetary policy is made by a committee rather than by a single policy maker, the expected outcome is an intermediate level of inflation. Thus the committee endogenously produces an outcome similar to that advocated by Rogoff (1985). The central bank has a strictly positive inflation bias, but produces less inflation on average than a policy maker who maximizes within-period social welfare would select. Because the welfare cost of inflation is increasing at an increasing rate, the smoother inflation produced by a committee also tends to make a committee more attractive than a single policy maker.⁷

We establish analytically some sufficient conditions for a committee to be better than a rule or discretionary policy making by a single dove. If the variance of the shocks is small enough, then a zero-inflation rule is better than discretionary policy making. If the variance is not too small and if the proportion of hawks in the candidate policy maker population is sufficiently high, we show that the committee produces a lower expected welfare loss than a zero-inflation rule.

⁶ Backus and Driffill (1985) adopt Kreps and Wilson's (1982) reputation model to provide the original monetary policy model of hawks and doves. Sibert (2003) extends this framework to a committee structure, similar to the one here. Neither Backus and Driffill nor Sibert consider an activist role for monetary policy.

⁷ This is different than the policy smoothing in Waller (2000). There, independent monetary policy committees with members who serve staggered terms in office reduce excess policy variability resulting from political turnover.

If the variance of the shocks is sufficiently large, discretion is better than rule. We show that unless the variance is very large, the committee is better than discretion as long as the fraction of doves in the candidate policy maker population is not too small.

More precise results require specification of the shock's distribution and a numerical solution. We assume that the shock is lognormally distributed. When the variance is such that discretion and a zero-inflation rule yield the same expected welfare loss, committees are better than either rule or discretion no matter what the ratio of hawks to doves. For higher variances, the committee is still better if the ratio of hawks to doves in the policy maker population is low enough. This cutoff ratio falls as the variance rises. With a lower variance, there is a minimum proportion of hawks that is necessary to ensure committees are better than a rule. As the variance falls, this minimum proportion rises. For a large range of variances of the shock, committees are better than rules or discretion for a wide range of policy maker populations.

This welfare result suggests that the independent committees described here provide an attractive way of trading off low inflation and responding to shocks.⁸ They also require less government commitment than does a contingent rule or an escape-clause solution. There is no need for the government to monitor or influence the central bank's behavior, it needs only to set up an independent central bank.⁹ This appears possible; it may be that opportunistic governments can sometimes commit themselves to a broad constitutional or quasi-constitutional arrangement.¹⁰ The solution does not require or allow any intervention to punish a deviating government. Thus, a government cannot use the excuse of punishing a deviation or invoking an escape clause to intervene inappropriately. Furthermore, the solution does not require that the government knows – let alone can *choose* – the preferences of the central bank. It works because society does not know the central bank's type. The government can improve welfare, however, by making a more concerted attempt at appointing hawks or doves, thus changing the public's prior beliefs about the composition of the potential policy maker population.

⁸ To be precise, the committee is *goal* independent in that it can set its own goals. An *instrument* independent committee only has control over the instrument of monetary policy.

⁹ Usually, it is assumed that the society (or the government) can commit to an institutional arrangement (presumably written in a law) but it cannot commit to a policy. Our model is not an exception as we will assume that the society will honor the committee structure and rules governing appointment, reappointment and impeachment of central bankers.

¹⁰ This is discussed in more detail in Buiters and Sibert (2001).

The model is presented in Section II. In Section III, we look at expected inflation when policy is made by a committee. In Section IV, we compare the expected welfare loss under a committee with the expected welfare loss with a zero-inflation rule and with the expected welfare loss produced by discretionary policy making by a single policy maker with the same preferences as society. Section V is the conclusion.

II. THE MODEL

The underlying macroeconomic framework is a variant of the Barro-Gordon (1983b) model. Society's within-period welfare loss is increasing in inflation and decreasing in output. Inflation is disliked because it leads to shoe-leather and menu costs; it makes the domestic currency an inconvenient unit of account; it may redistribute income in a way that is viewed as unfair; and with staggered nominal price contracts it distorts relative prices. Either nominal wage contracting and rational expectations, as in the Barro and Gordon (1983b) model, or a Lucas (1973) expectations view of aggregate supply ensure output is rising in unanticipated inflation.

The loss to society in period t is represented by

$$\frac{\pi_t^2}{2} - \chi(\pi_t - \pi_t^e)\epsilon_t \quad (1)$$

where π_t is period- t inflation, π_t^e is the public's expectation of period- t inflation, conditional on variables dated $t - 1$ and earlier, ϵ_t is an *i.i.d.* shock with density function $f(\epsilon)$ on \mathbb{R}_+ , and $\chi > 0$ is the weight society places on output loss relative to inflation.

As in Barro and Gordon (1983a), the loss function is assumed to be linear in output and can be interpreted as representing social preferences over inflation and unemployment with a standard expectations-augmented Phillips curve.¹¹ This assumption, which is also made by Backus and Driffill (1985) and Cukierman and Meltzer (1986), is necessary for tractability here because it ensures the policy

¹¹ Drazen (2000) provides an extensive discussion of this as well as other loss functions used in this literature.

maker has a dominant strategy in his final period in office and makes first-period expected inflation an important constant in a policy-maker's optimization problem.¹²

The multiplicative, rather than additive, form of the output shock in equation (1) is somewhat unusual.¹³ With a nominal-wage contracting story, it can be viewed as a technological shock. For a Cobb-Douglas production function it is a shock to labor's share of output. In the Lucas (1973) model it is a shock to the slope of the (expectations-augmented) Phillips curve. An example would be a decrease in the volatility of aggregate demand that lowers the variance of the general price level and flattens the Phillips curve. Consistent with the particular specification, we assume that the shock has mean one, implying that the expected slope of the Phillips curve is χ . The interpretation of the multiplicative shock to the slope of the Phillips curve is particularly intuitive because a large shock flattens the curve and, as we show, increases the incentive to inflate. There may be an additive component to the shock as well, but this is not made explicit as it can be treated as a constant in the central bank's optimization problem.

Monetary policy is made by a committee comprised of members with overlapping terms. We find this structure attractive for two reasons. First, it replicates the way monetary policy is actually made in many countries. Second, reputation models with a single policy maker have the empirically unattractive result that inflation tends to be low in the first part of a dove's tenure and high at the end.

Choosing the simplest scenario, we suppose the committee has two members and they serve two periods. We assume that the period is defined by the length of wage contracts, which justifies why expectations of inflation are formed for one period in the future. Policy makers come in two types. Hawks always vote for zero inflation. They can be viewed as mechanistic or as caring solely about inflation. Doves are opportunistic and benevolent, wanting to minimize social welfare loss.¹⁴

¹² The alternative quadratic specification implies booms are disliked as much as recessions. However, it has the attractive feature, missing here, that society dislikes output volatility.

¹³ Both Dixit and Lambertini (1999) and Dixit and Jensen (2000) consider multiplicative shocks. The alternative specification of an additive shock, coupled with quadratic preferences, provides a stabilization role for the central bank. The activist role for monetary policy that is analyzed here is the multiplicative shock analogue of the stabilization role for monetary policy that is more commonly discussed in the literature.

¹⁴ Assuming that some agents are opportunistic, while others are mechanistic, is standard in reputation models. (See, for example, Backus and Driffill (1985)). The presence of hawks gives doves an incentive to build a reputation for inflationary toughness by emulating hawks.

A policy maker's type is his private information and it is common knowledge that a fraction $\rho \in (0, 1)$ of policy makers are hawks.¹⁵

The policy maker taking office at time t is denoted by θ_t . At the beginning of period t , the private sector forms its expectation of inflation, π_t^e , then the shock is observed by all, and then θ_{t-1} and θ_t jointly choose inflation and their individual votes are published.

Suppose a single opportunistic policy maker were to take office at time t . If he held office for only one period, he would minimize social welfare loss. Minimizing equation (1), taking π_t^e as given, he would choose inflation to be $\chi\epsilon_t$. Note that this choice of inflation leads to higher inflation at times when the Phillips curve is flatter and the output gain is higher. If his tenure lasts two periods, then in his second period in office, he would choose inflation to be $\chi\epsilon_{t+1}$. But, in his first period in office he might choose zero inflation to increase the private sector's belief that he might be a hawk. By strengthening this belief, he would increase the benefit of inflating unexpectedly in his second period in office.

If there are two policy makers, then at time t each will vote for inflation of either $\chi\epsilon_t$ or zero.¹⁶ If both prefer the same policy, that policy is implemented. If one policy maker prefers zero and one policy maker prefers $\chi\epsilon_t$, then a compromise inflation rate $\alpha\chi\epsilon_t$ is enacted.¹⁷ We will assume that α is such that the loss for the society is equal to the average of the loss if dove's preferred inflation rate is implemented and the loss if the hawk's choice of zero is chosen. Then, α must satisfy

Alternatively, Vickers (1986) and Sibert (2002) assume that all agents are strategic and care about both inflation and output, but some dislike inflation more than others. They show that relatively inflation-averse types inflate less than they otherwise would to signal they are not less inflation averse. This separating equilibrium does not exist when the most inflation-averse policy maker puts no weight on output as this policy maker then has no incentive to distinguish himself from less inflation-averse policy makers.

¹⁵ It is usual in reputation models to imagine that ρ is small. This need not be the case here. Blinder (1997) suggests that central bankers tend to be inflation averse, saying, "... the noun 'central banker' practically cries out for the adjective 'conservative' (page 14)."

¹⁶ No one can credibly claim they want anything else.

¹⁷ Another possibility would be to have an odd-numbered committee with the median voter's preferred inflation chosen. However, it appears common for monetary policy groups to vote for a consensus view. Blinder (1997, p.16) claims that the United States' FOMC makes decisions by consensus, not by majority rule.

$$\frac{(\alpha\chi\epsilon_t)^2}{2} - \chi(\alpha\chi\epsilon_t - \pi_t^e)\epsilon_t = \frac{1}{2} \left[\frac{\chi^2\epsilon_t^2}{2} - \chi(\chi\epsilon_t - \pi_t^e)\epsilon_t \right] + \frac{1}{2} [\chi\pi_t^e\epsilon_t] \quad (2)$$

Solving yields that the above expressions equal $\chi^2\epsilon_t^2/4 + \chi\pi_t^e\epsilon_t$ and $\alpha = 1 - 1/\sqrt{2} < 1/2$.¹⁸

Consider the scenario in period t . The retiring policy maker votes for zero inflation if he is a hawk and for inflation of $\chi\epsilon_t$ if he is a dove. The new policy maker votes for zero inflation if he is a hawk and solves a two-period problem by backwards recursion if he is a dove.¹⁹ The solution is the probability that he does *not* vote for inflation in period t . We refer to this probability as his strategy and we allow mixed strategies, where the probability is between zero and one. We suppose that doves and the public have the common discount factor $\delta \in (0, 1]$

If the policy maker taking office at t is a dove, he knows he will vote for inflation in period $t + 1$. Expected social welfare loss in $t + 1$ depends on the likelihood θ_{t+1} is a dove and the conjectured probability that θ_{t+1} votes for inflation in period $t + 1$ if he is a dove. Thus, we must specify how θ_t and the private sector believe θ_t 's actions and strategy affect the strategy of θ_{t+1} , if he is a dove.

Following Prescott and Townsend (1980), we restrict attention to equilibria in minimal state or memoryless Markov strategies.²⁰ Thus, we assume that the strategy of a dove who has just taken office is a time-invariant function of the current shock. Our selection of compromise inflation ensures that a junior dove's strategy does not depend on the senior policy maker's type. By equation (1), the current gain to voting for, rather than against, inflation is $(\chi\alpha\epsilon_t)^2/2 - \chi^2\alpha\epsilon_t^2$ if the senior policy maker is a hawk, and $(\chi\epsilon_t)^2/2 - \chi^2\epsilon_t^2 - (\chi\alpha\epsilon_t)^2/2 + \chi^2\alpha\epsilon_t^2$ if he

¹⁸ The assumption that policy makers compromise in this way is admittedly *ad hoc*. The way that the central bank reaches a decision might be written into its constitution and need not be the result of a bargaining process. We chose this value of because it allows us to solve the model and characterize equilibrium strategies. A more realistic model will attempt to build the incentive structure into the model by imposing punishment for failure to agree on the inflation rate. Sibert (2003) examines the effect of varying α .

¹⁹ The policy maker may care about what happens after he leaves office, but he cannot influence inflationary expectations beyond his tenure. Therefore, he solves a two-period problem.

²⁰ The Markov restriction rules out repeated-game equilibria where past strategies influence current play, not because they influence the state of the economy, but solely because players believe that past strategies matter.

is a dove. By equation (2), both these gains equal $-\chi^2 \epsilon_t^2/4$.

Let $\phi^*(\epsilon_{t+1})$ denote the public's and θ_t 's conjectured probability that θ_{t+1} votes for zero inflation if he is a dove. Then, the probability that an *arbitrary* policy maker taking office at time $t+1$ votes for zero inflation at $t+1$ is conjectured to be $y^*(\epsilon_{t+1}) := \rho + (1 - \rho)\phi^*(\epsilon_{t+1})$.

Let p_{t+1} denote the private sector's beginning of period $t + 1$ probability assessment that the policy maker who took office at time t is a hawk. Then, the private sector's expectation of inflation in period $t + 1$ is

$$\begin{aligned} \pi_{t+1}^e &= \pi^e(p_{t+1}) \equiv \\ \chi \int_0^\infty \{ &(1 - p_{t+1})y^*(\epsilon)\alpha + p_{t+1}[1 - y^*(\epsilon)]\alpha + (1 - p_{t+1})[1 - y^*(\epsilon)]\} \epsilon f(\epsilon) d\epsilon = \\ & \chi \int_0^\infty [y^*(\epsilon)\alpha + 1 - y^*(\epsilon)] \epsilon f(\epsilon) d\epsilon - \chi p_{t+1} A^* \end{aligned} \quad (3)$$

where $A^* \equiv 1 - \alpha - (1 - 2\alpha) \int_0^\infty y^*(\epsilon) \epsilon f(\epsilon) d\epsilon$

By equation (3) and the definition of y^* , A^* is decreasing in ρ . An increased belief that θ_t is a hawk increases the likelihood of compromise inflation rather than within-period optimal inflation if θ_{t+1} is a dove, and increases the likelihood of zero inflation rather than compromise inflation if θ_{t+1} is a hawk. Because $\alpha < 1/2$, the former gain exceeds the latter. Thus, an increase in the likelihood that θ_{t+1} is a hawk lowers the value of a gain in reputation.

The private sector updates its beliefs with Bayes' rule. Thus,

$$p_{t+1} = \begin{cases} P(y^*(\epsilon_t)) \equiv \frac{\rho}{y^*(\epsilon_t)} & \text{if } \theta_t \text{ votes for zero inflation at } t, \\ 0 & \text{otherwise.} \end{cases} \quad (4)$$

By equation (4) and the definition of y^* , P is increasing in ρ . If the junior dove votes for inflation, he is revealed to be a dove. If he does not, the public is unsure whether he is a hawk or a dove masquerading as a hawk. The greater the

proportion of hawks, the more likely it considers the former scenario to be. Thus, an increase in ρ makes it easier to gain a reputation for inflationary toughness.

By equation (1) and the Markov restriction, social welfare loss at time $t + 1$ depends on the action of the time- t policy maker solely through π_{t+1}^e . By equation (1), π_{t+1}^e depends on the action of the time- t policy maker solely because it affects p_{t+1} . Thus, if the time- t policy maker is a dove, his loss function can be written as

$$-\frac{\phi_t \chi^2 \epsilon_t^2}{4} + \delta \chi [\phi_t \pi^e (P(y^*(\epsilon_t)) + (1 - \phi_t) \pi^e(0))] \quad (5)$$

where unimportant constants are ignored.

By equation (3), each term in equation (5) is some expression that does not depend on χ multiplied by χ^2 ; hence, χ is an unimportant constant in the optimization problem. The intuition is that an increase in χ raises the cost of lower current inflation and the benefit of higher expected inflation proportionately. Using equations (3) and (4) and eliminating unimportant constants, the opportunistic junior policy maker minimizes

$$\phi_t [\epsilon_t^2 / 4 - \delta P(y^*(\epsilon_t)) A^*] \quad (6)$$

If the junior dove does not vote for inflation, inflation will be further below its within-period optimal level than it would have been had he voted for inflation. The first term in the brackets represents this cost. The second term represents the discounted gain from not voting for inflation. This gain is equal to the increase in reputation (P) multiplied by the value of an enhanced reputation (A^*).

Given conjectures, an increase in δ increases the current benefit to voting against inflation. If the future becomes more important, so does gaining a reputation and the incentive to inflate falls. An increase in ρ , however, has an ambiguous effect. It increases P and lowers A^* .

Equation (6) is linear in ϕ_t ; hence a solution has

$$\epsilon_t^2 - 4\delta P(y^*(\epsilon_t)) A^* \begin{cases} > \\ = \\ < \end{cases} 0 \text{ and } y \begin{cases} = \rho \\ \in [\rho, 1] \\ = 1 \end{cases} \quad (7)$$

If the current cost to zero inflation exceeds the expected future benefit, then junior doves never vote for zero inflation. If the expected future benefit exceeds

the current cost, then they always do. If the cost equals the benefit, then junior doves are indifferent over randomization between inflating and not inflating.

Consistency requires conjectures to be correct. The Markov restriction implies strategies are not time-varying. Thus $\phi_t = \phi^*(\epsilon_t) = \phi(\epsilon_t)$ and $y_t = y^*(\epsilon_t) = y(\epsilon_t)$ where $y(\epsilon_t) = \rho + (1 - \rho)\phi(\epsilon_t)$ for every t . Substituting equation (4) into equation (7) and using the definition of A^* from equation (3) yields that an equilibrium must satisfy

$$\epsilon_t^2 y(\epsilon_t) - 4\delta\rho \left[1 - \alpha - (1 - 2\alpha) \int_0^\infty y(\epsilon)\epsilon f(\epsilon)d\epsilon \right] \begin{cases} > \\ = \\ < \end{cases} 0 \text{ and } y(\epsilon_t) \begin{cases} = \rho \\ \in [\rho, 1] \\ = 1 \end{cases} \quad (8)$$

The left-hand side of equation (8) is continuous in the shock and is strictly negative at $\epsilon_t = 0$. Thus, there exists a right-hand-side neighborhood of zero such that doves never vote for inflation if the shock is in that interval. If the shock is sufficiently large, junior doves always vote for inflation. Thus, solving equation (8) requires finding two cutoff values of ϵ_t . If ϵ_t is below the lower cutoff value, $y(\epsilon_t) = 1$ and junior policy makers never vote for inflation. If ϵ_t is above the higher cutoff value, $y(\epsilon_t) = \rho$ and hawks never vote for inflation, while doves always do. If ϵ_t is between the two cutoff values, then $y(\epsilon_t)$ is a function of ϵ_t that takes values on $(\rho, 1)$.

The second term of equation (8) does not depend on the realization of the shock. Thus, when (8) holds with equality, the realization of the shock cannot affect the first term either. Thus, between the two cutoff values, $y(\epsilon_t)$ must take the form c/ϵ_t^2 , where c is a strictly positive constant. Then, by equation (8), the lower cutoff value is the ϵ_t that satisfies $c/\epsilon_t^2 = 1$ and the higher cutoff value is the ϵ_t that satisfies $c/\epsilon_t^2 = \rho$. Thus, the two cutoff values are \sqrt{c} and $\sqrt{c/\rho}$ and

$$y(\epsilon_t) = \begin{cases} \rho & \text{if } \epsilon_t > \sqrt{c/\rho} \\ c/\epsilon_t^2 & \text{if } \sqrt{c} < \epsilon_t < \sqrt{c/\rho} \\ 1 & \text{if } \epsilon_t < \sqrt{c} \end{cases} \quad (9)$$

Substituting equation (9) into equation (8) when equality holds yields

$$c = 4\delta\rho(1 - \alpha) - 4\delta\rho(1 - 2\alpha)H(c, \rho) \quad (10)$$

$$\text{where } H(c, \rho) := \int_0^{\sqrt{c}} \epsilon f(\epsilon) d\epsilon + c \int_{\sqrt{c}}^{\sqrt{c/\rho}} \frac{f(\epsilon)}{\epsilon} d\epsilon + \rho \int_{\sqrt{c/\rho}}^{\infty} \epsilon f(\epsilon) d\epsilon \in (\rho, 1)$$

Definition 1. *An equilibrium is a strictly positive constant c such that equation (10) is satisfied.*

Proposition 1. *There exists an unique equilibrium c and it satisfies*

$$4\alpha\delta\rho < c < 4\delta\rho(1 - \alpha - \rho(1 - 2\alpha))$$

Proof. *See the Appendix.*

For small values of the shock, there is a pooling equilibrium where no junior policy maker votes for inflation. For large values of the shock, there is a separating equilibrium where hawks never vote for inflation and doves always do. For intermediate values of the shock, there is a semi-separating equilibrium where junior doves randomize between voting for and voting against inflation.

The proposition establishes that the equilibrium is unique. The indeterminacy associated with escape-clause models (see Obstfeld (1991)) does not arise here.

III. INFLATION

In this section we show how equilibrium inflation varies with model's parameters. We demonstrate that expected inflation (conditional on the shock) is a nonlinear function of the shock. Committees react more to large shocks than they do to small ones.

How do changes in the parameters δ and ρ affect the likelihood a junior dove or an arbitrary policy maker votes for zero inflation?

Proposition 2. *An increase in δ increases the likelihood that either a junior dove or an arbitrary policy maker votes for zero inflation. For every $\delta \in (0, 1)$ there exists $\rho^* \in (0, 1)$ such that an increase in ρ increases (decreases) the likelihood an arbitrary policy maker votes for zero inflation if $\rho < (>) \rho^*$. For δ sufficiently small, $\rho^* < 1$*

Proof. *See the Appendix.*

An increase in δ has no effect on hawks. It increases c ; hence, it strictly increases the likelihood a junior dove votes for zero inflation in the interval of shocks where doves randomize. It also increases the two cutoff points, enlarging the interval of shocks where junior doves always vote for zero inflation and shrinking the interval where they never do. The intuition is that if the future is more important, gaining a reputation is more valuable.

As previously discussed, a rise in ρ makes gaining a reputation for inflationary toughness easier, but it lowers the value of having a reputation. Thus, the effect of ρ on the likelihood either a junior dove or even an arbitrary junior policy maker votes for inflation is ambiguous.

By equation (9), expected inflation given that the current shock is ϵ_t is

$$\begin{aligned} & \{(1 - \rho)y(\epsilon_t)\alpha + \rho[1 - y(\epsilon_t)]\alpha + (1 - \rho)[1 - y(\epsilon_t)]\}\chi\epsilon_t \\ = & \begin{cases} (1 - \rho)(2\rho\alpha + 1 - \rho)\chi\epsilon_t & \text{if } \epsilon_t \geq \sqrt{c/\rho} \\ \{(1 - \rho + \rho\alpha)\epsilon_t - [\rho\alpha + (1 - \rho)(1 - \alpha)]c/\epsilon_t\}\chi & \text{if } \sqrt{c} < \epsilon_t < \sqrt{c/\rho} \\ (1 - \rho)\alpha\chi\epsilon_t & \text{if } \epsilon_t < \sqrt{c} \end{cases} \quad (11) \end{aligned}$$

The expected inflation curve is continuous in the shock with kinks at the cutoff values of the shocks, \sqrt{c} and $\sqrt{c/\rho}$. Above the higher cutoff value and below the lower cutoff value, expected inflation rises linearly in the shock. The slope is higher for shocks above $\sqrt{c/\rho}$ than for shocks below \sqrt{c} . It is important to stress that in both cases it is lower than χ , the value of the slope under discretion. Between the two cutoff points, inflation rises at a decreasing rate that is always greater than the slope of the curve below \sqrt{c} . Figure 1 illustrates the relationship between inflation and the underlying shocks. The particular curve is drawn for $\chi = 1, \rho = .3, \delta = .8$ and a mean-one lognormal density function.

[Insert Figure 1 here]

So far we have established the link between expected inflation and the model's key parameters under the assumption that we observe the value of the current shock. But to evaluate the advantages of having a committee, we need to establish the dependence of the unconditional expectation of inflation on the underlying structural characteristics of the economy.

By equations (10) and (11), unconditional expected inflation is:

$$E(\pi_t) = \chi \{1 - \rho + \rho\alpha - [\rho\alpha + (1 - \rho)(1 - \alpha)]H(c, \rho)\} \quad (12)$$

The following result establishes that expected inflation is decreasing in both δ and ρ .

Proposition 3. *An increase in either δ or ρ lowers unconditional expected inflation.*

Proof. *See the Appendix.*

An obvious consequence of Proposition 3 is that as more weight is put on the future, the lower is inflation. While an increase in ρ may lower expected inflation for some values of ϵ if ρ is close enough to one, an increase in ρ always lowers unconditional expected inflation.

IV. WELFARE

In this section, we examine the welfare implications of having inflation chosen by a committee. We compare the expected welfare loss with that under a zero-inflation rule and with an opportunistic central banker making policy at his discretion.

The social (command) optimum would be achieved if inflation were set equal to $\chi\epsilon_t - \chi$ in period t . In this case expected inflation equals zero and the central bank responds optimally to the shocks. Unfortunately, central bankers cannot commit themselves to doing this and it is unlikely that the government can credibly impose a state-contingent inflation rule on the central bank.²¹ If society could appoint a completely conservative central banker (a hawk) or credibly impose a zero-inflation rule, then the expected welfare loss in any period would be zero.

If the policy maker were a dove and society did not impose a zero-inflation rule, then inflation in period t would be $\chi\epsilon_t$ and the expected welfare loss would be $\chi^2(1 - \sigma^2)/2$, where σ^2 is the variance of the shock. As long as this variance is less than one, it would be better if society could appoint a hawk or follow a zero inflation rule. If society could pick a central banker with preference parameter

²¹ In the real world the shock would be an element of a high dimensional space. Realizations of such shocks will be difficult to verify and it will be impossible to list all possible realizations and the optimal response to them.

χ^* , then the expected social welfare loss would be $\chi^{*2}(1 + \sigma^2)/2 - \chi\chi^*\sigma^2$. The optimal choice of χ^* is $\chi\sigma^2/(1 + \sigma^2)$. It is optimal to appoint a central banker who is more conservative than society, but not so conservative as to place no weight on output. This is Rogoff's (1985) result.

Suppose monetary policy is the discretionary choice of a dove. The expected welfare loss can be written as $\int_0^\infty \chi^2(\epsilon - \epsilon^2/2)f(\epsilon)d\epsilon$. The integrand is positive for small shocks, but it is decreasing at an increasing rate and becomes negative if $\epsilon > 2$. This suggests that a regime mandating zero inflation for low shocks, but allowing discretion for large shocks would be better than either a rule or discretion. This is a rationale for the escape clauses in central banking legislation and the intuition behind Lohmann's (1992) proposal.

Figure 2 (which is drawn for $\chi = 1, \rho = .3, \delta = .8$ and a lognormal density function), depicts optimal inflation, discretionary inflation, inflation with Rogoff's optimally conservative central banker, and (conditional) expected inflation with a committee. From the above discussion and the figure, it is clear that the committee is somewhat similar to Rogoff's conservative central banker solution. By having both hawks and doves on the committee, the committee is more conservative than society, but not completely conservative. It also looks somewhat like a rule with an escape clause (not shown). Because strategic doves are more willing to sacrifice their reputations for big shocks than for small shocks, committees are more likely to inflate when faced with big shocks than with small shocks. This suggests that committees may share some of the welfare-enhancing qualities of both Rogoff's conservative central banker and a rule with an escape clause.

[Insert Figure 2 here]

It is possible to obtain simple analytical results relating the welfare with a committee to welfare with a zero-inflation rule and welfare with (opportunistic) discretionary policy making. Using equation (1) and the definition of α , the expected welfare loss with a committee is

$$-\frac{\chi^2}{4} \int_0^\infty \{\rho[1 - y(\epsilon)] + (1 - \rho)y(\epsilon) + 2(1 - \rho)[1 - y(\epsilon)]\} \epsilon^2 f(\epsilon) d\epsilon + \chi E(\pi_t) \quad (13)$$

By equation (9), this equals

$$-\frac{\chi^2}{4} [(2 - \rho)(\sigma^2 + 1) - G(c, \rho)] + \chi E(\pi_t) \quad (14)$$

$$\text{where } G(c, \rho) \equiv \int_0^{\sqrt{c}} \epsilon^2 f(\epsilon) d\epsilon + c \int_{\sqrt{c}}^{\sqrt{c/\rho}} f(\epsilon) d\epsilon + \rho \int_{\sqrt{c/\rho}}^{\infty} \epsilon^2 f(\epsilon) d\epsilon$$

and σ^2 is the variance of the shock.

Proposition 4. *If $\sigma^2 > 2\alpha^2$, then there exists a $\rho^* \in (0, 1)$ such that committees are better than a zero-inflation rule if $\rho > \rho^*$.²²*

Proof. *See the Appendix.*

Proposition 5. *If $\sigma^2 < 2(1 - \alpha^2)$, then there exists a $\rho^* \in (0, 1)$ such that committees are better than discretionary policy making by a dove if $\rho < \rho^*$.²³*

Proof. *See the Appendix.*

Propositions 4 and 5 are in the spirit of Rogoff's (1985) result. If all potential policy makers are hawks ($\rho = 1$), the outcome is zero inflation, but no response to shocks. If all potential policy makers are doves ($\rho = 0$), the outcome is an optimal response to shocks, but too high inflation. By increasing the ratio of hawks to doves in composition of the policy maker population, society can attain lower inflation at the cost of less activism. As long as the variance of the shock is not very small, some doves are better than none. Thus, a committee is better than a zero-inflation rule as long as ρ is not too small. If the variance of the shock is not too big, some hawks are better than none. A committee is better than discretionary policy making by a dove if ρ is not too big.

Over a wide range of variances, a committee can be better than either a rule or discretion, as long as the government has sufficient control over ρ . While it is unlikely that the government can reliably pick the preferences of a policy maker, it can easily affect the makeup of the potential policy maker population. It can, for example, appoint people from the financial sector in an attempt to get hawks or representatives from the manufacturing sector in an attempt to get doves. To a certain degree this argument makes ρ endogenous. It is, however, possible and realistic to argue that the sectors from which central bankers are

²² $2\alpha^2$ is approximately equal to 0.17.

²³ $2(1 - \alpha^2)$ is approximately equal to 1.83.

to be drawn is specified in the laws defining the institution. These laws change infrequently and are not subject to the commitment problems that we analyze in our paper.²⁴ This argument resembles the justification given by Faust (1996) for the current structure of the Federal Open Market Committee. Namely, at the time of appointment, which is the relevant time for our solution, ρ is already determined by the banking laws, and it cannot be affected by those who make the appointment. Alternatively, one can interpret our results as saying that in a cross-section of countries, those countries that have more hawks and committee structure will have lower inflation. One potential measure of the proportion of hawks in the population is the strength of the financial sector (see Posen, 1995).

The above results give *sufficient* conditions for a committee to dominate rules and discretion. An important aspect of reputation building was not exploited in the proofs, however. As noted above, when a dove makes policy at his discretion, the loss in any period decreases at an increasing rate in the size of the shock. When deciding between the benefits of current inflation or an enhanced reputation as a hawk, a junior dove is more likely to pick the former when shocks are large. Thus he is flexible, preferring price stability when shocks are small and activism when shocks are large.

To capture this feature, and evaluate the benefits of a committee more precisely, it appears necessary to specify the distribution function of the shocks and to solve the model numerically. We assume that the shock is lognormally distributed.²⁵ The expected welfare loss relative to that of a zero-inflation rule, discretion, and a single policy-maker subject to the same informational asymmetry as the committee is shown in Figures 3 – 5 for different variances of the shock. We compute the losses for $\delta = 0.0, 0.6, 0.8$ and 1.0 and for the entire range of ρ (evaluated at intervals of $.05$).²⁶

Figure 3 depicts the case where the variance of the shock, σ^2 , equals one. This is the knife-edge case where the expected welfare loss is the same for both the rule and discretion. It is seen that the committee does better than either a rule or discretion for δ equal to $0.6, 0.8, 1.0$, no matter what the ratio of hawks to

²⁴ We do abstract from the issue of how governments can commit to institutions and not to policies. This assumption is made implicitly in most of the papers in this literature. See Bullard and Waller (2004) for a recent example.

²⁵ The experiments were replicated with the assumption of a gamma distribution with little change in the results.

²⁶ The integrals in H and G were solved with a 16-point Gauss-Legendre quadrature rule.

doves is. The optimal policy maker population for these values of δ has between 25 and 35 percent hawks.

We can also compare the expected welfare loss with a committee with the expected welfare loss produced by a single policy maker of unknown type serving for two periods. To reduce clutter, Figure 3 shows the expected welfare loss for the latter case only for $\delta = 0.8$. The graph clearly shows that the expected welfare loss with a single policy-maker is greater than the loss with a committee for all values of ρ . This is a consequence of the smoother inflation produced by the committee.

[Insert Figure 3 here]

Figure 3 also shows the case of $\delta = 0$. This corresponds to a committee of hawks and doves where there is no reputation building on the part of doves. We include this to illustrate an important mechanism of the model. Having both hawks and doves in the policy maker population allows society to trade off low inflation and activism in a similar fashion to Rogoff's (1985) conservative banker. However, reputation-building confers an additional advantage by making the junior doves more apt to inflate when shocks are large than when they are small.

[Insert Figure 4 here]

Figure 4 depicts the case where $\sigma^2 = 0.5$. In this case a zero-inflation rule is better than discretion, and so is the committee, for every possible composition of the policy-makers' population. For the plausible case of $\delta \geq 0.6$ the committee does better than the rule as long as at least thirty-five percent of the candidate policy makers are hawks. When $\delta = 1.0$, the committee is better as long as at least about a fourth of the policy makers are hawks. The main reason for the welfare ranking in this case is that with small shocks activism has little value. It is rare that the tradeoff between inflation and output is very favorable and therefore sticking to zero inflation is usually superior. Again, the committee produces a better outcome than a single policy-maker of unknown type.

[Insert Figure 5 here]

Figure 5 depicts the case where $\sigma^2 = 1.5$ and both discretion and a committee are preferred to a rule. In this case, for $\delta \geq 0.6$, the committee is better than discretion as long as at least about forty percent of the policy maker population is made up of doves. The volatility of the economy is such that active monetary policy is often needed to generate higher welfare. Therefore, if the committee

has too many hawks, it might be inferior to a purely discretionary policy maker. Figures 4 and 5 suggest that countries that have a volatile Philips curve slope are better off with a relatively high fraction of doves in their potential policy maker population; countries with a more stable Philips curve slope are better off with a relatively low fraction of doves in their potential policy maker population.

[Insert Figure 6 here]

[Insert Figure 7 here]

Figures 6 and 7 give the range of policy maker populations such that committees dominate rules and discretion for different values of σ^2 . Figure 6 depicts the minimum fraction of hawks in the policy maker population for a committee to be as good as a rule for variances less than one. It is seen that this minimum fraction rises as the variance falls, but that even as the variance becomes close to one, there is some composition of the policy maker population that makes a committee better than a rule. Figure 7 depicts the maximum fraction of hawks in the policy maker population for a committee to be better than discretion for variances greater than one. This maximum fraction falls as the variances rises and even for very large variances, a committee is better than discretion for some types of policy maker populations.

We do not compare the expected welfare achieved by an independent committee with that produced by either Rogoff's (1985) conservative central banker or Lohmann's (1992) escape-clause mechanism. There are two reasons for this. First, the economic environments are not comparable. Rogoff and Lohmann allow for a continuum of policy maker types and no uncertainty about these types. We allow for only two types of central bankers and these types are the policy makers' private information. Second, we do not claim that our solution produces higher expected welfare than Rogoff's or Lohmann's. Rather, we claim that the strong welfare results associated with their solutions require an unrealistic ability of the government to precisely pick the central banker's preferences and, in the case of Lohmann's model, an unrealistic ability of the government to commit itself to *policy* intervention in abnormal times and to not intervening in normal times. We view our solution as a regime that endogenously replicates some of the desirable features of Rogoff's and Lohmann's models and is at the same time realistically possible to implement.

V. CONCLUSION

If central bankers' types are unknown, this paper suggests that an independent monetary policy committee is – for a wide range of parameters – better than either a zero-inflation rule or a discretionary policy making by an opportunistic central banker. This arrangement requires only limited credibility on the part of the government. The government need not monitor the committee or attempt to influence its behavior.

The welfare result is obtained for three reasons. First, if candidate central bankers can be inflation hawks or inflation doves, then a typical committee will be more conservative than society and this, by itself, will improve welfare. Second, committees of policy makers of unknown types produce smoother inflation than does a single policy maker of unknown type. Third, less conservative central bankers have an incentive to masquerade as more conservative central bankers in their first term in office. Their desire to gain a reputation for inflationary toughness causes them to vote for zero inflation as long shocks are small. However, in the face of a sufficiently large shock, the reputational gain will not be worth the cost of lost output. Thus, the central bank will tend to have low inflation in normal times, but will respond to large shocks.

There are many features of the decision-making process in monetary policy committees that our model does not capture — internal group dynamics, the building up of consensus in the process of debating, or the use of personal 'credibility' capital within the committee to insist on one action or another. A recent paper by Gerling et al. (2003) provides an excellent survey of many topics related to information acquisition and decision making in committees, which we do not cover in this paper. Similarly, on the basis of experimental analysis Blinder and Morgan (2000) argue that groups solve problems better than individuals. In addition, in our future research we plan to link our model to the process of appointment and reappointment of central bankers in the spirit of Waller (1992). To this end we have to allow for the type of policy makers to vary continuously between the two extremes – doves and hawks, so that we can investigate how partisan politics affect the type that is appointed at different times of the ruling party's tenure. Our current model does not have the machinery to analyze why committees are superior to single policy makers in data-processing and it does not discuss how to design committees when information acquisition is costly or unobservable or how to design committees given the political landscape in the

country. However, the model does describe a powerful and realistic mechanism — the willingness to forego reputation-building at times when it is costly while fighting inflation as a hawk when the economic environment is relatively stable.

VI. APPENDIX

Proof of Proposition 1. By Liebnitz's rule, $\partial H/\partial c = \int_{\sqrt{c}}^{\sqrt{c/\rho}} f(\epsilon)/\epsilon d\epsilon > 0$. (The terms involving derivatives of the limits of integration cancel out.) Hence, the right-hand side of equation (10) is strictly decreasing in c . As $c \rightarrow 0$, $H \rightarrow \rho$ and the right-hand side of equation (10) goes to $4\delta\rho[(1-\alpha) - \rho(1-\alpha)] > 4\delta\rho\alpha > 0$. As $c \rightarrow \infty$, $H \rightarrow 1$ and the right-hand side of equation (10) goes to $4\delta\rho\alpha$. The left-hand side of equation (10) is strictly positive and strictly increasing on \mathbb{R}_+ ; hence, equation (10) has a unique solution contained in $(4\alpha\delta\rho, 4\delta\rho(1-\alpha - \rho(1-2\alpha)))$

Proof of Proposition 2. By equation (10),

$$\frac{\partial c}{\partial \delta} = \frac{c/\delta}{1 + 4\delta\rho(1-2\alpha)\partial H/\partial c} \tag{15}$$

The result in the proof of proposition 1 ensures this is strictly positive. By equation (10) and the result in the proof of proposition 1, $dc/d\rho > 0$ iff

$$H + \rho \int_{\sqrt{c/\rho}}^{\infty} \epsilon f(\epsilon) d\epsilon < \frac{1-\alpha}{1-2\alpha} \tag{16}$$

The left-hand side of (16) is strictly increasing in ρ . As $\rho \rightarrow 0$, $c \rightarrow 0$ and thus, $H \rightarrow 0$. Hence, (16) holds. This implies that for every δ , there exists $\rho^* \in (0, 1]$ such that $dc/d\rho > (<)0$ as $\rho < (>)\rho^*$. As $\rho \rightarrow 1$, $H \rightarrow 1$, and thus $c \rightarrow 4\delta\alpha$. Thus, we must have $\int_{2\sqrt{\delta\alpha}}^{\infty} \epsilon f(\epsilon) d\epsilon < \alpha/(1-2\alpha) < 1$ for equation (16) to hold as $\rho \rightarrow 1$. This is not true if δ is sufficiently small. This implies that for δ sufficiently small, $\rho^* < 1$.

Proof of Proposition 3. The effect of δ is obvious. By (12), $E(\pi_t)$ is decreasing in ρ iff

$$1 - \alpha - (1 - 2\alpha)H + [\rho\alpha + (1 - \rho)(1 - \alpha)]dH/d\rho > 0 \tag{17}$$

$H \in (0, 1)$; hence this is true if $dH/d\rho > 0$

By (10),

$$\frac{dH}{d\rho} = \frac{\partial H}{\partial c} \frac{\partial c}{\partial \rho} + \frac{\partial H}{\partial \rho} = \frac{\frac{c}{\rho} \frac{\partial H}{\partial c} + \frac{\partial H}{\partial \rho}}{1 + 4\delta\rho(1 - 2\alpha) \frac{\partial H}{\partial c}} > 0 \quad (18)$$

Proof of Proposition 4. If $\rho \rightarrow 1$, then by (10), $H \rightarrow 1$ and $c \rightarrow 4\delta\alpha$. By (12), $E(\pi_t) \rightarrow 0$. By (14), $G \rightarrow 1 + \sigma^2$. Hence, by (14), the expected welfare loss goes to zero — the loss associated with the rule. By (10), (12) and (14), the expected welfare loss is increasing in ρ iff

$$\frac{1}{4} \left\{ \sigma^2 + 1 + \frac{\partial c}{\partial \rho} \int_{\sqrt{c}}^{\sqrt{c/\rho}} f(\epsilon) d\epsilon + \int_{\sqrt{c/\rho}}^{\infty} \epsilon^2 f(\epsilon) d\epsilon \right\} -$$

$$1 - \alpha - (1 - 2\alpha)H + [\rho\alpha + (1 - \rho)(1 - \alpha)] \left[\frac{\partial c}{\partial \rho} \int_{\sqrt{c}}^{\sqrt{c/\rho}} \frac{f(\epsilon)}{\epsilon} d\epsilon + \int_{\sqrt{c/\rho}}^{\infty} \epsilon f(\epsilon) d\epsilon \right] > 0 \quad (19)$$

By (10) and (14),

$$\frac{\partial c}{\partial \rho} = \frac{\frac{c}{\rho} - 4\delta\rho(1 - 2\alpha) \int_{\sqrt{c/\rho}}^{\infty} \epsilon f(\epsilon) d\epsilon}{1 + 4\delta\rho(1 - 2\alpha) \int_{\sqrt{c}}^{\sqrt{c/\rho}} \frac{f(\epsilon)}{\epsilon} d\epsilon} \quad (20)$$

As $\rho \rightarrow 1$, $\partial c/\partial \rho$ remains finite; hence, the loss is strictly increasing as $\rho \rightarrow 1$ if

$$\sigma^2 + 1 + \int_{\sqrt{4\delta\alpha}}^{\infty} \epsilon^2 f(\epsilon) d\epsilon - 4\alpha \left(1 + \int_{\sqrt{4\delta\alpha}}^{\infty} \epsilon f(\epsilon) d\epsilon \right) > 0 \quad (21)$$

The left-hand side of (21) is increasing in δ , hence this is true if: $2(\sigma^2 + 1) - 8\alpha > 0$. By $4\alpha - 1 = 2\alpha^2$ and a continuity argument, the result is true.

Proof of Proposition 5. By (10), as $\rho \rightarrow 0$, H and c go to zero and $c/\rho \rightarrow 4(1 - \alpha)\delta =: s$. By (20), $\partial c/\partial \rho \rightarrow s$. Hence, by (19), the expected welfare loss is decreasing in ρ as $\rho \rightarrow 0$ iff

$$\sigma^2 + 1 + s \int_0^{\sqrt{s}} f(\epsilon) d\epsilon + \int_{\sqrt{s}}^{\infty} \epsilon^2 f(\epsilon) d\epsilon - 4(1 - \alpha) \left[1 + s \int_0^{\sqrt{s}} \frac{f(\epsilon)}{\epsilon} d\epsilon + \int_{\sqrt{s}}^{\infty} \epsilon f(\epsilon) d\epsilon \right] < 0 \quad (22)$$

This is true iff

$$2(\sigma^2 + 1) - 8(1 - \alpha) + \int_0^{\sqrt{s}} \left[\epsilon - 4(1 - \alpha) \right] \frac{s - \epsilon^2}{\epsilon} f(\epsilon) d\epsilon < 0 \quad (23)$$

The integral in (23) is strictly negative, hence (23) is true if $\sigma^2 + 1 < 4(1 - \alpha)$. By the definition of α , this is true if $\sigma^2 < 2(1 - \alpha)$.

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Figure 1: Conditional Expected Inflation
 ($\rho=0.3; \delta=0.8; \chi=1$)

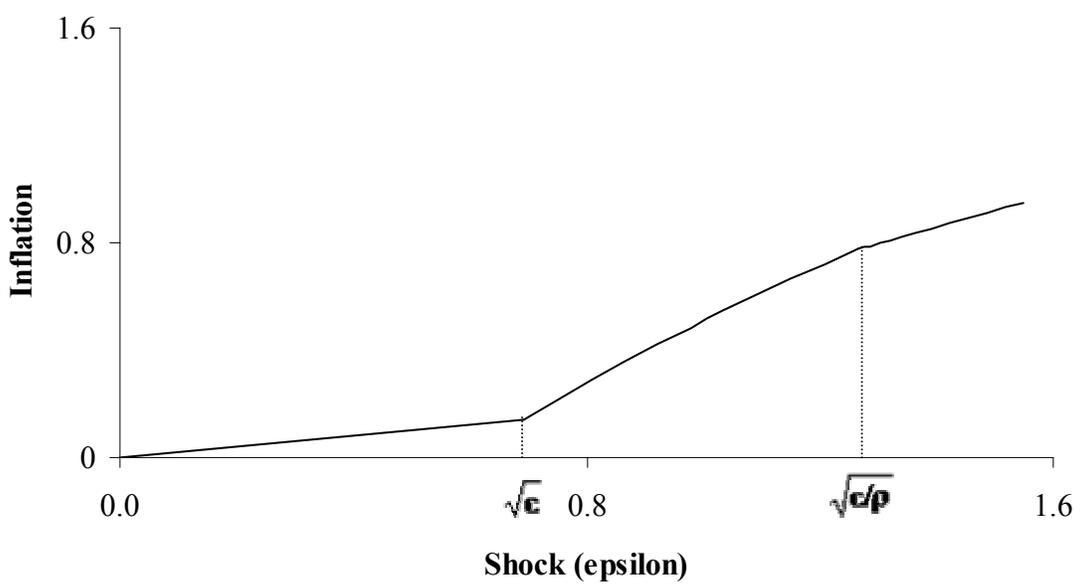


Figure 2: Inflation under Various Regimes
 ($\rho=0.3; \delta=0.8; \chi=1; \sigma=1$)

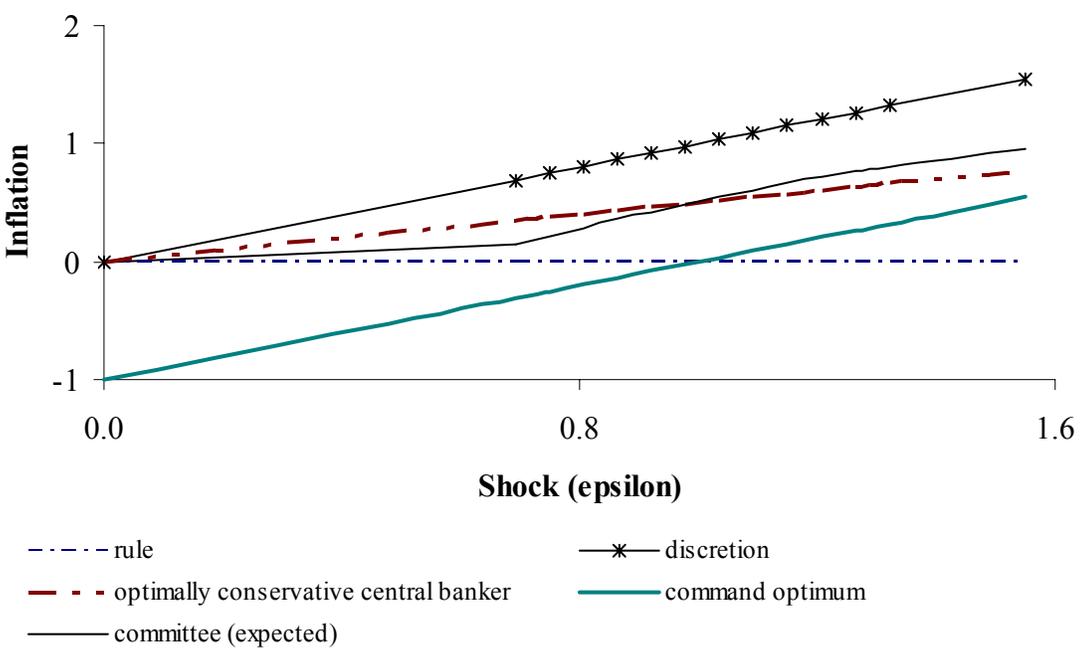


Figure 5: Welfare Loss When Shocks Have Variance = 1.5

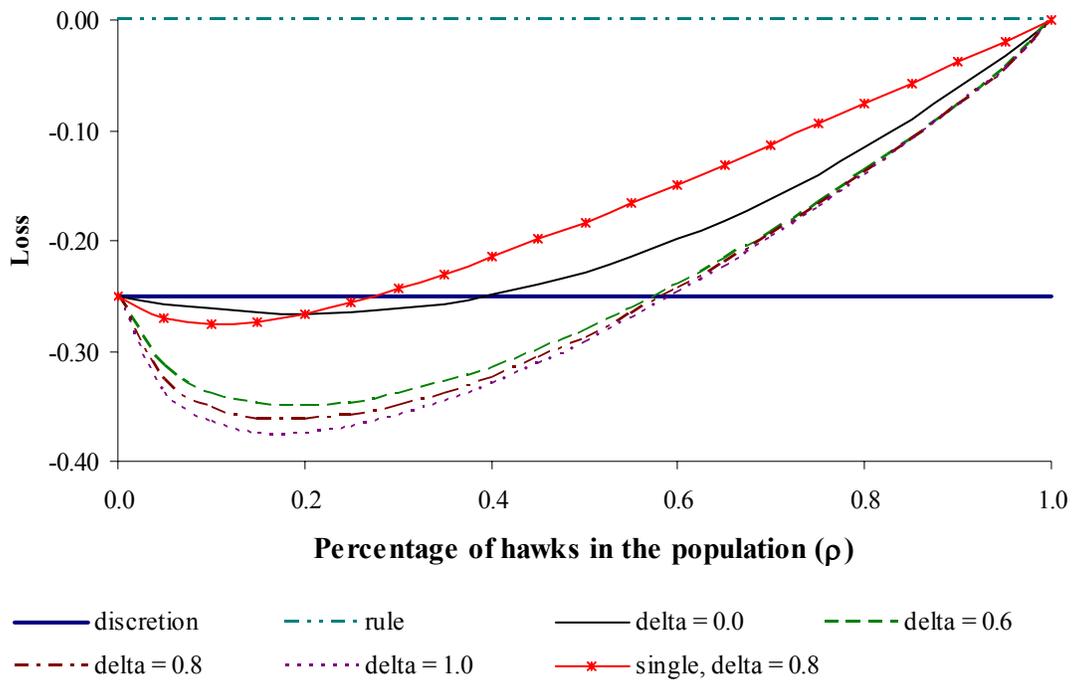


Figure 6: Minimum Fraction of Hawks for a Committee To Be at Least As Good As a Rule

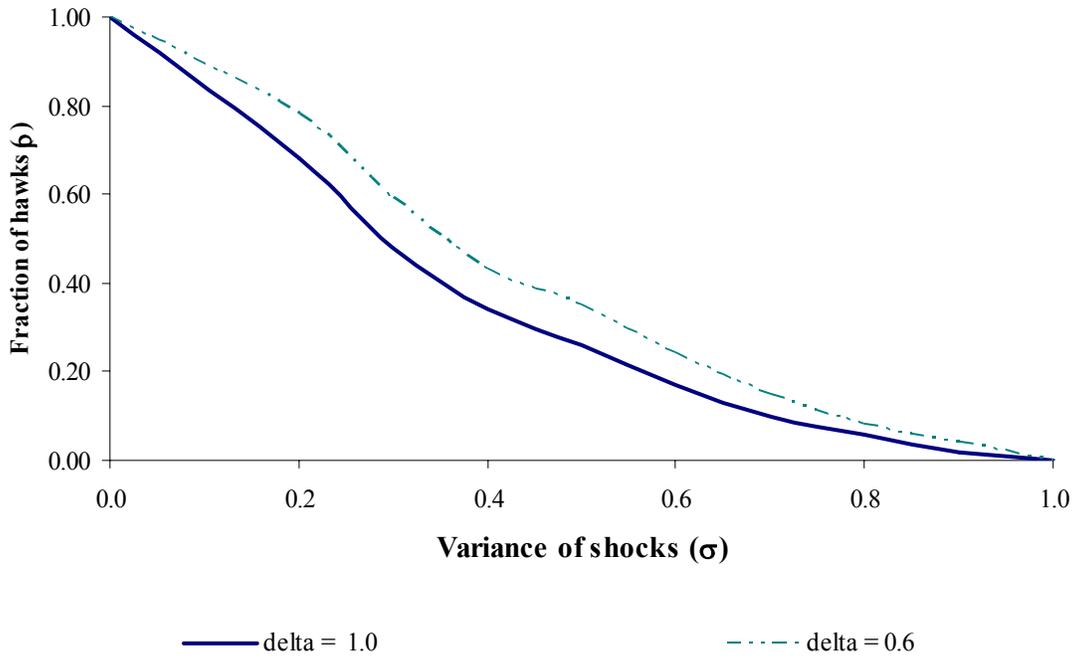


Figure 7: Maximum Fraction of Hawks for a Committee To Be at Least As Good As Discretion

