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Abstract

Approaching monetary policy as a principal agent problem provides a useful framework for interpreting alternative delegation schemes. In this paper, we consider the effectiveness of central banker incentive schemes when the principal delegates monetary policy through contracts but remains uncertain about the central bankers responsiveness to such schemes. We adopt a simple principal-agent model and assume that the central bankers trade-off between social welfare and the incentive scheme is private information. We consider two types of central bankers; one who responds to the incentive scheme (selfish) and one who does not and only cares about social welfare (benevolent). We demonstrate that when a benevolent central banker accepts a contract designed for a selfish central banker, positive inflation surprises occur and output exceeds its natural rate. We further show that a benevolent central banker with an inflation bias has an incentive to masquerade as selfish. Mechanisms exist that solve that problem by achieving preference revelation. We consider a simple mechanism in dominant strategies that induces the benevolent type either not to breach or not to accept the appointment (contract) in the first place. This multi-period mechanism works with either inflation targets, or the appointment of a conservative central banker. Our results suggest that more complicated incentive schemes, embedded within broader constitutional arrangements, are required in the presence of private information for them to work effectively.

Journal of Economic Literature Classification: E42, E52, E58

1. Introduction and Motivation

Recent research on monetary policy making has grown dramatically. In addition to considering how monetary policy affects the economy, analysts now dissect the monetary policy decision-making process. That is, the central bankers' decision becomes endogenous. Monetary policymakers act not only subject to the constraints implied by the structure of the economy, but also to "incentive constraints" that relate to both credibility and political problems (e.g., Persson and Tabellini 1994).

Much work attempts to mitigate the time-inconsistency problem of monetary policy. A part of this literature examines reputational effects in repeated games (e.g., Barro 1986). Others suggest the appointment of a conservative central banker who places more weight on price stability than society (Rogoff 1985). And still others propose inflation targets to affect the inflation bias in the objective function of the central banker (e.g., Svensson 1997). Assigning the central banker with an excessively low inflation target induces the choice of the optimal one, once the inflation bias works its effect. More recently, researchers consider central banker's incentive schemes. One institutional approach considers monetary policy delegation in the context of a principal-agent framework (Persson and Tabellini 1993, Walsh 1995a,), shifting from exogenous preferences to incentives. That is, regardless of the central banker's preferences, a set of incentives exists that can deliver the optimal results (i.e., the policy outcomes that are equivalent to those under precommitment).

The literature on central banker contracts shows that the government can delegate monetary policy in an explicit principal-agent framework to deliver policy outcomes equivalent to those under credible commitment. Typically, an efficient punishment (transfer) mechanism exists that neutralizes the policymaker's tendency to produce high inflation, by raising the marginal costs of such actions. Furthermore, when considering alternative institutional designs, monetary policy delegation schemes that incorporate a combination of contracts with either conservative central bankers or inflation targets perform strictly better than each of them in isolation (e.g., Beetsma and Jensen 1998, Muscatelli 1998 and 1999, Schaling et al. 1998).

In addition, central banker contracts can provide an efficient mechanism that allows competent governments to signal their types cheaply and avoid political business (monetary) cycles (al-Nowaihi and Levine, 1998). A central banker contract combined with the appropriate central banker type can also form the optimal policy design when a monopoly union sets the nominal wage rate rather than atomistic wage setters (Lawler, 2000). Finally, optimal central banker contracts can secure optimal cooperative policies for the problem of international monetary policy coordination (Jensen, 2000).

Why do we not often observe explicit optimal central banker contracts as equilibrium outcomes in practice? One response is that specifying a feasible contract is complicated. Indeed, the relevant literature typically shows that an optimal contract exists; it does not describe how this contract is operationalized. As its main advantage, the principal-agent approach, however, provides a theoretically consistent framework for thinking about monetary policy delegation. After all, a number of central banks recently adopted inflation targeting,[1] and theoretical research shows that inflation targeting and central banker contracts are equivalent (e.g., Svensson, 1997 and Jonsson, 1997).[2]

Weaknesses of contracts include the possibility of renegotiations (McCallum 1995, 1997, and Jensen 1997), uncertain preferences between inflation and output stabilization (e.g., Beetsma and Jensen 1998, Muscatelli 1998 and 1999, Schaling et al. 1998), incomplete agency structure (Chortareas and Miller, 2002), and common agency problems (Chortareas and Miller, 2000).

While the initial work on optimal central banker contracts assumes full information (e.g., Walsh 1995a and Persson and Tabellini 1993), subsequent research identifies various dimensions of asymmetric information, where the central banker or private sector possess private information.[3] We only consider the situation where the central banker possesses private information. Typically private (incomplete)

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[1] Central banks that have adopted explicit inflation targeting frameworks include those of Canada, New Zealand, Sweden, and the United Kingdom.

[2] Indeed, some punishment-reward scheme must exist to enforce inflation targeting outcomes.

[3] For example, Herredorf and Lockwood (1997) assume that the private sector (monopoly trade union) enjoys private information about supply-side shocks and the optimal Walsh-type contract does not minimize social losses.

information emerges in two forms.[4] Either the central banker holds information about the structure of the economy that the private sector does not (e.g., a signal about a productivity or velocity shock as in Canzoneri 1985 and Garfinkle and Oh 1993), or the private sector does not know some central banker characteristic (e.g., preferences different from the private sector as in Cukierman 1992, Cukierman and Liviatan 1991, Cukierman and Meltzer 1986, Vickers 1986, Backus and Driffil 1985a,b, and Barro 1986). Within the second type, several contract papers assume that the public experience uncertainty about the relative choice of the central banker between inflation and output stabilization (e.g., Beetsma and Jensen 1998, Muscatelli 1998 and 1999, Schaling et al. 1998).[5]

This paper examines a more fundamental form of uncertainty, incomplete information about the central banker's selfishness. The central banker's self-interest (selfishness) constitutes the keystone of the optimal central banker contract approach. The selfish motivation of central bankers typically associates with policy choices inferior to those of a central banker with a public interest motivation (e.g., Toma and Toma 1986). Selfishness, however, becomes the sine-qua-non of the contracting model, since the effectiveness of the contract requires a selfish central banker. The more selfish the central banker is, the lower is the fixed cost of implementing a contract regime. Knowledge of the central banker's type enables the principal to design the appropriate incentive scheme. Brennan and Buchanan (1985, p. 147) observe, however, that if both private and public interest (both internally conceived notions) enter an individual's utility function as positively valued goods, a potential trade-off emerges between them. Moreover, the observed degree of either private self-interested or altruistic behavior will depend on their relative costs as determined by the institutional setting.

The introduction of a conservative central banker a la Rogoff improves the design of the delegation scheme, which now becomes a combination of a contract and a conservative central banker.

4 For other "groupings " of models with incomplete information in monetary policy see, Blanchard and Fisher (1989), and Cukierman (1992).

5 Models that do not consider contracting, but do consider uncertainty about inflation versus output stabilization include Cukierman and Meltzer (1986), Briault et al. (1996), Lossani et al. (1998), and Nolan and Schalling (1996).

Our analysis demonstrates, however, that when the central banker's selfishness is private information, inflation surprises can occur and output can exceed its natural level. We demonstrate that a short-sighted central banker with an inflation bias, who assigns a greater importance to social welfare than to personal reward (i.e., a benevolent central banker), experiences an incentive to masquerade as selfish in the first period of the game. The task of designing a mechanism that solves this problem by achieving preference revelation emerges. We consider a simple dominant strategy mechanism that induces the benevolent type either not to breach or not to accept the appointment (contract) in first place. This multi-period mechanism works with either inflation targets, or the appointment of a conservative central banker. Such an institutional design, however, must not succumb to the pressure of any particular policymaker who may hold the office over time. Thus, a broader constitutional arrangement must exist for the optimal contracts, augmented by the mechanism design, to form effective delegation in the long run.

The rest of the paper is organized as follows. Section 2 develops the basic central banker principal-agent model as a response to the time-inconsistency problem. Section 3 introduces incomplete information about central banker's selfishness under contracts and shows how monetary policy can be non-neutral in the short-run. Section 4 develops an incentive scheme that overcomes the problems of incomplete information about a central banker's selfishness. Section 5 discusses the mechanism and Section 6 concludes.

2. Basic Model: Commitment, Discretion, and Optimal Contracts

We model the economy as a variation of the Barro-Gordon (1983a,b) model of monetary policy (e.g., Canzoneri 1985, Walsh, 1995a, Jensen 1997). The economy possesses nominal wage contracts and a Lucas supply function, so that inflation surprises can increase output beyond the natural rate. That is,

$$y = y^n + \alpha(\pi - \pi^e) + \varepsilon\,, \tag{1}$$

where y is actual output, y^n is the natural rate of output, π is the inflation rate, $\pi^e = E_t(\pi_{t+1}|I_t)$ is the expected inflation conditional on the information set available at time t, and ε is an identically, independently distributed aggregate supply (productivity) shock with $E(\varepsilon) = 0$ and no persistence. The supply shock permits a potential stabilizing role for monetary policy, if the monetary authority owns superior information about its occurrence. In the context of our one-period model, t is the beginning of the period and t+1 is the end. For simplicity, we drop all time subscripts.

We assume that the *ex-ante* one-period social loss function is given by

$$\Lambda^{S} = \Lambda^{CB} = (y - y^*)^2 + \beta\pi^2 , \tag{2}$$

where y^* denotes targeted output. The central banker employs the same loss function as society ex-ante and wants output higher than the socially optimal natural level of output ($y^* = y^n + z$, $z \geq 0$), where z reflects the central banker's expansionary bias.[6] The term β (β∈[0,∞]) reflects society's aversion to inflation as well as the central banker's conservatism. A higher β implies more concern about inflation stabilization than output stabilization. The desired inflation rate is zero for simplicity ($\pi^* = 0$).

The events follow the typical sequence. First, workers enter into contracts and the private sector forms rational expectations about the rates of money growth and inflation. Second, the central banker observes a signal (λ) about the realized supply shock (ε), which is private information. Once the central banker receives the signal (λ=ε+e), where (e) is a measurement error, he forms his expectations about the stochastic supply shock as follows: $E_{\lambda}^{CB}(\varepsilon) = \rho\lambda,\ 0 < \rho \leq 1$. The coefficient (ρ) is a "rule" by which the central banker evaluates the signal. Third, the central banker sets the policy instrument (growth rate of a monetary aggregate, m) according to the reaction function by taking the private sector's expectations as given. Fourth, the supply shock (ε) is realized. Finally, policy outcomes are realized.

The inflation rate depends on the money growth rate (m), which is directly controlled by the central banker, and is given by

$$\pi = m + \nu - \gamma\varepsilon , \tag{3}$$

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[6] Typically, principal-agent models of monetary policy assume that the political principal (government) and the central banker share the same utility function (e.g., Walsh 1995a, Persson and Tabellini 1993). Exceptions are Waller's (1995) "rogue" central banker and Fratianni et al.'s (1997) politically elected central banker.

where ν is a control error or velocity shock, with $E(\nu) = 0$, $E(\nu^2) = \sigma_\nu^2$, and $E(\nu\varepsilon) = 0$. The velocity shock is stochastic for both the public and the central banker. The term (-γ) shows the countercyclical response of the central banker to unexpected supply shocks. The central banker's choice variables, therefore, are m and γ. We focus on m, taking γ as given.

Under discretion, the central banker minimizes the loss function (equation 2) each period subject to the structure of the economy (equations 1 and 3) and the expansionary bias, taking the private sector's expectations as given. This yields the following reaction function (superscript *d* stands for *discretion*),

$$m^d = [\gamma - \alpha/(\alpha^2 + \beta)]\varepsilon - \nu + [\alpha^2/(\alpha^2 + \beta)]m^e + [\alpha/(\alpha^2 + \beta)]z \quad . \tag{4}$$

Based on equation (4), the private sector forms rational expectations about the growth rate of the monetary aggregate as follows:

$$E(m^d) = m^{e,d} = (\alpha/\beta)z. \tag{5}$$

The actual money growth rate, given the public's expectations, corresponds to the discretionary rate of growth of the policy instrument as follows [i.e., substitute equation (5) into equation (4)]:

$$m^d = [\gamma - \alpha/(\alpha^2 + \beta)]\varepsilon - \nu + (\alpha/\beta)z\,. \tag{6}$$

The rate of money growth that solves the central banker's loss minimization problem under rational expectations implies the following inflation and output outcomes under discretion (time-consistent policy outcomes):

$$\pi^d = [-\alpha/(\alpha^2 + \beta)]\varepsilon + (\alpha/\beta)z\text{, and} \tag{7}$$

$$y^d = y^n + [\beta/(\alpha^2 + \beta)]\varepsilon\,. \tag{8}$$

The typical policy outcomes when a commitment technology exists are as follows:

$$\pi^f = [-\alpha/(\alpha^2 + \beta)]\varepsilon\text{, and} \tag{9}$$

$$y^f = y^n + [\beta/(\alpha^2 + \beta)]\varepsilon\,. \tag{10}$$

Thus, the equilibrium inflation rate under discretion exceeds the outcome under credible commitment by [$(\alpha/\beta)z$], reflecting the expansionary bias of the policymaker. Despite the higher inflation rate, the private sector, given the rational expectations assumption, is not "surprised" and the monetary expansion does not increase output beyond its natural rate.

Linear Central Banker Inflation Contracts

Consider now a linear incentive scheme that penalizes the central banker for high inflation rates. The contract can take the general form $(t_0 - t\pi)$, where (t_0) is a fixed reward and (t) a marginal penalization rate that reduces the policymaker's reward for realized inflation above a given target (e.g., Walsh 1995a, Persson and Tabellini 1993, and Fratianni et al. 1997). Recalling that the inflation rate target is zero, this scheme penalizes the central banker for positive inflation rates. Now, the central banker's additively separable loss function is as follows:

$$\Lambda^{CB} = \omega[(y - y^*)^2 + \beta\pi^2] - \xi(t_0 - t\pi)\,. \tag{2a}$$

The preferences that the central banker attaches to the incentive scheme and to aggregate social welfare are reflected in ξ and ω, respectively. Such loss (utility) functions appear in models where policymakers explicitly care about monetary rewards, such as the trade models by Dixit (1996), Grossman and Helpman (1994, 1995), and Levy (1999) where the rewards represent contributions to politicians. We normalize and set ω=1, so that ξ indexes the extent to which the central banker cares about the incentive scheme relative to social utility. We also normalize the reservation utility of the central banker to zero and assume that the participation constraint holds, the central banker's expected utility from accepting the contract exceeds his reservation utility [$E(U^{CB}) \geq U^{CB,R} = 0$].

The money growth rate that minimizes the central banker's expected loss in the presence of a linear inflation contract is given as follows:

$$\begin{aligned} m^c = {} & [\gamma - \alpha/(\alpha^2 + \beta)]\varepsilon - \nu + [\alpha^2/(\alpha^2 + \beta)]m^e \\ & + [\alpha/(\alpha^2 + \beta)]z - \{\xi/[2(\alpha^2 + \beta)]\}t \end{aligned}\,. \tag{11}$$

The actual rate of money growth once the public forms rational expectations is as follows:

$$m^c = (\gamma - \alpha/(\alpha^2 + \beta))\varepsilon - \nu + (\alpha/\beta)z - (\xi/2\beta)t\ . \qquad (12)$$

Thus, there exists an optimal penalization rate $t^* = (2\alpha/\xi)z$ that produces policy outcomes equivalent to the policy outcomes under credible commitment. That is, $m^c = m^f$, $\pi^c = \pi^f$, and $y^c = y^f$. Under the optimal incentive scheme, the public's rational expectations for the rate of money growth and inflation equal zero ($m^{e,c} = \pi^{e,c} = 0$).

3. Central Banker Contracts, Uncertainty, and Monetary Policy Surprises

The effectiveness of central banker contracts depends importantly on the degree of selfishness of the central banker. The contracting approach introduces an incentive scheme that penalizes deviations from the principal's desired (targeted) money growth rate (i.e., we assume that the central banker holds an ex-post expansionary bias). That is, the incentive scheme increases the central banker's marginal costs and offsets the marginal benefits from money growth.[7] Therefore, the central banker trades off some utility from achieving the ex post socially desirable outcome for a transfer payment[8]. This trade off, though, differs across potential central bankers according to their selfishness, among other things. In particular, the increased marginal (penalty) cost refers to the private component of the central banker's utility function, while the marginal benefit refers to the social welfare component. A necessary condition for an effective contract, however, is that the central banker is sufficiently selfish. But are potential central bankers selfish enough? On one hand, the assumption of self-interest underlies the behavior of homo-economicus. On the other hand, Buchanan (1987) argues "there is no need to assign net wealth or net income a dominating influence on behavior in order to produce a fully operational economic theory of

[7] The benefits from monetary expansion fail to materialize, however, because the private sector incorporates the central banker's behavior when setting its expectations.

[8] Again, the expansionary outcome is not socially optimal ex-post, but is optimal ex-ante in the eyes of the central banker, who suffers from the expansionary bias (as given by the reaction function).

choice behavior, in market or political interaction" (p. 245).[9] Moreover, the public-interest view of public officials' behavior, suggests that their primary concern is public welfare. [10]

What happens if the central banker's utility function does not have a private component? This section considers the contracting model of central banker decisions when uncertainty exists about the selfishness of the central banker. Assume a world where the government writes contracts with the central banker to whom monetary policy is delegated. In addition, assume that a continuum of candidate central bankers exists with different degrees of selfishness, where selfishness defines the central banker's type. In other words, the *i-th* central banker possesses a degree of selfishness $\xi_i \in [0, \infty]$. For simplicity, we consider two types of central bankers, a central banker with a high degree of selfishness ($\overline{\xi}$), which we call "self-interested", and a low degree of selfishness ($\underline{\xi}$), which we call benevolent. To further simplify, we set $\underline{\xi} = 0$ (i.e., benevolent implies selfless) and $\overline{\xi} > 0$. The self-interested type cares about both social welfare and transfer payments. The benevolent central banker cares only about social welfare. In fact, our benevolent central banker represents a special case of the criticism that central banker contracts may suffer from low power (e.g., Blinder, 1998). In our case the central banker cares only about the social welfare component of the loss function (i.e., no power rather than low power). Our model incorporates an inflationary bias, while in Blinder's (1998) discussion does not.

Society knows that if the central banker can implement discretionary monetary policy, he follows the ex-post-optimal policy (i.e., the time-consistent policy). Society then delegates monetary policy through a contract to an independent central banker to implement the ex-ante optimal policy. A central banker contract, however, will not deliver the first-best outcomes unless it matches the type (selfishness)

[9] This view corresponds with that of Becker (1993) who assumes that individuals receive motivation not only from selfishness or material gain but also from a richer set of values and preferences.

[10] The central banker may also experience pressures from government (i.e., legislative or executive) as the literature on political business cycles suggests. Chortareas and Miller (2000) also explore the possibility that if a contract with one principal (government) exists, then another contract offered by another principal (interest group) may also exist that neutralizes the first contract.

of the appointed central banker. In other words, although we know the functional form of the penalization rate that enforces the optimal outcome, we cannot determine its precise value unless we know all parameters (α, ξ, and z). Since, the economy's structure is public information and since the central banker suffers from the expansionary bias, α and z are known. How does the government choose t when uncertainty exists about ξ?

Incomplete Information in a Single-Period Model with a Benevolent Central Banker

To begin, society (government) offers a contract to a central banker drawn from a population of candidates. The principal (society), however, cannot know the central banker's selfishness a priori; the central banker type is private information. The acceptance of the contract signals a "strong announcement" or a "highly credible announcement" that the central banker will deliver results equivalent to those under precommitment. Moreover, the credibility of the central banker's announcement increases because of a strong incentive scheme (i.e., the contract). The credibility of the announcement, however, depends on the central banker's selfishness (i.e., ξ). Thus, our model makes the credibility of a central banker's contract-based announcement endogenous in his selfishness.

Assume now that the benevolent central banker can successfully masquerade as the selfish central banker, and that the government offers a contract tailored for a selfish central banker to a benevolent one. This mimicking behavior by central bankers does not violate the truthfulness requirement that is typical in agency theoretic models, since truthfulness typically refers to the strategies of the principal (government). In monetary policy games, the lack of a commitment technology prevents the central banker from truthfully revealing his type.

Since the benevolent central banker's ξ is zero, the loss function only has a social welfare component [see equation (2)]. Therefore, the reaction function of the benevolent central banker in the presence of a contract reduces to the discretionary reaction function [see equation (11)]. This reaction function includes the inflation bias term {i.e., $[\alpha/(\alpha^2+\beta)]z$ } because the benevolent central banker does not respond to the contract. The self-interested central banker does respond to the contract and $[\alpha/(\alpha^2+\beta)]z$ does not appear in the reaction function.

Now, further assume that a fraction of the population (ϕ) believes that the central banker's announcement is credible. The rest of the population *(1-ϕ)* suspects that the central banker's announcement is not credible and that he will create an inflation surprise. In the extreme case where ϕ=1, we have a naïve public that fully believes that the contract will eliminate the central banker's bias. In the other extreme case where ϕ=0, the sophisticated public doubts that the central banker will abide by the contract.

We can conveniently summarize as follows:

$$prob(\xi)\begin{cases}=0 \text{ is } (1-\phi)\\ >0 \text{ is } \phi\end{cases}.$$

Our analysis mirrors Cukierman and Liviatan (1991) and Cukierman (1992), who consider the ability of a central banker to commit and how the public under asymmetric information perceives the commitment announcement.

The reaction function of the benevolent central banker under a contract reduces to that under discretion [see equation (11)]. Since the central banker's type is private information, the private sector's aggregated expectation about the rate of monetary growth is as follows:

$$E(m)=m^e=\phi(m^{e,c})+(1-\phi)(m^{e,d}). \tag{13}$$

The probabilities that the central banker is self-interested or benevolent are ϕ or (*1*-ϕ), respectively. The fraction of the public believing that the central banker will not implement the contract (*1*-ϕ) sets its rational expectation at the discretionary equilibrium level of money growth.[11] The fraction of the population believing that the central banker will implement the contract (ϕ) sets its rational expectations according to the optimal contact equilibrium. That latter group believes that the contract binds the central banker's actions and therefore treats the central banker's acceptance of the optimal contract as an effective commitment technology. Thus,

$$E(m^U) = m^{e,U} = \pi^{e,U} = (1-\phi)\left(\frac{\alpha}{\beta}\right)z\,. \tag{13a}$$

That result emerges by substituting the expected rate of money growth under discretion [expected value of equation (6)] into the expectations aggregate [equation (13)]. The higher the fraction (ϕ) of the public that believes that the central banker's announcement is credible, the lower is the aggregate expected rate of money growth.

Using the public's rational expectations (13a) and the benevolent central banker's reaction function, the actual rate of money growth reduces to

$$m_B^{b,U} = \left(\gamma - \frac{\alpha}{\alpha^2+\beta}\right)\varepsilon - \nu + \left(\frac{(1-\phi)\alpha^2+\beta}{\alpha^2+\beta}\right)\left(\frac{\alpha}{\beta}\right)z\,, \tag{14}$$

where the subscript (*B*) stands for the benevolent central banker under contracts, the superscript (*b*) for breaching, and the superscript (*U*) for uncertainty regarding the central banker's selfishness. Note that since $0 < \phi < 1$ and $\left(\frac{(1-\phi)\alpha^2+\beta}{\alpha^2+\beta}\right) < 1$, the money growth rate is lower than under discretion [equation (6)], but higher than under the contract without breaching (i.e., under a contract with a selfish central banker). The limiting cases of (ϕ=*1*) and (ϕ=*0*) are discussed below in more detail.

The corresponding inflation and output outcomes are as follows:

$$\pi_B^{b,U} = \left(\frac{(1-\phi)\alpha^2+\beta}{\alpha^2+\beta}\right)\left(\frac{\alpha}{\beta}\right)z - \left(\frac{\alpha}{\alpha^2+\beta}\right)\varepsilon\,, \text{ and} \tag{15}$$

$$y_B^{b,U} = y^n + \left(\frac{\beta}{\alpha^2+\beta}\right)\varepsilon + \left(\frac{\phi\alpha\beta}{\alpha^2+\beta}\right)\left(\frac{\alpha}{\beta}\right)z\,. \tag{16}$$

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[11] Alesina (1987), Cukierman (1995), and Cukierman and Liviatan (1991) provide a similar modeling of the public's expectations under uncertainty.

The average inflation rate that prevails under incomplete information exceeds that under credible commitment, but falls short of that under discretion. That result always holds with the exception of the limiting case where all private agents are "distrustful" and expect the central banker to breach the contract ($\phi=0$), which yields the discretionary outcome. More importantly the money growth rate exceeds its expected level, as does the inflation rate. Note that $\pi_B^{b,U} > \pi^{e,U}$, and an inflation surprise emerges that generates output levels higher than the natural output, unless $\phi=0$.

PROPOSITION 1: *In a one-period model, a benevolent central banker produces an inflation surprise and output exceeds the natural rate of output as long as a fraction (ϕ) of the private sector believes that the central banker has a positive degree of selfishness (i.e.,* $0 < \phi \leq 1$*).*

Proof: Comparing equations (13a) and (15), the actual inflation exceeds the expected inflation as long as ϕ strictly exceeds zero. Moreover, equation (16) shows that expected output exceeds the natural rate of output because of that inflation surprise.

Q.E.D.

Proposition 1 emerges because incomplete information about the central banker's type exists. When the entire public is distrustful ("sophisticated") ($\phi=0$), both the rate of money growth and inflation equal their discretionary levels and output equals the natural level. That is, $\lim_{\phi \to 0} m_B^{b,U} = m^d$, $\lim_{\phi \to 0} \pi_B^{b,U} = \pi^d$, and $\lim_{\phi \to 0} y_B^{b,U} = y^d$. When ($\phi>0$), however, the rates of money growth and inflation always exceed their expected values, ignoring any aggregate supply (productivity) shocks, by a multiplicative term $\phi\left(\frac{\alpha}{\alpha^2+\beta}\right)z$, since

$$m_B^{b,U} - m^{e,U} = \pi_B^{b,U} - \pi^{e,U} = \phi\left(\frac{\alpha}{\alpha^2+\beta}\right)z \,. \tag{17}$$

That difference creates a policy surprise and makes output exceed its natural level in the short-run.

Those results strengthen in the other limiting case, a fully "naïve" public (i.e., $\phi=1$), since the rate of money growth ($\lim_{\phi\to 1} m_B^{b,U\,d}$) and inflation ($\lim_{\phi\to 1} \pi_B^{b,U}$) fall short of those under discretion by $\left(\frac{\alpha}{\beta}\right)\left(\frac{\alpha^2}{\alpha^2+\beta}\right)z$. Output ($\lim_{\phi\to 1} y_B^{b,U}$), however, exceeds the natural level, which prevails under both commitment and discretion, by $\left(\frac{\alpha^2}{\alpha^2+\beta}\right)z$.

Our results can be summarized as follows:

$$m^f < m_B^{b,U} \le m^d ;$$
$$\pi^f < \pi_B^{b,U} \le \pi^d ; \text{ and} \tag{18}$$
$$y^f = y^d \le y_B^{b,U} .$$

The above result is immune to McCallum's (1995, 1997) criticism of time-inconsistency models. In particular, McCallum asks whether a central banker has the motive to follow discretionary policy. That is, if the central banker solves the model, he will discover that he cannot surprise the economy and discretionary output cannot exceed that of precommitment. This is not true in the current model.

PROPOSITION 2: *In a one-period model, a benevolent central banker always accepts a contract and breaches if a fraction (ϕ) of the private sector believes that the central banker has a positive degree of selfishness (*$0 \le \phi \le 1$*).*

Proof: Substituting the policy outcomes into the loss function of the benevolent central banker and taking expectations, we derive his expected loss when he breaches under uncertainty about his type as follows:

$$E(\Lambda_B^{b,U}) = \begin{pmatrix} \frac{\beta}{\alpha^2+\beta}\sigma_\varepsilon^2 + \left(\frac{\left((1-\phi)\alpha^2+\beta\right)^2}{(\alpha^2+\beta)\beta}\right)z^2 \\ -\frac{2\left((1-\phi)\alpha^2+\beta\right)}{\alpha^2+\beta} z\rho\lambda \end{pmatrix}. \tag{19}$$

Substituting the contract policy outcomes given the public's rational expectations [equation (13a)] generates the expected loss of the benevolent central banker when he abides by the contract. That is,

$$E(\Lambda_B^{c,U}) = \begin{pmatrix} \dfrac{\beta}{\alpha^2+\beta}\sigma_\varepsilon^2 + \left(\dfrac{(1-\phi)\alpha^2+\beta}{\beta}\right)^2 z^2 \\ -2\left(\dfrac{(1-\phi)\alpha^2+\beta}{(\alpha^2+\beta)}\right) z\rho\lambda \end{pmatrix}. \tag{20}$$

Comparing the benevolent central banker's expected losses when he breaches and when he does not, the expected loss is always lower under breaching, since

$$E(\Lambda_B^{c,U}) - E(\Lambda_B^{b,U}) = \left(\frac{[(1-\phi)\alpha^2+\beta]^2}{(\alpha^2+\beta)\beta^2}\right)\alpha^2 z^2 > 0\,. \tag{21}$$

Q.E.D.

Incomplete Information in a Single-Period Model with a Selfish Central Banker

When incomplete information exists about the central banker's type, a benevolent central baker always enters a Walsh-type contract and then breaches, generating an inflation surprise. What happens when the central banker is selfish under incomplete information?

The public's expectations are given by equation (13a). Substituting that expression into the reaction function of the selfish central banker [equation (11)] produces

$$m_S^{c,U} = \left(\gamma - \frac{\alpha}{\alpha^2+\beta}\right)\varepsilon - \nu + \left(\frac{(1-\phi)\alpha^2+\beta}{\alpha^2+\beta}\right)\left(\frac{\alpha}{\beta}\right) z - \frac{\xi}{2(\alpha^2+\beta)} t\,. \tag{22}$$

Substituting the optimal t* from the Walsh contract gives the actual money growth rate as follows:

$$m_S^{c,U} = \left(\gamma - \frac{\alpha}{\alpha^2+\beta}\right)\varepsilon - \nu + \left(\frac{\alpha^2}{\alpha^2+\beta}\right)\left(\frac{(1-\phi)\alpha}{\beta}\right) z\,. \tag{23}$$

Thus, even if the central banker is selfish, actual money exceeds the optimal (m^f) when a fraction ($1-\phi$) of the population believes that the central banker is benevolent. As ($1-\phi$) goes to zero (i.e., the fraction of the population believing that the central banker is selfish goes to one), we have the typical contract solution.

Thus, the inflation rate and output are given as follows:

$$\pi_S^{c,U} = \left(\frac{(1-\phi)\alpha^2}{\alpha^2+\beta}\right)\left(\frac{\alpha}{\beta}\right)z - \left(-\frac{\alpha}{\alpha^2+\beta}\right)\varepsilon \text{ , and} \tag{24}$$

$$y_B^{b,U} = y^n + \left(\frac{\beta}{\alpha^2+\beta}\right)\varepsilon - \left(\frac{(1-\phi)\alpha\beta}{\alpha^2+\beta}\right)\left(1-\frac{\alpha}{\alpha^2+\beta}\right)\left(\frac{\alpha}{\beta}\right)z \text{ .} \tag{25}$$

A negative inflation surprise occurs in the short-run and output falls bellow its first-best level. Thus, when a selfish central banker accepts a (Walsh) contract and the private sector is uncertain about central banker's type, not only does inflation exceed the inflation rate under the contract but also output falls below its natural level. This is a policymaker's nightmare. How can this be? The answer: The (Walsh) penalization rate (t*) does not completely eliminate the inflation bias. Moreover, the resulting positive inflation falls below its expected value, driving output below its natural level.

A central banker contract does exist, however, that restores the first best outcome. We define this contract as (t_0 -t**π). Substituting the public's expectations [equation (13a)] into the reaction function of the central banker and solving for the marginal penalization rate that sets the actual money growth rate equal to the money growth rate under the first-best outcome gives:

$$t^{**} = [(1-\phi)\alpha^2 + \beta]\left(\frac{2}{\xi}\right)\left(\frac{\alpha}{\beta}\right)z \text{ ,} \tag{26}$$

where t** is the optimal penalization rate. When no uncertainty exists about the central banker's type (i.e., ϕ=1), t** reduces to the Walsh marginal penalization rate t*. When a chance exists that the central banker may be benevolent, the optimal contract must more harshly penalize the central banker. In other words, the marginal penalization rate (t**) exceeds the Walsh marginal penalization rate (t*) by:

$$t^{**} - t^{*} = [(1-\phi)\alpha^2]\left(\frac{2}{\xi}\right)\left(\frac{\alpha}{\beta}\right)z > 0 \text{ .} \tag{27}$$

Thus, a modified Walsh contract (t_0-t**π) delivers inflation and output results equivalent to the first best when uncertainty exists about the central banker's type and a selfish central banker holds office. Such a contract, however, cannot solve the problem for a benevolent central banker.

4. A Dominant Strategy Revelation Mechanism under Incomplete Information about the Central Banker's Selfishness

We identify six different combinations of central banker types – selfish and benevolent -- and the public's beliefs -- $\phi \to 0, \phi \to 1, 0 < \phi < 1$. Only one combination, if the public is naïve (i.e., $\phi \to 1$) and the central banker is selfish, allows central banker contracts to deliver the socially optimal results under certainty. Does a remedy exist for such problems?

We develop a remedy that induces the benevolent central banker to reveal his type and not accept contracts designed for a selfish central banker. We resort to mechanism design rather than reputation to deter a central banker from breaching a contract. As noted above, a benevolent central banker possesses an incentive to pretend that he is selfish. Given the contract, the private sector believes that the marginal costs for the central banker from expanding the economy are raised enough to counteract the marginal benefits from doing so (i.e., the expansionary bias is eliminated). What the public does not know, though, is that the benevolent central banker only cares about social welfare.

The problem emerges because no signaling device exists for a selfish central banker to signal his type. The central banker accepts or rejects the contract. A benevolent central banker always accepts the contract, because his expected loss under a contract (with or without breaching) falls below or equals his expected loss when another (selfish) central banker accepts the contract. This observation has important implications for writing contracts in practice. Since the contracting approach is new, no history of central bankers' behavior under contracts exists. If a central banker serves under a contract, typically he cannot be re-appointed.

In our suggested mechanism, the public does not impose discipline but rather the discipline comes from the institutional design. In particular, when central banker contracts are written, the policy of the central banker should be evaluated at fixed points within the central banker's term. Then a trigger strategy can apply as follows:

$$\text{if } m = \begin{cases} m^{c} & \text{, then the central banker continues his term under the contract} \\ m_{B}^{b^{U}} & \text{, then the contract is breached} \end{cases} .$$

If a contract breach occurs, then society must replace the central banker. What central banking (monetary policy) regime should replace the central banker contract regime when a breach occurs? We do not design an optimal long-term central banker regime, but rather design a regime that induces a benevolent central banker to reveal his type. That is, we propose a "transitional" central banker regime that punishes central bankers that breach and create inflation surprises. To the extent that this regime deters the benevolent central banker from entering a contract, the optimal central banker regime under contracts prevails. We consider two options: appointing a more conservative central banker, or setting an (over-ambitious) inflation target.

Divide each central banker term (contract) into sub-periods. At the end of each sub-period, the performance of the central banker is evaluated. The intertemporal loss function of the central banker is now given by

$$L^{CB} = \sum_{i=0}^{n} \delta_{t+i}^{i} \Lambda_{t+i}^{CB} , \tag{2b}$$

where δ_{t+i}^{i} is the discount factor ($0 \leq \delta_{t+i}^{i} \leq 1$). Assume two sub-periods to simplify. Further, assume that the discount factor is constant ($\delta = 1$). In order for the benevolent central banker not to masquerade as a self-interested one, accept the contract, and then breach it with the discretionary outcome, the expected loss from this strategy must exceed the two-period expected loss by implementing the contract (or letting a selfish central banker implement the contract). In other words,

$$E(\Lambda_{B,t}^{c,U}) + E(\Lambda_{B,t+1}^{c,U}) \leq E(\Lambda_{B,t}^{b,U}) + E(\Lambda_{B,t+1}^{CB*}) . \tag{28}$$

That is, the expected loss of the benevolent central banker from not breaching in any two consecutive periods must be less that the sum of the expected loss when a breach occurs in the first period and the expected loss of the new central banking regime in the second period. When this condition holds, the benevolent central banker either will not accept the contract, or accept and implement it.

We need to develop an institutional design that delivers $E(\Lambda_{t+1}^{CB*})$ that satisfies condition (28) and does not depend on the public's beliefs about the central banker's selfishness. In other words, what central banker regime in the second period induces preference revelation? We consider two alternative arrangements: appointing a conservative central banker, and adopting inflation rate targets. That is,

$$E(\Lambda_2^{CB*}) = \begin{cases} E(\Lambda_2^{CB,H}) \\ E(\Lambda_2^{CB,T}) \end{cases},$$

where superscripts H and T denote the "hawkish" (conservative) central banker and inflation targeting, respectively.

All components of equation (28) except for $E(\Lambda_{t+1}^{CB*})$ are known. The expected losses of the benevolent central banker in the first sub-period with breaching [$E(\Lambda_{B,1}^{b,U})$] and without breaching [$E(\Lambda_{B,1}^{c,U})$] appear in equations (19) and (20), respectively. The expected loss in the second sub-period without breaching is

$$E(\Lambda_{B,2}^{c,U}) = \left(\frac{\beta}{\alpha^2 + \beta} \sigma_\varepsilon^2 + \left(\frac{(1-\phi)\alpha^2 + \beta}{\beta} \right)^2 z^2 \right). \quad (29)$$

The mechanism design in the first sub-period gives the central banker the signal (λ), so that $E_t(\varepsilon_t \mid \lambda_t) = \rho\lambda_t$. The relevant signal (λ) for the second sub-period, though, does not yet exist, so that $E_t(\varepsilon_{t+1}) = 0$. Therefore, when the central banker decides on whether to breach, no information exists about the second sub-period's supply-side shock. That information reveals itself to the central banker early during the second period. The following sections examine those two alternative institutional arrangements.

Regime H: Appointing a Conservative ("Hawkish") Central Banker in the Second Sub-Period

To derive the benevolent central banker's expected loss in the second period when a conservative central banker replaces him, we derive the policy outcomes when a conservative central banker is appointed. Rogoff (1985) suggests that society appoint a central banker with a higher inflation aversion than society itself. In other words, the conservative central banker attaches a higher weight to inflation stabilization than to output stabilization. The conservative central banker can still have an output preference that exceeds the natural level. For simplicity, we assume that the conservative central banker has the same expansionary bias as the first period's central banker. The difference is the higher weight placed on the inflation objective by the conservative central banker, $\beta^H = (\beta + \chi),\quad 0 < \chi < \infty$ (H for hawkish). Therefore, the one-period loss function is given by:

$$\Lambda^{CB_j, H_j} = (y - y^*)^2 + (\beta + \chi)\pi^2 . \tag{2c}$$

Solving the optimization problem of the hawkish central banker gives the following policy outcomes.

$$\pi^H = \left(-\frac{\alpha}{\alpha^2 + (\beta + \chi)} \right)\varepsilon + \left(\frac{\alpha}{\beta + \chi} \right) z , \quad \text{and} \tag{30}$$

$$y^H = y^n + \left(\frac{\beta + \chi}{\alpha^2 + (\beta + \chi)} \right)\varepsilon , \text{ with} \tag{31}$$

As the conservatism of the central banker increases to infinity ($\chi \to \infty$), the inflationary bias in equation (28) goes to zero.[12]

When a conservative central banker replaces the benevolent central banker in the second sub-period, the expected loss of the latter in the second period is as follows:

$$E(\Lambda^H_{B,2}) = \left(\frac{(\beta + \chi)}{(\alpha^2 + \beta + \chi)} \right)\sigma^2_\varepsilon + \left(\frac{(\alpha^2 + \beta + \chi)}{(\beta + \chi)} \right) z^2 . \tag{32}$$

PROPOSITION 3: *If there exists a conservative central banker with* $\beta' = \beta + \chi$ *that can be appointed to conduct monetary policy in the period following breaching, the benevolent central banker does not breach the contract with society, provided that the second-period central banker has a sufficient degree of conservatism (* $\chi \geq \alpha^2$ *) and the stochastic shock is high enough {* $z[1/h(\phi)] \leq \sigma_\varepsilon$ *},where* $h(\phi) \geq 0$*, and* $h(0) < 1 < h(1)$*.*

[12] As is well known, the variance of inflation is also lower as compared to the previous central banking regimes. A high degree of central banker conservatism, however, makes the variance of output higher as compared to the first-best, discretionary outcome, and central banker contracts regimes. This is the drawback of the conservative central banker approach.

PROOF: Substituting equations (19), (20), (29), and (32) into inequality (28) produces after some manipulation the following relationship between σ_ε^2 and z^2:

$$z^2 \le \sigma_\varepsilon^2 (A/B) = \sigma_\varepsilon^2 [h(\phi)]^2 , \qquad (33)$$

where $A = \alpha^2 \beta^2 \chi(\beta+\chi)$ and

$$B = \{[(1-\phi)\alpha^2 + \beta]^2 (2\alpha^2+\beta)(\beta+\chi) - (\alpha^2+\beta)\beta^2(\alpha^2+\beta+\chi)\}(\alpha^2+\beta+\chi) .$$

To further facilitate discussion, B can be rewritten as follows:

$$B = [(1-\phi)^2 C + (1-\phi)D + \alpha^2\beta^2(\chi-\alpha^2)](\alpha^2+\beta+\chi)$$

where $C = \alpha^4 (2\alpha^2+\beta)(\beta+\chi)$ and

$$D = 2\alpha^2\beta(2\alpha^2+\beta)(\beta+\chi) .$$

Note that *A>0* and *B>0* (provided that $\chi \ge \alpha^2$) and therefore $h(\phi) = \sqrt{A/B} > 0$. Also $h(0) < 1 < h(1) \Rightarrow [1/h(0)] > 1 > [1/h(1)]$. Taking the square root of inequality (33) produces

$$z[\sqrt{B/A}] \le \sigma_\varepsilon => z[1/\sqrt{A/B}] \le \sigma_\varepsilon => z[1/h(\phi)] \le \sigma_\varepsilon . \qquad (34)$$

QED

Therefore, delegating monetary policy to a conservative central banker can deter the benevolent central banker from breaching in the first period provided that two conditions – one sufficient and the other necessary and sufficient -- hold. The first sufficient condition requires that the extra "conservatism" of the second period's central banker exceeds the squared coefficient of the inflation surprise ($\chi \ge \alpha^2$). In other words, the central banker in the second period should be conservative (hard-nosed) enough to overcome the temptation-to-inflate that arises from the structure of the economy. That condition is required only when society verges on the naïve public (i.e., high values for ϕ). That is, to ensure that B exceeds zero as ϕ approaches one requires that $\chi \ge \alpha^2$. The second condition, $z[1/h(\phi)] \le \sigma_\varepsilon$, requires that the standard deviation of the economy's stochastic shocks exceeds the central banker's (society's) expansionary (inflation) bias *z* by some multiple (fraction). If the variance of the supply side shocks is too low, then the benevolent central banker's implied losses from having monetary policy conducted by a conservative central banker in the second period do not deter breaching in the first period.

As the proportion of the naïve public (ϕ) increases, the preference revelation condition becomes easier to satisfy, since the term multiplying the inflation bias z decreases (i.e., breaching becomes more costly for the benevolent central banker). The expression $[1/h(\phi)]$ is decreasing in ϕ and is strictly concave, since

$$\frac{\partial\left(1/h(\phi)\right)}{\partial\phi} = -2\alpha^2[(1-\phi)\alpha^2+\beta](2\alpha^2+\beta)(\beta+\chi)(\alpha^2+\beta+\chi)\left(\frac{1}{\sqrt{AB}}\right) < 0 \text{, and}$$

$$\frac{\partial^2\left(1/h(\phi)\right)}{\partial\phi^2} = 2(\alpha^2)^2(2\alpha^2+\beta)(\beta+\chi)(\alpha^2+\beta+\chi)\left(\frac{1}{\sqrt{AB}}\right) > 0 \,.$$

To make this result more transparent, we rewrite the preference revelation condition [equation (28)] so that the terms involving ϕ are on the left-hand side and the expected loss under the second period post-breaching regime (which is independent of ϕ) is on the right-hand side. That is,

$$E(\Lambda_{B,t}^{c,U}) + E(\Lambda_{B,t+1}^{c,U}) - E(\Lambda_{B,t}^{b,U}) < E(\Lambda_{B,t+1}^{CB*}) \,. \tag{28a}$$

Differentiating the left-hand side of inequality (28a) with respect to ϕ produces

$$\frac{\partial[E(\Lambda_{B,t}^{c,U}) + E(\Lambda_{B,t+1}^{c,U}) - E(\Lambda_{B,t}^{b,U})]}{\partial\phi} = (-2\alpha^2)\left(\frac{[(1-\phi)\alpha^2+\beta]}{\beta^2}\right)\left(1+\frac{\alpha^2}{\alpha^2+\beta}\right)z^2 < 0 \,.$$

This expression corresponds to the sum of the derivatives of equations (21) and (29), which are both negative. Thus, the preference revelation condition (28) holds more easily for a higher proportion of a naïve public.

That result may seem counterintuitive. That is, the larger the proportion of the naïve population is, the stronger (larger) the effect of a monetary policy surprise is and the larger the benevolent central banker's utility gain from breaching is. A higher proportion of a naïve public, however, implies lower expected losses for the benevolent central banker who abides by the contact in both periods [equations

(20) and (29)].[13] Focus, however, on expression (21) that explicitly represents the incentive of the benevolent central banker to breach in period *t*. That incentive decreases in ϕ, but always remains positive. (The same holds for the expected loss in period t+1 of the benevolent central banker who abides by the contract.)

What is the intuition behind this result? When the authorities delegate monetary policy through contracts and uncertainty exists about the central banker's type, the resulting output and inflation outcomes differ from the optimal ones not only for a benevolent central banker but also for a selfish central banker who abides by the contract as long as $\phi < 1$. (See section 3 for details. In the extreme case when $\phi = 1$, the typical contract solution applies). In that case, the higher the proportion of the distrustful public is (i.e., $\phi \to 0$), the higher actual inflation is and the greater the deviation of output from its natural level is [see equations (24) and (25)]. In this particular case, therefore, society is better off when the public believes that the central banker is selfish (i.e., $\phi \to 1$), because the typical contract results obtain. That the selfish central banker's expected losses are lower when the public is more naïve ($\phi \to 1$) than when it is more distrustful ($\phi \to 0$) is true not only under breaching but also under abiding by the contract [see equations (19), (20), and (29)].

Finally, that the preference revelation condition holds more easily for higher values of ϕ does not emerge because of the preference revelation mechanism design, but is a feature of the model structure. In particular, the selfish central banker's expected loss (when the responsiveness to the contract is private information) is greater when $\phi \to 0$ and lower when $\phi \to 1$.[14]

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[13] This statement holds in period t, if the expected shock is not too strong. That is, $\rho\lambda < [(1-\phi)\alpha^2 + \beta](z/\beta)$ holds.

[14] In fact, the magnitude of ϕ is of greater importance to the (selfish) central banker's expected losses under a contract than under breaching. To verify this, it is enough to compare the selfish central banker's expected loss for the two extreme cases ($\phi = 1$, and $\phi = 0$) under contracts and breaching [using equations (19) and (20)]

$$E(\Lambda_B^{c,U})_{\phi=0} - E(\Lambda_B^{c,U})_{\phi=1} > E(\Lambda_B^{b,U})_{\phi=0} - E(\Lambda_B^{b,U})_{\phi=1}.$$

Regime T: Adopting an Inflation Target in the Second Sub-Period

The conservative central banker regime requires that the central banker who breaches the contract must be fired. What if institutional constraints exist that prevent society from firing the central banker despite poor performance? The mechanism described above can incorporate inflation-rate targeting in the second period, which can be implemented by either a new central banker, or the same benevolent central banker.

Inflation targeting implies that the central banker's loss function in each period becomes

$$\Lambda^{T_\pi} = (y - y^*)^2 + \beta(\pi - \pi^*)^2 . \tag{2d}$$

Solving for the one-period optimal inflation target generates the following:

$$\pi^* = -\frac{\alpha}{\beta} z .^{15} \tag{35}$$

Under the optimal target, $m^T = m^f$, $\pi^T = \pi^f$, and $y^T = y^f$.

The expected loss of the benevolent central banker for the second sub-period under inflation targeting is given by

$$E(\Lambda_{B,2}^{T_{\pi^*}}) = \left(\frac{\beta}{(\alpha^2 + \beta)}\right)\sigma_\varepsilon^2 + \left(\frac{(\alpha^2 + \beta)}{\beta}\right)z^2 + \beta(\pi^*)^2 + 2\alpha z\pi^* . \tag{36}$$

PROPOSITION 4: *The benevolent central banker will not breach (or will not accept the contract) in period t, if an inflation target can be set for period t+1 that either is lower or exceeds the one-period optimal inflation target by* $\frac{\alpha}{\beta} z\sqrt{1+\Gamma}$, where $\Gamma > 0$.

PROOF: Substituting (19), (20), (29), and (36) into the preference revelation condition (28) and manipulating generates

$$\beta(\pi^*)^2 + 2\alpha z\pi^* - (\alpha^2 z^2 / \beta)\Gamma \geq 0 ,$$

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[15] The over-ambitious optimal inflation target under an inflation targeting regime is a standard result in the relevant literature (e.g., see Svensson, 1997 and Muscatelli, 1998)

where $$\Gamma = \left\{ \frac{[((1-\phi)\alpha^2 + \beta]^2 (2\alpha^2 + \beta) - (\alpha^2 + \beta)^2 \beta}{\alpha^2 (\alpha^2 + \beta)\beta} \right\} > 0 .$$

Solving this inequality produces two roots that correspond to the post-breaching period (t+1) inflation targets that satisfy preference revelation. Those roots must either fall below the smaller root, or exceed the larger root (π_1 * and π_2 * respectively). Those roots are as follows: $\pi_1^* = -\frac{\alpha}{\beta} z[1 + \sqrt{1+\Gamma}] < 0$ and $\pi_2^* = -\frac{\alpha}{\beta} z[1 - \sqrt{1+\Gamma}] > 0$. Comparing π_1^* and π_2^* with the one-period optimal inflation target π^* [equation (35)] verifies that Proposition 4 holds. *QED*

The revelation-preference-mechanism inflation targets depend on how naïve or distrustful the public is (i.e., π_1 * and π_2 * depend on ϕ). Note that $\frac{\partial \pi_1 *}{\partial \phi} = -\frac{\alpha}{2\beta} z(1+\Gamma)^{-\frac{1}{2}} \frac{\partial \Gamma}{\partial \phi} > 0$, and $\frac{\partial \pi_2 *}{\partial \phi} = \frac{\alpha}{2\beta} z(1+\Gamma)^{-\frac{1}{2}} \frac{\partial \Gamma}{\partial \phi} < 0$, since $\frac{\partial \Gamma}{\partial \phi} < 0$. That is, the greater the fraction of the naïve public is, the closer the inflation revelation-preference inflation target is to the one-period optimal inflation target. The intuition matches the discussion of Proposition 3. A larger fraction of the naïve public makes revelation preference easier regardless of the *(t+1)* period regime.

The inequality (≤) that corresponds to the preference revelation condition [equation (28)] is satisfied as an equality because society wants to induce preference revelation at the minimum possible social loss. Society is indifferent between the two targets since the expected loss of society under the two targets is the same [i.e., $E(\Lambda_{t+1}^{society}) \big| \pi_1^* = E(\Lambda_{t+1}^{society}) \big| \pi_2^* = \left(\frac{\beta}{\alpha^2 + \beta} \right) \sigma_\varepsilon^2 + \frac{\alpha^2}{\beta} z^2 (1+\Gamma)$].

In a one-period model with inflation targeting, decision makers must set an inflation target lower than the desired outcome to counteract the central banker's inflation bias through its effect on the public's expectations (see, Svensson 1997, Beetsma and Jensen 1998, and Muscatelli 1998). Realized inflation overshoots the target, but the result is socially optimal. A similar, but intertemporal, process works here, since the inflation target that induces preference revelation differs from the one-period optimal inflation target. In contrast to one-period models with certainty where realized inflation overshoots targeted inflation in equilibrium, inflation can here either overshoot or undershoot the targeted inflation. In one-period models, the inflation target counteracts only the inflation bias; in our model, the inflation target punishes the benevolent central banker for inflation surprises realized in period *t*. An inflation target either lower than $\pi_2^1 *$ or higher than $\pi_2^2 *$ serves this objective. Such deviations from the one-period optimal target create an equally undesirable outcome for the benevolent central banker, since inflation will differ from zero (which is the socially desirable inflation).

The inflation targeting approach does not require the firing of the central banker. Monetary policy based on an inflation target can be conducted either by keeping the benevolent central banker or by appointing a selfish central banker. The optimal target counteracts the expansionary bias as does a contract, but the targeting approach does not require a self-interested central banker. Another advantage of inflation targeting over a conservative central banker is that no qualification exists for inducing preference revelation. For example, we have seen in Proposition 3 that appointing a conservative central banker does not deter the benevolent central banker from entering a contract designed for the selfish, if supply shocks are not sufficiently large.

Discussion of the Mechanism

In section 3, we show that if monetary policy is delegated through contracts and the central banker's selfishness is private information, then the inflation and output outcomes differ from the commitment outcomes (i.e., those that the contract was supposed to deliver). In other words, when the public does not know the central banker type, the contract cannot eliminate the inflation bias and fails to deliver the ex-ante optimal outcomes. The presence of private information about the central banker's selfishness makes the anchoring of private sector's expectations more difficult and renders the simple Walsh-type (one-period) contract incomplete (even when the central banker is selfish). Note that the emergence of this result does not imply a violation of either the incentive compatibility or the individual rationality constraints.[16]

As a remedy, we introduce a simple mechanism design over two periods that can be interpreted as a broader "contract" itself. Under this intertemporal mechanism (contract), the monetary policy regime in the second period depends on the policy outcome in the first period.

Despite the superficial similarity of our trigger mechanism with trigger strategies in reputational models, our proposed remedy differs fundamentally. Our approach relies on institutional design rather than the repetitive nature of the policy game. "Folk theorems" for infinitely repeated games suggest that when the central banker and the public display a high degree of patience, rational results (payoffs) are enforced in equilibrium. In this context, the central banker expects unrelenting punishment for the first one-period deviation from the equilibrium path (Friedman 1971, and Fudenberg and Maskin 1986). Barro and Gordon (1983b) call the permanent loss of reputation of a central banker "a form of capital punishment". Such reputational mechanisms usually imply multiple equilibria (Waller and Walsh, 1996)

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[16] We rewrite the central banker's objective function in terms of utility rather than losses. The following individual rationality (IR) and incentive compatibility (IC) constraints must hold for both central banker types (s and b):

$$U_S(tr_S - \Lambda_S) \geq U_S^R = 0\,, \qquad \text{(IRs)}$$
$$U_B(tr_B - \Lambda_B) \geq U_B^R = 0\,, \qquad \text{(IRb)}$$
$$U_S(tr_S, m_S) \geq U_S(tr_B, m_B)\,, \text{ and} \qquad \text{(ICs)}$$
$$U_B(tr_B, m_B) \geq U_B(tr_S, m_S)\,. \qquad \text{(ICb)}$$

The individual rationality (or participation) constraint (IR) suggests that the central banker will not accept the contract unless utility exceeds the reservation utility, which is set to zero for simplicity. The incentive compatibility (or "self-selection") constraint (IC) states that the central banker chooses the pair of transfer payments (tr) and action (m) designed for his type. The principal (government), who moves first, has to design a contract so that the agent chooses voluntarily the action that maximizes the principal's utility. With many types of agents, the principal must design the contract so that each agent picks the contract designed for his type. The transfer schemes and actions under breaching correspond to the following expressions in our model:

$$tr_S = (t_0 - t\pi) > 0,\ tr_B = 0,\ m_S = m^c = m^f = 0,\ m_B = m^d.$$

If the government knows the candidate central banker type, it will not offer a contract to the benevolent central banker who represents the ex-post optimal (time-consistent) society's preferences. The other pair (tr_B, m_B) corresponds to the discretionary solution. Under complete information, society always delegates monetary policy to the selfish central banker. (A more detailed discussion is available upon request from the authors.)

and require infinite repetition (or, at least, that the policymaker has a past and/or a future). Central banker legislation in many countries, however, requires non-renewable terms. In contrast to Walsh's (1995b) dismissal rule that requires the central banker to care about reappointment, the preference revelation mechanism works even if the possibility of reappointment does not exist. This occurs because the mischievous central banker does not seek reappointment, but rather wants particular policy outcomes that imply higher social welfare (as perceived by the central banker) in the current period.[17] This mechanism, as a remedy for uncertain central banker preferences, also does not possess the "last period" problem. Under a simple dismissal rule, a central banker who knows that he will not be re-appointed delivers the discretionary outcomes the last period in office. The preference revelation mechanism, however, implies that if the central banker expands the last period, monetary policy will be conducted so that the cumulative two-period expected loss exceeds the cumulative two-period expected loss under breaching. This mechanism simplifies to a two-period mechanism where at the end of the first period, the agent (central banker) is evaluated. If the policies fall within the contract limits, then the following period becomes the first period again. If the central banker does not breach the contract, then we have an infinite repetition of the first period. If the central banker breaches, on the other hand, then we pass to the second period, a period of "punishment".

Our approach also differs from monetary policy games that apply entry deterrence models to the time-inconsistency problem. In those models, repetition of the game between the central banker and the public imposes discipline on the central banker's actions. The source of discipline or the punishment threat comes from the private sector that sets expectations accordingly. In our model, we have a principal (society), an agent (central banker), and a third party (public). The central banker acts strategically not only with respect to the public, but also with respect to the principal. The principal must implement the second-period optimal monetary regime implied by the preference revelation mechanism. Both the

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[17] That the central banker does not seek reappointment does not necessarily imply that he does not care about appointment at other (private or public) institutions as well.

conservative central banker and the inflation targeting regimes, in the second period of the mechanism, are not subject to the problem of principal's time-inconsistent preferences. Thus, the preference revelation mechanism avoids the criticism of principal-agent models that the contracts may be subject to renegotiations (e.g., Jensen 1997, McCallum 1997).

This mechanism must appear in a constitution to work. That is, the ease of policymakers (or elected majorities) changing such arrangements should be more difficult than changing ordinary law (Buchanan, 1986). In particular, when the central banker breaches, the following period's punishment regime must come into effect by default. Allowing choice in the corrective regime after breaching (i.e., allow for discretion in the choice of the second period regime) calls into question the credibility of the mechanism. The choice of the second period's monetary regime would then be subject to the time-inconsistency problem itself.

Finally, note that if the central banker does not breach, everything works exactly as if a typical Walsh-type contract is in effect but without uncertainty about the central banker's preferences. No extra costs associate with the mechanism.

5. Conclusion

The contracting approach to monetary policy delegation incorporates incentive mechanisms that affect the private welfare of the central banker. Utility gains from higher rates of money growth because of the central banker's inflationary bias are counteracted by private utility losses through the incentive scheme. What the literature has so far failed to recognize, however, is that the central banker's loss (or utility) function may not include such a private component. If the central banker is selfless (benevolent), he does not respond to the contract. When monetary policy is delegated through a principal-agent contract, the public does not know whether the central banker is selfish or selfless (benevolent). We show that when the selfishness of the central banker is private information, a benevolent central banker can generate inflation surprises. The public knows that when monetary policy is delegated through contracts, the incentive scheme eliminates the inflation bias. Thus, the public lowers its inflation expectation. When a benevolent central banker accepts a contract designed for a selfish one, then the inflation bias remains intact. Inflation exceeds that under precommitment, but is lower than under discretion. More importantly, the inflation rate exceeds the public's expectations and output exceeds its natural level. That outcome resembles the positive inflation surprises generated by electoral uncertainty in partisan models of political business cycles with rational expectations (Alesina 1987).

The benevolent central banker has a clear incentive to masquerade as a selfish one and achieve those policy outcomes. We design an intertemporal mechanism in dominant strategies that penalizes such behavior not in terms of its private utility but in terms of its social utility, leaving the intertemporal expected social loss intact. The optimal central banker regime that follows breaching prevents the benevolent central banker from breaching in the first instance. We show that preference revelation occurs by appointing a conservative (hawkish) central banker or by adopting an inflation target. Our results do not suggest that the incentive approach to central banking is inappropriate but that more complicated incentive schemes are required in the presence of private information for such incentive schemes to be effective. In fact, the simple remedy suggested here is an incentive mechanism itself (that kicks in only when the simple one-period Walsh-type contract fails). Its intertemporal nature and its use of constitutional features to achieve monetary order make it different from the one-period contracts.

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